Indian Journal of Dental Sciences.
October 2014 Supplementary Issue
Issue:4, Vol.:6

www.ijds.in

Review Article

Indian Journal of Dental Sciences

E ISSN NO. 2231-2293 P ISSN NO. 0976-4003

# Dental Light Curing Units - A Review

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**Submission :** 19th April 2013
**Accepted :** 1st May 2014

Quick Response Code

**Abstract**
Recent advances in resin adhesives and restorative materials, as well as an increased demand for esthetics, have stimulated a great increase in the use of resin-based composites. However, despite the remarkable developments in the technology of the restorative resins, clinical failures of resin restorations are still reported due to polymerization shrinkage and low Depth of Cure of restorative materials during curing procedure by a dental light curing unit which in turn causes degradation, substance loss, bulk fracture, discoloration with marginal staining of restoration. Thus curing lights are an integral part of daily practice in restorative dentistry. This review is principally focused on assessing the clinical relevance of curing systems available; in terms of their selection and maintenance in dental operatory; thus optimizing their clinical performance.

**Key Words**
LED LCUs; polymerization; depth of cure.

## Introduction

The introduction of resin-based dental materials near the middle of the last century has revolutionized modern restorative dentistry[1]. With the dramatic rise in use of composite restoratives, there is also a rapid increase in the number of light-activation units[2]. Visible light-curing units, or LCUs, are an integral part of modern adhesive dentistry. They are used to cure resin-based composite restorative materials, resin-modified glass ionomers and preventive pit and fissure sealants, as well as to bond orthodontic brackets to teeth.

They also are used to polymerize light-activated liners and bases, core build-up materials, provisional restorative materials and most dentin bonding systems[3]. Clinical performance of light-cured composite restorations is greatly influenced by the quality of curing light. Characteristics such as resin composition, resin shade, filler size, light source intensity, exposure time and the loading level determine the final properties of light-activated composite resins[4],[5]. Additionally curing light units effective spectral output and wavelength also play an important role for adequate polymerization of a resin composite[6]. Visible light-activated resin systems use a diketone absorber to create free radicals that initiate polymerization. Most dental photoinitiator systems use camphoro quinone as a diketone absorber, with the absorption maximum in the blue region of the visible light spectrum at a wavelength of 470 nanometers (nm)[3]. Physical properties of restoration will be compromised if all of these parameters are not met, and early failure may be expected. Therefore, it is important to have dental curing light units that can provide continuous and adequate spectral output[6].

## Evolution of lights

Ultra-Violet light curing unitwas the first to be used in curing light cured composites. The technology came from other industry such as ink, paint and coating materials that used the ultraviolet light in photopolymerization process. The wavelength is in the range of 364-367 nm. Ultra-violet systems enjoyed popularity for a time because of its common sets. Later, it was found that this light could cause damage to the eye. Since then the use of this unit in clinical practice has been discarded and are no more available in the market.

Halogen light curing unithas been innovated to replace the ultra-violet light curing unit. This unit is able to produce flux in the range of 400-500 nm that is within the camphorquinone spectrum. Most of the units use tungsten filament halogen lamps that incorporate a blue filter. The light is directed using a wave-guide such as a fused glass bundle. The amount of time required to cure the composite was relatively high.

High Performance Halogen light curing unithas been developed to overcome the problem of conventional halogen light that requires a longer time to cure the composite restoration. This unit has a special tungsten quartz halogen optibulb whose performance does not degrade with time. It also has an 8 mm light guide, which emits a full spectrum light filtered as blue with a range of 400 to 505 nm. This light has a boost mode, which increases the light output to 1,000mWatt/cm2 in 10-second cycles with a five second beep which allowed the composite to be cured in five seconds.

Adaptor light guideis a modification of light guide has been designed as a direct replacement for the original light guide of the halogen curing light. This guide has been designed using computer technology. It has a unique flat tip with maximum tapered optic fibers. It is able to increase the light output 2.5 times more than the original light guide used with the halogen curing units. The light output ranges from 880 to 1120 mW/cm2. The guides are currently available in various sizes and shapes.

Plasma Arc Light Curing Units has been developed after the technology used by

NASA in aeronautical engineering. The plasma arc light system has filters that are able to narrow the spectrum of visible light to a band centred at 470 nm. It has two electrodes with a large voltage potential that are able to ionize xenon plasma gas to emit the light. These lights have an energy level of 900 mV, which is much higher than halogen lights. This allows curing times to be as short as possible.

Blue Light Emitting Diode (Blue LED) Curing Unit- The breakthrough in semiconductor technologyhas led to the use of LED in curing light curedcomposites. LED is a solid-state light source. It is manufactured by layering the metal organicchemical vapour deposition of different semiconductor materials on top of another in specialfilms.This unit uses Indium Gallium Nitrate technology. As current flowsthrough the semiconductor chips, electrical energy is converted directly into light. The result is a stable, efficient and longlasting output of blue light. The spectrum of lightproduced is in the range of 430 to 490 nm.

Argon laser curing unithas utilized the laser technology which provides sources that emit high intensity light within the energy band required by the initiator in light cured composites. Laser light has been described as consisting of a single, narrow band of waves travelling in parallel and in phase spatially and temporally. The argon laser is monochromatic and emits light over a narrow band of wavelengths in the blue-green spectrum. It provides high output energy at 488 nm for the rapid polymerization of dental composites. Argon laser's waves are coherent; the photons are in phase with one another and do not collide as they do in halogen light[7].

**Types of lights used today**

Currently, the most commonly used light source for polymerization is conventional quartz-tungsten-halogen (OTH). Although these lights are manufactured with relatively low-cost technology, the shorter life of the QTH light bulb and the gradual degradation of the filter compromises consistent light output. The next generation of lights, plasma-arc (PAC) and argon laser units were designed to increase the effectiveness of the constant high light output and decrease the time required to polymerize resin composite. Laser units require a larger capacity for power supplies and cooling, making them complex and expensive, besides stipulating user precautions.

The newest technology is the light emitting diode (LED) designed with major advantage over existing light curing units, such as being lightweight, cordless, portable, having a longer life span, no requirement for filter systems and less heat generation[6]. It was not until 2000 that the First Commercial LED LCU became available: the LuxOMax LED LCUwas a large pen-like cordless battery-powered design using 27 discrete LEDs[1]. The power density of the first-generation LEDs was low as these units consisted of an array of relatively low-powered chips offering a comparative low output, and poor curing performance compared to conventional quartz-tungsten-halogen (OTH) lights. Generally, these lights had to be used for longer exposure times to provide similar curing to that of QTH lights, but resulted in less temperature generation in the target.

Second generation models (ultralume 2) demonstrate better performance, using a single chip of much higher surface area that emits only one color range of greatly increased output power[8]. This produces higher power density and justifies reduced exposure time[5]. The Third Generation LED (Ultralume 5) units are characterized by incorporating the same blue chip as the second generation products, but include 1 or more low-powered chips that emit a second frequency in the violet spectral range[8].

In addition to light output, ergonomic features of curing light units have also become important. Some of the new light designs are aimed at increasing safety and efficacy of the curing light units and providing ergonomic advantages to clinicians[5].

Recently Fourth Generation LED Light has been introduced into the market as Scanwave by MiniLed (Acteon). Significant improvement in design including patented wavelength scanning technology incorporated into its mode selection including many ideal features of third-generation lights which have been incorporated that allows the dentist to choose the most appropriate spectral output mode and radiation time for any possible material and clinical situation. It has four different diode wavelengths, the most of any dental LED LAU to date offering broad spectrum curing in 'Full Scan'mode for all resin-based materials, irrespective of their photo-initiator chemistry[9].

**Technology Of LED Lights**

LEDs are a part of our daily lives. LED technology is applied in modern light sources for room lighting, car headlights and dashboards, traffic lights, state-of-the-art television flat screens or as LASER LEDs in CD or blue-ray DVD data/video storage equipment. Compared to conventional light sources, LEDs are small and energy efficient. Hence, dental light curing units (LCUs) based on LEDs are relatively small and can be battery powered, using high performance nickel - metal hydride (NiMH) or lithium-ion (Li-ion) batteries.

LEDs are semiconductor-based photonic devices in which the elementary particles of light (photons) play the key role. LEDs convert electrical energy into optical radiation by a phenomenon called electroluminescence. LEDs use both; n-type and p-type doped extrinsic semiconductors, indicating the majority charge carriers are electrons or holes, respectively[1]. This eliminates the need for filters and may reduce heat generation to the extent that cooling fans may not be required or need only be of low capacity. Consequently, LED curing lights can operate on battery-power, so providing the dentist with a portable, silent and cordless LCU, which should function much longer than the alternatives[10]. LEDs have a number of intrinsic advantages which make them ideally suited for the photopolymerization of oral biomaterials. The typical spectral line width of light for LEDs is 400–500 nm compared to the emission spectra from all other LCUs. This narrow emission range is themajor advantage of LED LCUs because photo initiators present in oral biomaterials have light absorption spectra withdistinct maxima. If the wavelength of the LED LCU is chosenin this range, effective and rapid photopolymerization is theresult.

For oral biomaterials containing more than one photo initiator with different light absorption spectra, LED LCUs emitting multiple wavelengths can be employed. These LED LCUs are sometimes called broad band LED LCUs. This term, however, is not correct because the LED emission characteristics apply. Rather than a broad light spectrum, two or more distinct narrow wavelengths bands are emitted from this collection of different wavelength LEDs, each with a distinct maximum. Thus, these types of LCUs are more appropriately referred to as poly-wave LED LCUs [1].

**Advantages of LED**

1. Thermal emission from curing lights has been a matter of concern to the dental profession. Heat transferred to the tooth may cause pulpal damage (Hussey, Biagioni & Lamey, 1995; Hanning & Bott, 1999). Studies have suggested that LED curing lights, with their narrow spectral emission, generate significantly less heat from the light guide than QTH lights (Yap & Soh, 2003; Knezevic & others, 2011).
2. LED curing lights produced greater depth of cure and curing efficiency than QTH lights (Mills, Jandt & Ashworth, 1999; Fujibayasha & others, 1998; Halvorson, Erickson & Davidson, 2004). The highly efficient, narrow emission spectrum of LED lights reportedly provides greater curing efficiency.
3. Leonard & others (2002) found that LED lights have a higher percentage of their output in the absorption spectrum of camphoroquinone compared with QTH curing lights. A recent study by Halvorson & others (2004) found that, despite a 31% greater relative efficiency, scapeback lengths from composite polymerized using the LED light were only 6% greater than those polymerized with a QTH light at similar energy densities.
4. LED curing lights are optimized for materials containing the photoinitiator camphoroquinone. Recently, Uhl, Mills & jandt (2003) found that some resin composites containing other photoinitiators, in addition to camphoroquinone, may not develop hardness values equivalent to those attainable with the broad spectrum QTH curing lights. Leonard & colleagues revealed that microfilled composites required twice the irradiance that hybrid composite did.
5. LED also are cordless, are resistant to shock and vibration and consume little power during operation as compared to QTH LCUs.
6. An important measure of a LED is its luminous efficacy (the ratio of luminous flux emitted to electrical power consumed) and is a measure of how well a light source produces visible light. For LEDs, the luminous efficacy is typically in the order of 60 lm W-1, whereas typical QTH lamps have a luminous efficacy of only 25 lm W-1.
7. Another important advantage of LED LCUs is their overall energy efficiency in terms of energy required for a cure cycle. A contemporary LED LCU that has one 5 W LED chip will operate approximately 25 min from a fully charged battery, Assuming a light curing cycle of 20 s, 75 curing cycles are possible from a charged battery and the energy required for this use is 25 W h-1, corresponding to 0.34 W h-1per curing cycle. In contrast, operating a typical 150 W QTH lamp based LCU, equipped with a 75 W (12 V) QTH source, for the same time (25 min), the energy required would be approximately 62.5 W h-1. This value corresponds to 0.84 W h-1per 20 s curing cycle: approximately 2.5 times the energy a LED LCU needs to perform the same task.
8. LEDs can have a typical lifetime of 100,000 h or more and undergo little degradation of light output over this time, if not over-driven. This level of durability is a distinct advantage when compared to the characteristics of QTH lampswhich have an effective lifetime of approximately 50 h.
9. Nomura and others (2002) reported that dental resins cured with blue LED have a higher degree of polymerization and more stable three-dimensional structures than those cured with halogen lamps.

**Maintenance of Light curing units**

A number of features must be checked to ensure that a visible light curing unit is operating at full capacity. Because the filters can pit, crack or peel, they must be checked regularly and replaced as needed. Resin contamination on the curing unit tip tends to scatter the light, considerably reducing the effective output. Therefore the tip should be cleaned of cured resin, when necessary using an appropriate rubber wheel on a slow speed handpiece.

**Problems with Curing Bulbs**

1. Bulb frosting: Bulbs become frosted when the glass enclosing the filament becomes cloudy or white. This occurs as a result of either deposition of metal oxides, which vaporize and form a film on the glass bulb. Frosting can result in a 45% drop in curing light output.
2. Reflector degradation: Occurs when there is a loss of the reflector film or a white or yellow coating of oxides develops over the reflector surface. This can result in a 66% drop in curing light output. Because of these problems, curing lights gradually lose intensity.Light-emitting diodes have generally fewer maintenance problems than halogen bulbs but must be checked for decreased power density owing to heat accumulation during long curing times. Heat can also result in LED degeneration over time.
3. Radiometers: A radiometer is a specialized light meter that quantifies blue light output; a radiometer determines the effectiveness of a curing unit by measuring the intensity of 468 nm light coming out of the tip of the light guide. Radiometers are sold as small handheld devices or may be built into curing units. It is important to test a curing light when it is new to obtain a baseline for future reference. Most radiometers measure light in the 400 to 500 mm bandwidth. This is broader than is required by most photoinitiators and makes these units less reliable in evaluating curing units with narrower spectral outputs (i.e. LEDs and lasers). A specialized radiometer capable of measuring a narrower band width around 468 nm would give a more precise measurement of any unit's spectral bandwidth.
4. Ocular Hazards of Curing Lights: The blue light used to polymerize composite is not well tolerated by the human eye. All light-cured polymerization systems use light that is harmful to vision.A number of studies show that blue light is damaging to the retina. It has been shown that blue light forms free radicals in the eye, just as it does in composite resins. However, in the

retina, these free radicals react with the water-content of cells, causing peroxides to form in the visual cells. These peroxides are reactive and denature the delicate photoreceptors of the eye.Researchers estimate that blue light is 33 times more damaging to the photoreceptors of the retina than is UV light. As exposure duration increased, the burns became more severe. This damage has been named "SOLAR RETINITIS". Some laboratory studies indicate that exposures of fewer than 2 minutes to visible light-curing units (total daily dose from 25 cm) may be safe.Younger eyes are more susceptible to blue light damage. It is important to educate staff about this so they can ensure that children are prevented from staring at curing lamps during treatment. The resulting damage could be profound and lifelong.

5. Eye Protection: The best eye protection is to completely avoid looking at the curing light source. Covering the curing site with a dark object would be ideal. Some clinicians cover the curing site with their hand. This may prove an unsafe practice. A simple yet effective way to provide shielding from curing lights is to cover the curing field with the reflective side of a mouth mirror. This prevents excess blue light from reflecting back against the restorative and improves curing. If it is necessary to look at the light source for placement, eye protection is warranted. Unfortunately, most optical glasses and plastic contact lenses transmit blue light and near-UV light radiation with little attenuation. A number of colored plastic glasses and handheld shields are available.It is easy to test the effectiveness of a light shield. The wavelengths that harm the eye are the same ones that cure composite. To test a shield (or pair of protective glasses), try to cure composite by shining the curing light through the shield onto composite. If the composite can be cured, the shield is ineffective for eye protection[11].

**Conclusion**

The introduction of LED LCUs has revolutionized the photopolymerization of oral biomaterials. Until the introduction of LED LCUs, QTH lamp based LCUs were the standard curing devices in most dental practices. Due to the physical characteristics of the solid-state light emitting diodes, LED LCUs have almost entirely replaced QTH LCUs whose inherent problems include a decay of light output over time, blue light filter degradation, relatively limited time of life of the QTH source, high energy consumption, bulky construction, a requirement for a mains electricity supply, and relatively high heat transfer to the pulp chamber of the tooth during photopolymerization. It is, therefore, not surprising that hand-held pencil-style, battery powered, compact LED LCUs are now the standard photopolymerization devices in most dental practices worldwide.

This paradigm change in photopolymerization development was made possible mainly by three factors: (i) the invention of visible light emitting diodes exactly 50 years ago; (ii) the introduction of high brightness blue light emitting GaN LEDs in 1994; and (iii) the creation of the first blue LED LCUs for photopolymerization of oral biomaterials.

The LED-based photopolymerization process has become the gold standard of curing dental composites at the beginning of the 21st century. With efficient high power, single LED LCUs commercially available, it is likely that this trend will not change for quite some time, especially if one considers the energy efficiency of LEDs, which are the green way to produce light. The history of LED photopolymerization of biomaterials is also a good example of how science works and progresses.

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Source of Support : Nill, Conflict of Interest : None declared