A Comparison of Properties of Restorative Composite Resins Cured with Quartz Tungsten Halogen (QTH) and Light Emitting Diode (LED) Light Curing Units: An Invitro Study

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Abstract

Purpose: The aim of the present study was to compare the different properties of restorative composite resin cured for specific period of time with conventional quartz tungsten halogen and light emitting diode light curing units.

Material and methods: Sixty specimens of standard dimensions (4mm in diameter and 8mm in length) were made from transparent polyester sheets. The specimens were divided into three groups and each specimen was filled with light cure composite resin (Esthet X, Dentsply) and cured with QTH and LED light curing units for 40 seconds. The comparative evaluation of compressive strength, surface hardness and depth of cure were done with Instron machine, Vickers hardness testing machine and standardized scrapping methods described in the ISO standard for resin based composite, ISO 4049: 2000, respectively.

Results: Statistical analysis of the data demonstrated a significant difference ($p < 0.05$) in the compressive strength and depth of cure of restorative resin cured with QTH and LED light curing units but there was no significant difference ($p > 0.05$) in the surface hardness at the illuminated surface of the composite resin cured with QTH and LED light curing units.

Conclusion: Careful selection of the light emitting diode light curing units having intensity equal or greater than conventional quartz tungsten halogen light curing units is very important to achieve desirable results, keeping in mind the certain advantages of LED as compared to QTH for the polymerization of composite resin.

Key words: QTH, LED, Compressive strength, Depth of cure, Surface hardness, Composite resin

Introduction

The light cure restorative composite resins are used extensively for the esthetic and functional restoration of both anterior and posterior teeth. Their clinical performance depends on the physical and chemical properties which are directly related to conversion of the monomers to polymers [1]. The polymerization of the light cure composite resins is directly influenced by type of the light source, light source intensity, exposure time and type of the composite resin. Inadequate polymerization might lead to fracture and marginal breakdown, thereby limiting the lifespan of the restoration.

Light source is one of the most important factors which determine the longetivity of light cure composite restoration in the oral cavity. Currently four types of light sources: Quartz tungsten halogen (QTH), light emitting diode (LED), Plasma arc lamp (PAL) and Argon ion lasers are available for the polymerization of the composite resins.

The QTH and LED are most commonly used in daily clinical practice compared to the other two light sources. QTH consists of tungsten filament halogen lamp to produce light. The most efficient wavelength to polymerize the light activated composite resin is 470 nm. The light of spectral wavelength produced below and above this range (400-500 nm) is undesirable because these spectral impurities produced by halogen lamp are absorbed by dental material inducing heating of the tooth and resin during the curing process. Blue filter produce light in the 400-500nm region by removing the undesirable spectral wavelength for effective polymerization [2]. But the light filters degrade with time due to their proximity to halogen bulb and high heat generation during function, which require fan for cooling. The life span of the halogen bulbs ranges between 50 – 100 hours [3]. Lack of maintenance and replacement of halogen bulb from time to time leads to decrease in irradiance output, thereby resulting in inadequate curing which could affect the long term success of the restoration.

The first LED curing unit was introduced in 2001 with the objective of overcoming the limitations of halogen lamps [4]. Instead of a hot filament, two different doped semiconductors are used to produce light of a definitive spectral output which usually falls within the absorption spectrum of camphoroquionone. They convert the electricity into light more effectively, do not require filter to produce blue light, produce less heat so no cooling fan is required, smaller in size, cordless, easy portable. The LED operates for thousands of hours with constant light out.

Different types of LED’s with variable light output are available in the market. Some LED’s have high and some have relatively low irradiance output. The low output LED might not perform as well as conventional QTH light source. Due to certain advantages, LED’s are presently most commonly used in clinical practice for curing of the composite. But due to variation in output, the selection of LED to achieve desirable physical properties of composite restoration is very important.

So, present study was conducted to compare the various physical properties such as compressive strength, surface hardness and depth of cure of restorative composite resin cured for specific period of time with conventional quartz

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tungsten halogen and commonly used light emitting diodes light curing units.

Materials and Methods

Sixty Polyester strip moulds of 4 mm in diameter and 8 mm in length were made. Each mould was then placed one by one on the glass slide with lower surface of specimen covered with Mylar strip. The composite resin (Esthet X, Dentsply) was carried with the help of plastic spatula from the syringe and placed in the mould till it was filled completely. When the mould was completely filled with the composite material, another Mylar strip was placed on the top of the specimen before placing another glass slide on the top of the specimen. The glass slides were gently and carefully pressed to extrude the excess material by squeezing it between two glass slides and to make both the surfaces of the specimen flat and to one level.

After making the surface of the specimen flat, the glass slide from the top of the specimen was removed and light guide tip of the light curing unit was adjusted to the center of the resin surface while keeping in close contact with the surface of composite resin during the curing process of each mould as per requirement for checking the three different properties.

Compressive strength measurement

For measuring the compressive strength, ten specimens were cured with QTH and ten with LED light curing unit. Each specimen was cured both from the top and bottom surface for 40 seconds each. The composite specimen was removed from the mould and compressive strength was measured for each specimen with the help of Instron universal machine. The composite specimen was placed in the center of the metallic plate which was present in the center of the carriage rest so that the specimen lies in the middle of another plate attached to the gripping jaw. The motor of the main derive was switch on by pressing the push button as result of which the carriage rest moved upward towards the gripping jaw to which a circular plate was attached. The carriage rest moved upwards till it came close to the upper plate.

Then, the gripping jaw with the metallic plate was started to move downwards towards the specimen to apply the compressive force. It was allowed to apply the compressive force until the specimen fracture under the load. The point at which the specimen fracture, the needle of the elongation scale stops automatically at that point. The amount of the compressive force (Load) was recorded in Newton from the scale guide. The compressive strength of the specimen was calculated by using the formula:

Compressive strength = load/cross sectional area of the specimen

Surface hardness testing

20 specimen filled with composite resin were cured with QTH (10 specimen) and LED (10 specimen) light curing unit for 40 seconds only from the top surface of the specimen. Surface hardness of each specimen was measured with the help of Vickers hardness testing machine. Each specimen was removed from the mould and placed on the platform below the Vicker hardness tester which was square based diamond pyramid. First, the position of the specimen was adjusted and then the light was allowed to fall on the shining surface of the specimen from the equipment. The light was collimated in such a way so that it fall specifically on the surface of the specimen. The reflectiveness of the surface of the specimen was confirmed by seeing through the microscope attached at the top of the equipment.

The Vickers hardness tester with the indenter present on the top surface was allowed to fall on the surface of the specimen under the specific weight for 15seconds. A square shaped indentation was obtained. One indention was made on the surface of each specimen. The length of the long diagonal of the impression (indention) left by indenter was measured in millimeter from the micrometer microscopic scale present in the equipment. . Each specimen was tested from both top (illuminated) surface and from bottom (non-illuminated) surface in order to compare the top and bottom surface hardness. The Vickers surface hardness of each specimen was calculated by using the following formula: Vickers hardness number (VHN) = 2P Sin α/2 D2

P = Applied Load), α = angle between opposite faces of the pyramid indenter which is 1360, D = Arithmetic average of the two diagonals of the indentation in millimeters, measured, after removing the load by means of micrometer microscope.

Depth of cure measurement

Ten (10) composite specimens were cured for 40 seconds only from the top surface with light emitting diode and Ten (10) with quartz tungsten halogen light curing unit for the same time. Depth of cure of the resin was measured by using standardized scrapping methods described in the ISO standard for resin based composite, ISO 4049: 2000 (17). ISO standard depth-of-cure requirement is 1.5 millimeters. The non- cured material was gently removed from the bottom (non-illuminated) surface of the mould with plastic spatula and the height of the cured material was measured at three different places with a electronic micrometer and the mean value divided into two was recorded as depth of cure in millimeters.

The statistical analysis of the data was done by using the software statistical package for social scientists (SPSS)

Results

Statistical analysis of the data for compressive strength (Table 1 and Graph 1a) done by student's t test and Karl Pearson correlation coefficient test found a highly significant difference ($p < 0.01$) between compressive strength of resin cured with QTH (mean CS – 367.37Mpa) and LED (305 Mpa). The difference was found to be 16.75%. The mean value of surface hardness (Table 2 and Graph 2a) at illuminated (top) surface was slightly higher with QTH LCU as compared to LED LCU. This difference was just 7.37% which was not statistically significant ($p = 0.306$) as confirmed by student's t-test. But the Vickers's surface hardness at the non-illuminated surface of the specimens (Table 3 and Graph 3a), cured with QTH light curing unit (56.15VHN) was higher than with LED light curing unit (23.76VHN). The difference between the two was (57.68%).

Mean depth of cure (Table 4 and Graph 4a) , obtained with conventional tungsten halogen light curing unit (6.61mm) was higher than light emitting diode light curing unit (4.87mm) when the specimen were polymerized for the same period of time. The difference was 26.32%.

Table 1. Comparison of compressive strength of the composite resin cured with light emitting diode (LED) and conventional halogen light curing units.

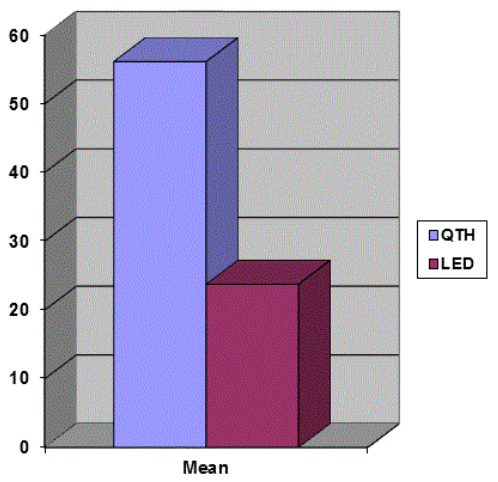
Group	Mean (MPa)	Standard deviation (MPa)	t	p	Significance
QTH	367.37	16.32	8	0	Highly significant
LED	305.8	18.14			

Table 2. Comparison of surface hardness of illuminated (top) surface of the composite resin cured with light emitting diode (LED) and conventional halogen light curing units.

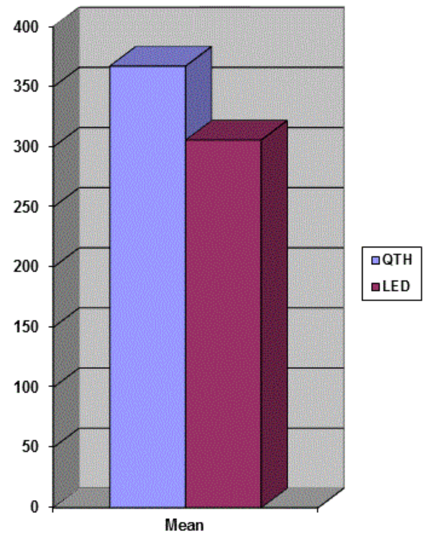
Group	Mean (VHN)	Standard deviation (VHN)	t	p	Significance
QTH	110.41	16.62	1.05	0.306	Non significant
LED	102.27	17.93			

Table 3. Comparison of surface hardness of non- illuminated (bottom) surface of the composite resin cured with light emitting diode (LED) and conventional halogen light curing units.

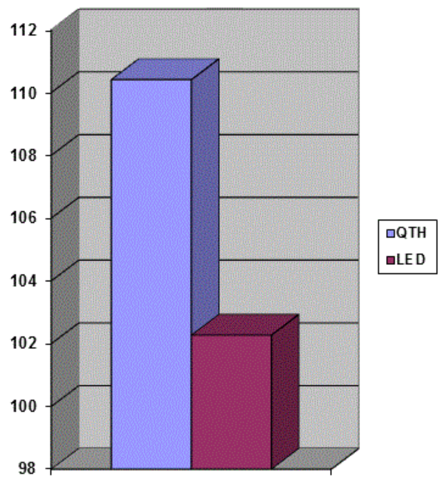
Group	Mean (VHN)	Standard deviation (VHN)	t	p	Significance
QTH	56.15	11.5	7.87	0	Highly significant
LED	23.76	6.05			



Graph 1a: Comparison of surface hardness of non- illuminated (bottom) surface of the composite resin cured with light emitting diode (LED) and conventional halogen light curing units.



Graph 2a: Comparison of compressive strength of the composite resin cured with light emitting diode (LED) and conventional halogen light curing units.

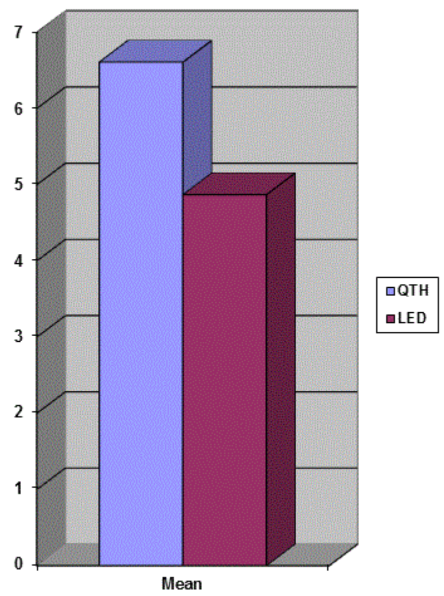


Graph 3a: Comparison of surface hardness of illuminated (top) surface of the composite resin cured with light emitting diode (LED) and conventional halogen light curing units.

Table 4. Comparison of depth of cure of composite resin cured with light emitting diode (LED) and conventional halogen light curing units.

Group	Mean (mm)	Standard deviation(mm)	t	p	Significance
QTH	6.61	0.256	13.74	0	Highly significant

LED	4.87	0.307			



Graph 4a: Comparison of depth of cure of composite resin cured with light emitting diode (LED) and conventional halogen light curing units.

Discussion

The most efficient wavelength to polymerize the light activated composite resin is 470 nm [5] because the absorption peak of camphorquionone which is a photoinitiator in light activated composite material is 468nm. Blue light produced by light curing unit is used to excite the camphorquionone photoinitiator which in turn stimulates the production of free radicals from the tertiary amine, initiating polymerization and hardening of the polymer composite.

The conventional quartz tungsten halogen light curing unit (QHL 75, Dentsply) produce blue light of wavelength 400-500 nm and power output of this unit is about 450mW/cm^2. The power output of QTH light curing unit decrease with usage due to degradation of halogen bulb, reflector, and filter caused by high temperature and heat produced during operation, lack of maintaince and replacement of halogen bulb from time to time thereby resulting in inadequate curing which could affect the long term success of the restoration. Many QTH units used in dental clinics operate below the minimum power out specified by the manufacturers [6]. This output may further deteriorate over time due to inadequate maintenance of light source, particularly light tip. Total light produced by QTH units, 80% is in infrared spectrum, 12% is heat and only 5% is visible blue light [7].

LED light curing units are currently commonly used in the clinical practice but due to variability in output of different generation of LEDs, the selection of LED is very important to achieve desirable properties of the composite restoration. It is clear from the present study that the LED having low output, results in inferior physical properties such as compressive strength, surface hardness and depth of cure as compare to QTH light curing unit having more irradiance output. It is very important to choose LED with high irradiance output for long life of composite restoration in the oral cavity. So the first generation of LED requires long exposure time and design improvements for the effective polymerization.

LED technology has been subjected to drastic changes over the last 10 years resulting in the development of the second and third generation of LEDs with high output. The first generation LED contain multiple, usually 10 – 15 diodes, having complicated design into a lamp with low output as compare to QTH. LEDs emit approximately 15% visible light and 85% heat but heat is usually produced in backward direction and not in the direction of curing tip as a result fan is not required for the cooling.

The clinical performance of the light cure composite resin which depends on the degree of the polymerization is greatly influenced by the quality and intensity of the light source, exposure time, and depth from the surface, material and shade of the resin. This study proved that the first generation LED, have found less depth of cure as compared to QTH.

The results of the present study showed that the physical properties of the composite resin cured with the QTH LCU were superior to those cured with LED light curing unit. The higher values of the compressive strength obtained with halogen unit was due to larger irradiance (power output) of the halogen LCU (450mW/cm^2) which was 4.2 times larger than the irradiance of the LED light curing unit (105mW/cm^2). The rate of polymerization increases 1.44 times when the intensity is doubled.

It was found that irrespective of difference in the irradiance of the QTH and LED light curing units, the surface in close contact with the light guide tip of the light curing unit was cured faster than the deeper layers because the chemical process that promotes curing occurs at a rapid rate on the surface in the presence of the light with both units. So hardness at the resin surface was not significantly different between these two units.

The difference in Vicker's surfaces hardness at non illuminated surface may be due to low irradiance–power output (105 mW/cm^2) of LED LCU as compared to irradiance of QTH LCU (450 mW/cm^2). Because of low intensity of the light emitted by this LED LCU it might not able to cure the deeper layers of the composite material as compared to QTH LCU. As a result of which the non-illuminated surface of the composite specimen cured with this LED LCU was found soft with low Vicker's surface hardness.

Depth of cure decreases with increase in the length of the specimen because as one moves towards the bottom surface of the composite specimen from the illuminated surface, the effectiveness of the light to polymerize the composite in deeper portion decreases and this decrease is much more with light of low irradiance.

Despite the certain advantages of the Light emitting diode light curing unit over the halogen LCU the light output of first generation commercially available light emitting diodes for resin based composite polymerization still requires improvement to rival the adequacy of cure of halogen-based LCUs.

Compressive strength, surface hardness and depth of cure are important and clinically relevant measures of the quality of cure. Due to the inherent advantages of the light emitting diode principle and swift progress in semiconductor technology, light emitting diode light curing units appear to have greater potential in clinical applications.

Conclusion

Based on the findings of the present study, it can be concluded that:

1. The compressive strength of the composite resin cured with Quartz tungsten halogen light curing unit was 16.75% superior to that cured with light emitting diode light curing unit.
2. The surface hardness at the illuminated surface of the composite resin cured with Quartz tungsten halogen light curing unit was almost equal to that cured with light emitting diode light curing unit.
3. The surface hardness at the non-illuminated surface of the composite resin cured with light emitting diode light curing unit was 57.68% inferior to that cured with Quartz tungsten halogen light curing unit.
4. The depth of cure of composite resin cured with Quartz tungsten halogen light curing unit was 26.32% greater than that cured with light emitting diode light curing unit.

So, careful selection of the light emitting diode light curing units having intensity equal or greater than conventional quartz tungsten halogen light curing units is very important to achieve desirable results, keeping in mind the certain advantages of LED as compared to QTH for the polymerization of composite resin.

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