Review Article

Light-curing unit (devices)

ABSTRACT

Bonding is the most published and researched procedure in orthodontics. Since its inception in 1954 by Buonocore, bonding material and technique have undergone major innovations and upgrading. Self-cured bonding materials were truly replaced with light cure ones, which provide an added advantage of controlled curing time and ease of operation. The light cure bonding material needs a specific light cure device for its curing. These devices have also undergone major changes in the past years. Halogen light cure devices were replaced by plasma arc, and recently, market is now flooded with light emitting diode light cure devices. However, literature search failed to reveal any review on this aspect. Hence, the author felt the need to review this untrodden topic. This article deals in detail with the various light cure devices used in orthodontics.

Keywords: Bonding, curing, light cure devices

INTRODUCTION

Since the introduction of bonding by Buonocore (1954), there has been a continuous attempt to formulate a material and technique which fulfills the requirements of bonding along with the expected physical, mechanical, and biological properties. Self-curing adhesives were introduced first, but quickly discarded because they had limitations such as less porosity and discoloration, longer working time, ease of manipulation and increased hardness and wear resistance of superficial layer. To overcome these limitations, light-activated composite resin was introduced in 1960s according to Strassler.[1] These resins contain photosensitizer (Camphoroquinone [CQ]), which absorbs blue light with wavelengths between 400 and 500 nm. Light-activated resin system utilizes light energy to initiate free radicals; thus, introduction of light-curing resin led to the development of the first curing light.

Clinical efficiency of a light-curing unit is crucial for obtaining the optimal polymerization and a successful outcome.[2] With the advancing research in the field of orthodontic bonding, a need for an appropriate curing unit has always been felt. In this article, the author has attempted to review the history, advantages, and disadvantages of various light-curing units available in the market.

Received: 01-Jan-2019 **Revised:** 23-Mar-2019
Accepted: 03-May-2019 **Published:** 23-Sep-2019

Access this article online	
	Quick Response Code
Website: www.orthodrehab.org	
DOI: 10.4103/ijor.ijor_1_19	

Visible light wavelength is between 400 and 700 nm. Most of the composites are sensitive within range of 400–520 nm wavelength (blue).

Photoinitiator like camphorquinone in the resin absorbs photon energy and then combines with activator Amine (DMAEMA) and creats free radicals which initiates polymerization. Process of formation of free radicals is described in Figure 1.

Other photoinitiators used are 1-phenyl 1,2-propanedione (PPD), Bis-acylphosphine oxide, and Tri-acyl phosphine.

HISTORY

According to Strassler,[1] in the early 1960s, the first

Pooja Garbadrao Hadole, Suchita Sadashiv Daokar
Department of Orthodontics, CSMSS Dental College and Hospital, Aurangabad, Maharashtra, India

Address for correspondence: Dr. Suchita Sadashiv Daokar, Department of Orthodontics, CSMSS Dental College and Hospital, Aurangabad - 431 002, Maharashtra, India.
E-mail: suchitadaokar@gmail.com

How to cite this article: Hadole PG, Daokar SS. Light-curing unit (devices). Int J Orthod Rehabil 2019;10:121-33.

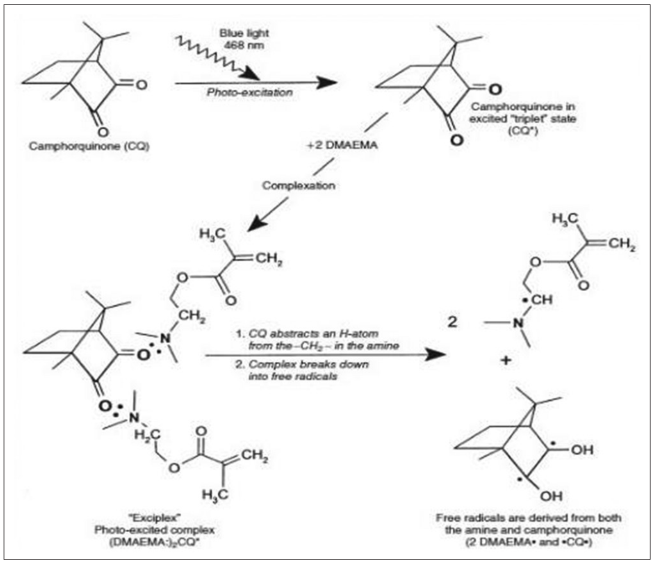

Figure 1: Process of formation of free radical

light-curing resin composites were introduced; this led to the development of the first curing light. The first dental-curing light was developed in the 1970s. It was the Nuva Light (developed by Dentsply/Caulk) that used ultraviolet light order to cure the material. This was discontinued because of the drawbacks of ultraviolet (UV) light used in the system. Furthermore, these lights were not very effective due to the shorter wavelengths that limited the depth of cure.

According to Rueggeberg,[3] during the early 1980s, advances in the area of visible light curing took place. Only a few years following the introduction of UV radiation for curing dental restoratives, the ability of using visible radiation was introduced: February 24, 1976. On that day, Dr. Mohammed Bassoiuny of the Turner School of Dentistry, Manchester, placed the first visible light-cured composite restoration on Dr. John Yearn, the then head of department. This advancement led to a curing device that now uses blue light. The next type of curing light that developed was the quartz-halogen bulb. This device had longer wavelengths of the visible light spectrum and allowed for greater penetrating curing light and light energy. The halogen curing light replaced the UV-curing light.

The 1990s presented great improvements in light-curing devices. It improved previous devices as well as developing new devices. The main focus was to improve the intensity to be able to cure faster and deeper.

In 1998, the plasma arc curing light was introduced. It uses a high intensity light source, a fluorescent bulb containing plasma, to cure the resin-based composite. It claimed to be able to cure material in 3 s. However, on average, it took between 3 and 5 s.

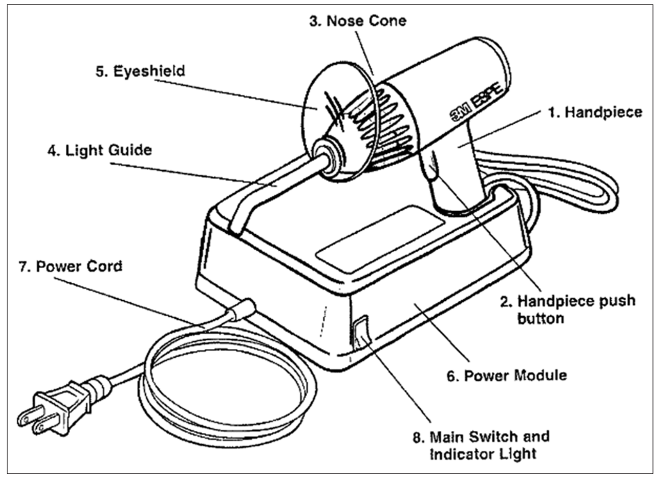

Figure 2: Components of light-curing unit

DIFFERENT ASPECTS OF LIGHT-CURING UNIT

Light-curing unit is an instrument capable of generating and transmitting a high-intensity blue light with a wavelength oscillating between 400 and 500 nm that is designed specifically to polymerize visible light sensitive dental material.

The ideal light-curing unit should have:

- Broad emission spectrum
- Sufficient light intensity
- Minimal drop-off of energy with distance
- Multiple curing modes
- Sufficient duration for multiple curing cycles
- Durability
- Large curing footprint
- Easily repairable.[4]

The light-curing units are classified into the following five generations:

- 1st Generation - Ultraviolet light
- 2nd Generation - Visible light-curing units
- 3rd Generation - Plasma arc units
- 4th Generation - Light-emitting diodes (LEDs)
- 5th Generation - Lasers.

The basic components of light-curing units are as follows [Figure 2]: handpiece, handpiece push button, nose cone, light guide, eye shield, power module, power cord, main switch, indicator light, fuse, plug, bulb, filter, and fan.[5-7] Some of the light-curing units have integrated curing meter, microprocessor, and battery charger.[5,8]

To lowest to highest intensity

- LED lamps
- Quartz-tungsten halogen lamps

Figure 3: Quartz-tungsten halogen

- PAC lamps
- Argon laser lamps.

ULTRAVIOLET CURING

UV-curing unit was introduced in dentistry in 1970. UV light-curing unit was the first to be used in curing light-cured composite. The technology came from other industry such as ink, paint, and coating materials that used the UV in photopolymerization process.[5,9,10] This unit utilized the polymerization process of a composite that can be accomplished by the energy derived from ultraviolet light. The wavelength is in the range of 364–367 nm.[5,11] Ultraviolet curing units used benzoin ether type of compound as photoinitiator in sealant at that time.

Disadvantages

- It was time-consuming, as a 90 s application must be given to each bracket
- It has the potential to cause retinal damage and the possibility of selectively
- Altering the oral microflora through exposure of ionizing radiation[5,12]
- Limited depth of cure
- Carcinogenic
- Loss of intensity over time.

QUARTZ-TUNGSTEN HALOGEN

QTH was used in 1990. These lights contain lamp with a tungsten filament in an inert gas with a small amount of halogen gas. An electric current passing through QTH heats the tungsten to 2700°C and creats visible light and infrared radiation [Figure 3]. The light is filtered to approximately 380–500 nm.[12]

Disadvantages

- Short-curing depth
- Gradual loss of high energy wavelengths in their light output

Figure 4: Different types of adaptor light guide

- Very high heat generation as most of its energy dissipated in the form of heat rather visible light; these lights is that they only use 9% of the total energy produced and majority is dissipated as heat and so requires cooling fan and filter[12]
- Furthermore, this light requires frequent monitoring and replacement of the actual curing light bulb because of the high temperatures that are reached. (For example, one model uses a bulb with an estimated life of 50 h which would require annual replacement, assuming 12 min use per day, 250 days per year)
- The time needed to fully cure the material is much more than the LED curing light
- This implicates a reduction of curing efficiency over time by aging of the components.[13]

HIGH-PERFORMANCE HALOGEN-CURING LIGHT

Advantage of high performance halogen-curing light is less curing time over conventional halogen light cure. 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 40–505 nm. Curing time for metal is 8 s and ceramic bracket – 5 s. This light has boost mode, which increases the light output to 1000 mWatt/cm^2 in 10-s cycles with a 5 s beep. This will allow the composite under metal bracket to be cured in 5 s. The light produced by this unit is intense, and the tip of the guide may occasionally cause some discomfort to the skin mucosa.

Disadvantages

- Bigger in size
- The light performance degrades with time
- It generates more heat and requires filter and ventilating fan.[12]

ADAPTOR LIGHT GUIDE

Adaptor light guide is made by computer technology having maximum tapered optic fibers for better output compared to others. The surface area is about 28 mm^2. The light output ranges from 880 to 1120 mW/cm^2. The guides are currently available in various sizes and shapes [Figure 4].

Advantages

- It can be sterilized either chemically or in an autoclave; it can cure the composite with reduced time It is economical since the adaptor is cheaper than other light-curing units.[12]

Disadvantages

- Its usage relies heavily on the halogen-curing unit. Therefore, whatever problems encounter by the halogen-curing unit may have an effect on its performance.

ARGON LASER

Argon laser was introduced in 1991 having 488 nm wavelength [Figure 5]. Dual-wavelength argon lasers are used in minor procedures such as gingival recontoring and coagulation. They operate at 488 nm for curing and 514 nm, respectively.[14] The time required to cure the orthodontic composite is 5 s.

It has potential to cause retinal damage and the possibility of selectively altering the oral micro flora through exposure of ionizing radiation but it does not damage the pulp tissue.

Disadvantages

- The curing depth is limited to 1.5–2 mm
- The curing tip is small, so more time is needed to cure the red blood cells (RBCs)
- They have narrow spectral outputs
- They are expensive.[12]

PLASMA ARC

In the mid-1990s, plasma arc were introduced as a more affordable, high-speed curing light. This unit has been developed after the technology used by the United States National Aeronautics and Space Association in aeronautical. This light uses xenon gas, distilled from liquid air, and then electric current is passed through the gas which ionizes it and produces negative and positive charged particles. High-powered light produced is then filtered to an effective curing wavelength of 450–500 nm. These lights have an energy level of 900 mV from 2000 mV [Figure 6].

Figure 5: Argon Laser

Figure 6: Plasma arc

Advantage

- It can cure the composite in 2 s.

Disadvantage

They are expensive and produce more heat so filters and

- Ventilating fan are required
- More bulky and heavy to use.[12]

LIGHT-EMITTED DIODE

LED were introduced by Mills in 1995.[12] They used junctions of doped semiconductors to generate visible light with no light filtration required. LEDs are highly efficient light sources that produce light within a narrow spectral range. Blue LEDs curing unit has an advantage over halogen light-curing unit in that it is inexpensive. The LED unit has no bulb or filter that requires maintenance. They do not require filters because they emit light at a specific wavelength within the 400–500 nm [Figures 7 and 8]. Overtime, only little degradation of light output is observed and they do not

Table 1: Basic specifications of light-curing units that are available in the market

Type of light-curing unit	Time required to cure a metal bracket (s)	Light output (mV)	Spectrum of light (nm)
Halogen light	40	300	400-500
High-performance halogen light	8	1000	400-505
Adaptor light guide with halogen light	10	880-1120	400-500
Plasma arc light	2	900	430-490
Blue LED	10-40	400-2000	430-490
Argon laser	5	800	454-496

LED: Light-emitted diode

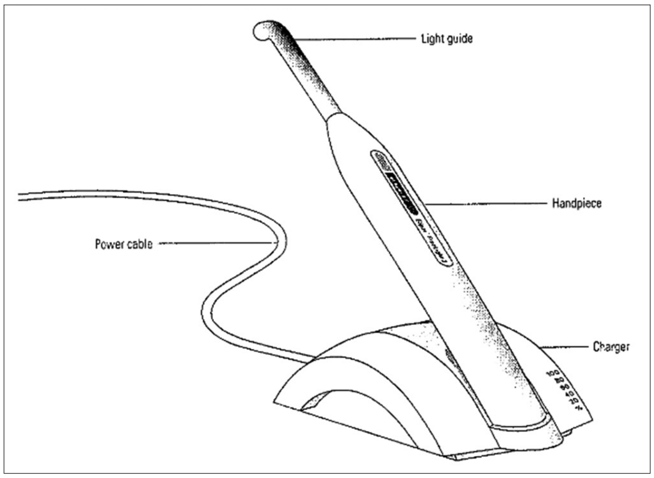

Figure 7: Blue light-emitting diode light-curing unit

Figure 8: Blue Phase light-emitting diode

Figure 9: Camphorquinone (left) and Lucirin TPO (right)

produce heat. This may be another advantage for avoiding any possible gingival or pulpal irritation – the light performance degrades with time. LED is very popular among pediatric dentists particularly, since less chair time and an adequate polymerization is the main goal. It has been suggested that even though the strength is inadequate, by far, it is the most reliable.[12]

Disadvantages

- Cost is more than conventional halogen lights
- The curing time is more than plasma
- Need to recharge batteries.[12]

Basic specifications of light-curing units that are available in the market summarized in Table 1.[5]

DISCUSSION

There are several factors related to light curing that can influence the polymerization process and the strength of the material such as intensity of the light, curing time, and depth of cure.[5,15-18]

Intensity of light

Lambert's Law – When a light beam hits an orthodontic adhesive surface, penetration of light into the relatively thin layer of material depends on many factors related to the light beam itself, the application mode, and the material characteristics.

First, the distance of the source from the surface and the path that the incident beam will have to travel to reach the adhesive has a large effect on the intensity of incident light. The well-cited Lambert Laws in this field describe the variation of intensity with distance as:

$$I = Io\ e^{-yd}$$

Where I is the light intensity at distance d, I_0 the intensity departing from the source, and y the absorption coefficient of the medium.

Curing time

If curing time increases, bond strength also increases, and if production of heat increases from increased curing time, there are more chances of irreversible pulpitis.

Depth of cure

Depth of curing depends on intensity of light.

The light-curing unit should be able to cure the composite to the optimum bond strength. Curing lights all generate heat and require a cooling fan, especially halogen which generates noise and so bulb life reduces to only 100 h and minimum is generated by LED.[19] Halogen lights do significantly increase the pulpal temperature more than other light cures. Because LED uses minimal energy and produces less heat, they are marketed as cordless units with a rechargeable battery and with no other parts or light filaments present so they better resist vibrations and shock. Therefore, these are effective for more than 10,000 h.[12,20]

The manufactures go to another photoinitiators rather than CQ because one of the main problem of CQ initiator is their yellow color rather than their need to prolonged light curing, which give the RBC undesirable yellow color after polymerization [Figure 9].

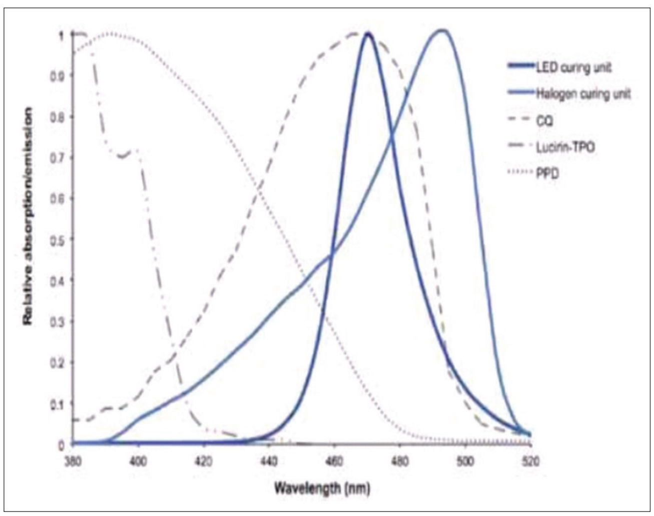

Figure 10: Graph

Figure 12: Decreased light exposure

From this Graph [Figure 10], we should see:

- The peak of wavelength of LED units is perfectly matching the wavelength needed to activate CQ initiators
- The initiators like Lucerin TPO and PPD their peak near UV wave length away from LED wavelength zone.

If increased light exposure, there is increased depth of cure, increased conversion i.e., polymerization and increased hardness upto threshold level [Figure 11]. If decreased light exposure, there is inadequate polymerization. Due to inadequate polymerization, there is lack of retention, increased wear, color instability, and microleakage, and due to microleakage, postoperative sensitivity and secondary caries occur [Figure 12].

There are two types of light-curing techniques:

1. Continuous curing techniques:
   a. Uniform continuous curing
   b. Step cure
   c. Ramp cure
   d. High-energy pulse cure.

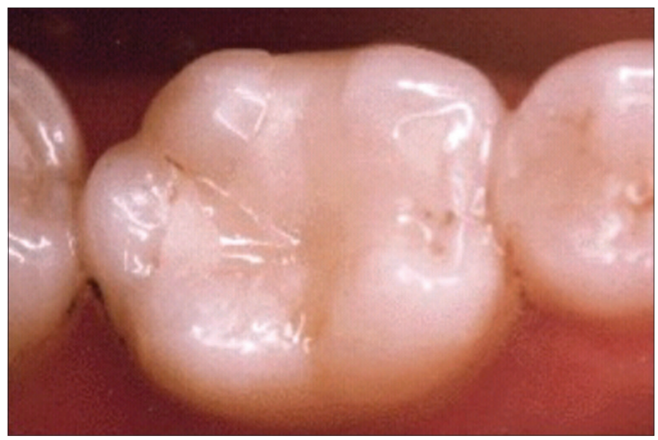

Figure 11: Increased light exposure

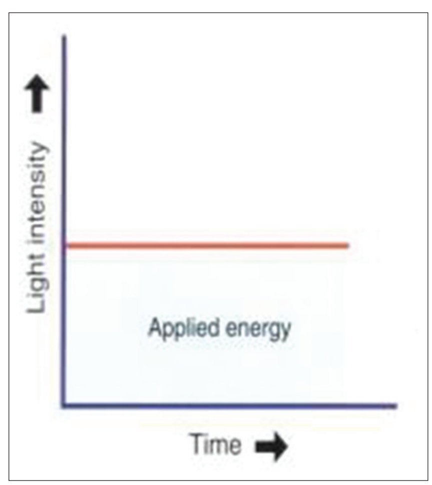

Figure 13: Uniform continuous cure

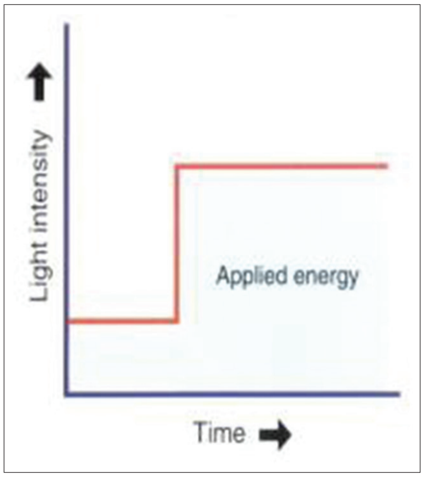

Figure 14: Step cure

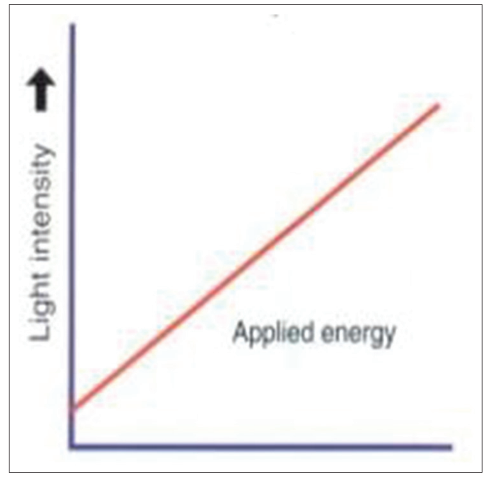

Figure 15: Ramp cure

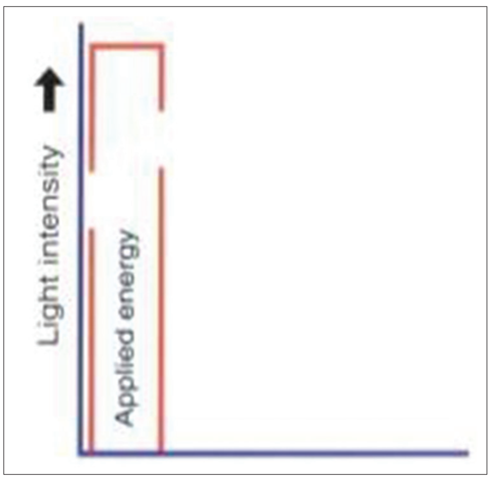

Figure 16: High energy pulse

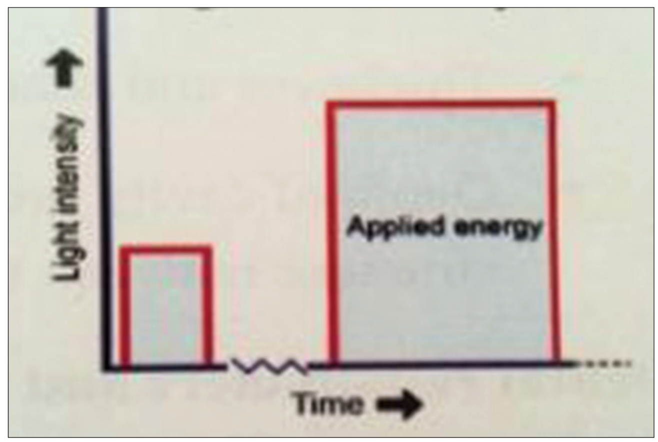

Figure 17: Pulse delay cure

2. Discontinous cure techniques:
   a. Pulse delay cure.

1. Uniform continuous cure [Figure 13]

In uniform continuous curing technique, light of medium constant intensity is used and applied to composite for period of time. It is the most familiar method that is currently used. In QTH and LED curing units uniform continuous curing technique is used.

2. Step cure [Figure 14]

In step cure technique, first, we used low energy and then stepped up to high energy. The purpose for step cure is decreasing the degree of polymerization shrinkage and polymerization stresses by allowing the composite to flow while it is in gel state. Step cure cannot be carried out by plasma arc or laser.

3. Ramp cure [Figure 15]

In ramp cure technique, light is applied in low intensity and then gradually increased over the time. It decreases initial stresses and polymerization shrinkage. It cannot be carried out by plasma arc or Laser curing.

4. High energy pulse cure [Figure 16]

High energy (1000–2800 mW/cm^2) is 3 or 6 times more than the normal power. High energy pulse cure technique is used in bonding of ortho brackets or sealents. In argon laser, plasma arc, 3rd generation of LED high energy pulse curing technique is used.

5. Pulse delay cure [Figure 17]

In pulse delay cure technique, single pulse of light applied to restoration then followed by pause then a second pulse with higher intensity and longer duration. The first low intensity pulse slows the rate of polymerization and decreases the rate of shrinkage and stresses in the composite whereas the second high-intense pulse allows the composite to reach the final state of polymerization. It is carried out by QTH light cure.

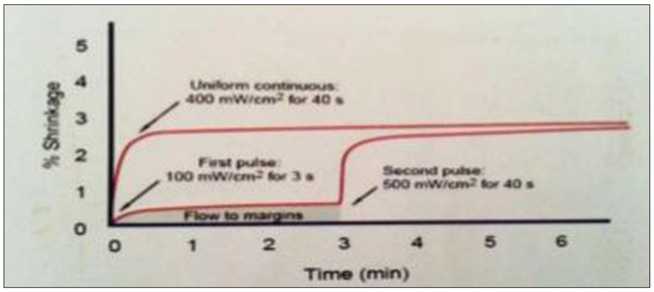

Figure 18: Pulse delay curing compared to uniform continuous curing

Table 2: Factors influencing curing time

Increase curing time	Decrease curing time
Lower irradiances	Higher irradiances
LED	Plasma arc
Halogen	
Microfill composites	Hybrid composites
Darker shades	Lighter shades
Flowable composites	
Greater distances	Close distances
Poor collimation	Good collimation

LED: Light-emitted diode

When pulse delay cure technique compared to uniform continuous cure technique more amount of shrinkage take place in uniform continuous cure technique [Figure 18].

Irradiance is the Power (mW) incident on an surface area of the tip of the light guide (cm^2) [Figure 19].

$$\text{Irradiance} = \frac{\text{mW}}{\text{cm}^2}$$

If surface area of the tip of the light guide is larger, then irradiance is lower. If surface area of the tip of the light guide is smaller, then irradiance is higher. Radiometer is used to check irradiance [Figure 20].

Factors affecting the bond are as follows:[12]

- From orthodontic point of view, increase in thickness of resin reduces the shear strength of bonding enamel–bracket interface[21]
- Penetration of light depends on shade and opacity of composite. Translucent, very light shades will have easier penetration than dark ones. Light translucent shades may cure about 3 mm below the surface, while darker ones may be only 1 or 2 mm
- Bulk of material– Bulk filling should only be done on shallow preparations to make certain that the deepest layer is polymerized
- Depth of cure and time:
  - A standard time of 20 s is usually required to cure to a depth of 2.0–2.5 mm by most curing-light units having a power density of 800 mW/cm^2 in clinical practice. The battery and for a unit emitting 400 mW/cm^2, an exposure time of 40 s is important

Figure 19: Irradiance

  - With standard metal brackets, recommended curing times for a complete cure are 15–20 s on the mesial and distal of each bracket using a halogen light, 10 s mesial and distal for LED lights, 4 s mesial and distal using an argon laser, and 2 s mesial and distal with a plasma arc lamp while ceramic brackets require only half of the total time. Bondable molar tubes require about 150% longer curing times on each of the mesial and distal aspect. Latest introduced light curing devices bonds the metal brackets within 6s time.
- Distance between the light-curing tip and composite:
  - However, the decrease in light intensity of the light-curing unit was found not to obey the inverse square law for the distances 0–15 mm[22-24]
  - Ideally, tip of curing light should be within 3 mm of composite to be effective.
- When long wavelength of light is used, there will be more penetration of light and better curing.[25]
- Size of light-curing unit tip.
  - A light-curing unit standard diameter tip (11 mm) energy is more scattered, whereas in a light-curing unit with a smaller tip (3 mm), it is more focused and so less time to cure but at the same time more temperature can be dangerous to tooth pulp.

Which of them do you think the most appropriate technique to use??

To answer this question, we need to know some points:

- Process of light curing is variable process with different factors affecting it
- There is no single curing protocol that we can depend on it completely in curing all types of composite.

The ideal results from light-curing RBC:

- No negative effects such as marginal staining and restoration fracture
- No microleakage, debonding, recurrent caries, or postoperative pain

Figure 20: Light-emitting diode – Radiometer to check irradiance

Figure 21: Maintenance by periodic visual inspection of unit such as filters and bulb

Figure 22: Optics maintenance kit

Figure 23: Dental radiometer

- However, no clear correlation between contraction stress in dental composites and the success of composite restoration was found clinically.

How long does it take to adequately cure a composite?

Depends on energy density, distance from composite, collimation of light, wavelength, and composite type.

So, how long should I cure composite?

For this, refer to the manufacturer's instructions for guidance.

Factors influencing curing time as shown in Table 2.

General considerations:
- A good rule of thumb is that the minimum power density output should never drop below 300 mW/cm^2
- Shifting from a standard 11 mm diameter tip to a small 3 mm diameter increases the light output eightfold
- Ideally, the fiber optic tip should be adjacent to the surface being cured but this will lead to tip contamination
- Intensity of light is inversely proportional to the distance from the fiber optic tip to the composite surface
- Therefore, the tip should be within 2 mm of composite to be effective
- Light transmitting wedges for interproximal curing and light focusing tips for access into proximal boxes are available
- Intensity of the tip output falls off from the center to the edges. Hence, bulk curing of the composite produces bullet-shaped curing pattern
- Most light-curing techniques require minimum of 20 s for adequate curing
- To guarantee adequate curing, it is a common practice to postcuring for 20–60 s. Postcuring improves the surface properties slightly
- More intense curing units have been developed to hasten the curing cycles. For example, PAC and laser units
- Rapid polymerization may produce excessive

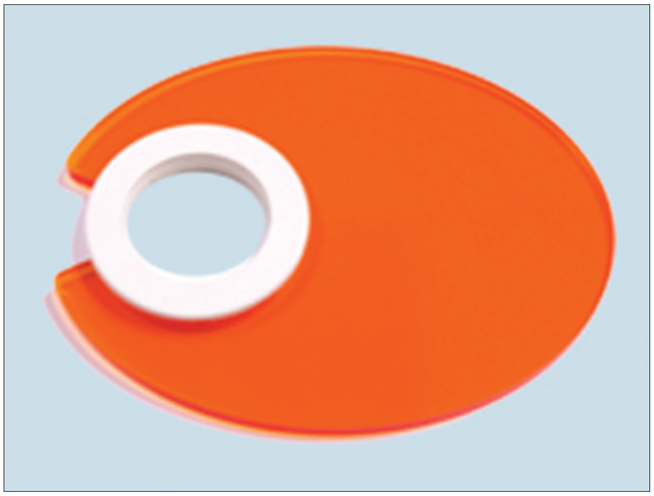

Figure 24: Light shield

Figure 25: Eye glasses for protection of eyes from light-emitting diode

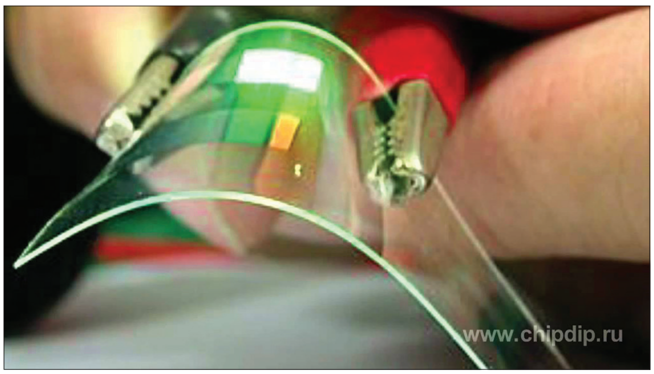

Figure 26: Organic light-emitting diode

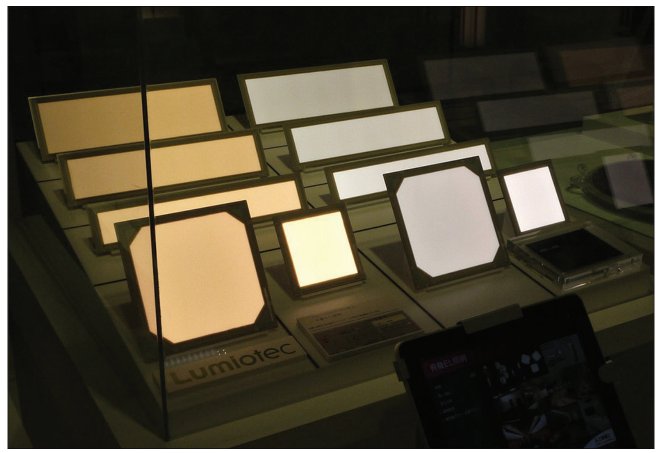

Figure 27: Organic light-emitting diode

polymerization stress and weaken the bonding system layer against tooth structure.

For maintenance of light guide, do periodic visual inspection of unit such as filters and bulb [Figure 21], check irradiance using radiometer.

If light tip contaminated, it reduces passage of light, reflects light increases heat build-up shortens bulb life, remove debris using polishing kit and blade [Figure 22].

HOW CAN THE PERFORMANCE OF THE LIGHT-CURING UNIT BE MEASURED?

The light produced by the light-curing unit can be measured either directly or indirectly. It can be measured directly using curing radiometer and indirectly, in terms of the bond strength of the materials cured by each unit in clinical trials or laboratory studies.

Dental radiometer is specialized light meter that quantifies blue light output, to measure the effectiveness of the curing unit. It may be built in or small handled device [Figure 23].

For optical safety do not look directly at light, wear eyes glasses and shields [Figures 24 and 25].

Comparison between shear bond strength of Halogen light and LED for bracket bonding.[26]

- The halogen lamp provided the highest mean shear bond strength of brackets, but without statistical significance in relation to three other protocols performed with LED devices
- The 3M/ESPE LED device had shear bond strength of brackets similar to that obtained by halogen source, even with the protocol with 10 s of activation
- The Gnatus LED device showed shear bond strength of brackets similar to the one obtained by halogen source, only with the activation protocol of 40 s, being significantly lower when used for 10 s.

Future development in light-curing system:

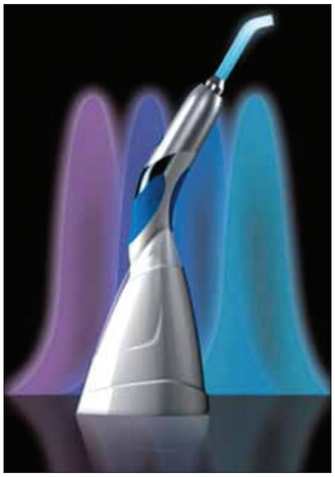

Figure 28: Cordless Scanwave by MiniLed unit in base station

Figure 30: Profile view of Scanwave by MiniLed unit. Modified pen style with activation buttons on both sides of handpiece allows either "pen" or "gun" style grip

Organic LEDs [Figures 26 and 27] are flexible and extremely thin video display to be made, but at current technology, their output level remains below LED chips. Its utilized in impression tray with walls and floor lined with these emitting films which designed to evenly irradiate all surface of photo curable impression material. Organic LED used in vital bleaching and cementation of veneers.

RECENT ADVANCES IN LIGHT-CURING UNIT

Recently, Scanwave is been introduced by MiniLed™ (Aceton) which could be considered as the first fourth-generation LED light to come to the market [Figures 28-30]. Along with incorporating many of the ideal features of the best third-generation lights, other significant improvements have been incorporated into its design. It is the first of its type and hence discussed in detail. It features patented wavelength scanning technology incorporated into its mode selection. This enables the dentist to choose the most appropriate

Figure 29: Display window showing operating mode (full scan), radiation time, battery status and Laser Target ring alignment aid activated for Scanwave by MiniLed

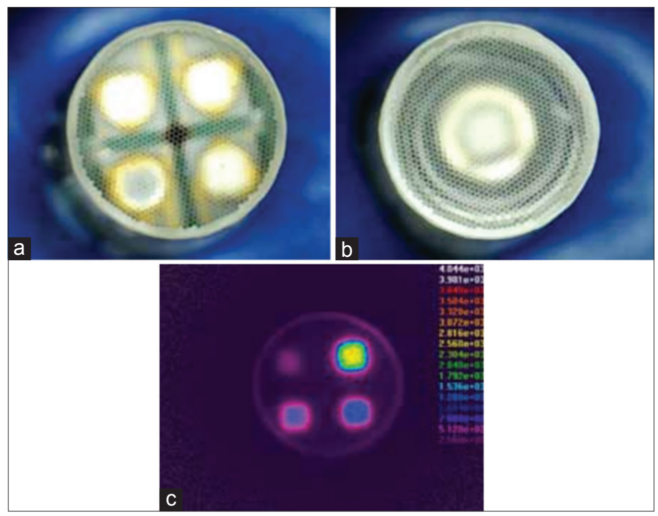

Figure 31: (a and b) Digital images of light guide faces of Scanwave and the high irradiance single blue light emitting diode source, (c) beam profile image of Scanwave's light guide tip or exit window seen "end on" showing the four different wavelengths of diode operating sequentially in "Full Scan" mode

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 photoinitiator chemistry. The diodes are spaced off center which helps distributes the energy across the light guide face and prevents "central hot spots," which can occur with high irradiance third-generation single blue diode LED units [Figure 31a and b]. Preliminary investigations on a prototype Scanwave unit have revealed that by sequentially activating different diode wavelength combinations throughout the irradiation cycle in "Full Scan" mode, it allows good conversion in depth while minimizing heating effects, which are common with high irradiance

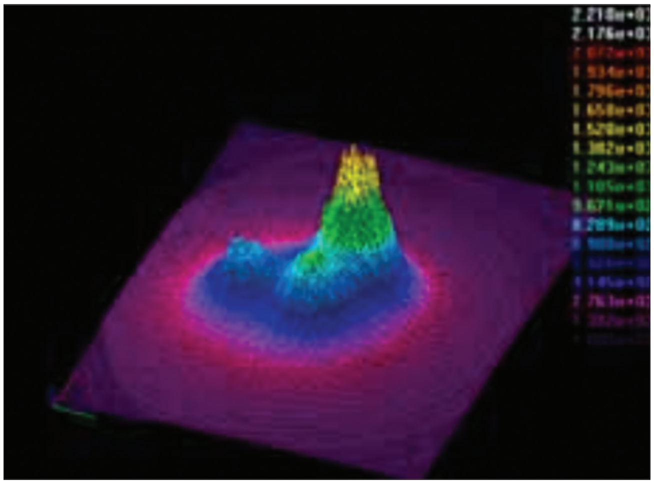

Figure 32: Beam profile camera image as for Figure 31c but with a Lambertain diffuser screen interposed between the light source and the camera lens to induce light scattering as might occur within a restoration

second- and third-generation LED LAUs [Figure 8]. Beam profile imaging has revealed the sequential on/off nature of the different diode wavelengths in full and "soft" scan menus [Figures 31c and 32]. Scanwave has dedicated bonding and orthodontic menus, allowing customization of irradiation time and wavelength selection for curing adhesives and restoratives in a timely manner, thus minimizing heating and associated polymerization stress events. By sequencing the activation of the different wavelength diodes in scan modes, the manufacturer has integrated broad-spectrum-curing capability for universal curing of all materials while eliminating overheating issues, which challenge unit stability. The soft scan menu allows advocates of "soft" polymerization to use ramp, pulse, and "soft stop" concepts in a single sequence, optimizing cure while negating high stresses possible with bulk polymerization of fast-setting high modulus materials and thermal stressing caused by sudden light cessation. Scanwave's dual button activation system, coupled with its modified pen-style handpiece, allows improved ergonomics by allowing either pen or gun style grasps. It has also been designed to meet best practice from a cross-infection risk viewpoint. The intraoral optical guide is removable for autoclaving, thus meeting the gold standard and eliminating the need for barrier protection, which may reduce light delivery significantly. The grasping part of the handpiece has a metal casing for efficient disinfection, and its exclusive cooling system obviates the need for a fan, thus avoiding stagnation of microorganisms within the unit body, which may be a cross-infection risk for patients and the dental team.[27,28] The charging base of this cordless unit features a drain to avoid trapping cleaning fluids. Scanwave is also available in an OEM-corded version for integration into a dental unit. The award-winning inbuilt Laser target ring feature allows the operator to view and control the zone to be irradiated, maximizing light delivery [Figure 28]. This innovative unit sets the standard for the next generation of LED LAUs.

CONCLUSION

- The commonly used term of irradiance measured at the light tip should no longer be used to describe the output of curing lights as it implies that this is the irradiance the specimen is receiving and takes no account of distance between the LCU and the RBC or the effects of beam inhomogeneity
- Ideally, both manufactures and researchers should include the following information about the LCU:
  - Radiant power output throughout the exposure cycle and the spectral radiant power as a function of wavelength
  - Analysis of the light beam profile and spectral emission across the light beam
  - Measurement and reporting of the light the RBC specimen received as well as the output measured at the light tip.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Strassler HE. Cure depths using different light units. Dental Town Magazine; 2002.
2. Malhotra N, Mala K. Light-curing considerations for resin-based composite materials: A review. Part I. Compend Contin Educ Dent 2010;31:498-505.
3. Rueggeberg FA. State-of-the-art: Dental photocuring – A review. Dent Mater 2011;27:39-52.
4. Oyama N, Komori A, Nakahara R. Evaluation of light curing units used for polymerization of orthodontic bonding agents. Angle Orthod 2004;74:810-5.
5. Radzi Z, Yahya NA, Zamzam N, Wood DJ. Light curing units: Tips for orthodontists. Annal Dent Univ Malaya 2004;11:13-23.
6. Rueggeberg FA, Caughman WF, Curtis JW Jr., Davis HC. Factors affecting cure at depths within light-activated resin composites. Am J Dent 1993;6:91-5.
7. Elipar™2500 Halogen Curing Light… Available from: http://cms. 3m.com/cms/CA/en/2-21/kFeeiFY/view.jhtml. [Last accessed on 2004 Nov 22].
8. Instructions. Available from: http://cms. 3m.com/cms/GB/en/2-21/zRiiEL/view.jhtml. [Last accessed on 2004 Nov 22].
9. Craig RG. Chemistry, composition, and properties of composite resins. Dent Clin North Am 1981;25:219-39.
10. Lu RT. Photo Polymerization of Unsaturated Polyester Resin. Canadian Patent 1,004,200; 1977.
11. O'Brien WJ. Dental Material and Their Selection. 3rd ed. Canada: Quintessence; 2002.
12. Chaukse A, Dubey R, Agrawal N, Jain A. A review of orthodontic curing

lights. Indian J Stomatol 2013;4:40-4.
13. Mangat P, Dhingra A, Bhardwaj G. Curing Lights and the science behind them – An overview. IOSR J Dent Med Sci 2014;13:35-9.
14. Okte Z, Villalta P, Garcia-Godoy F, Garcia-Godoy F Jr., Murray P. Effect of curing time and light curing systems on the surface hardness of compomers. Oper Dent 2005;30:540-5.
15. International Organization for Standardization. ISO 4049:2000. Dentistry-Polymer Based Filling, Restorative and Luting Materials. 3rd ed. Geneva, Switzerland: International Organization for Standardization; 2000.
16. de Gee AJ, ten Harkel-Hagenaar E, Davidson CL. Color dye for identification of incompletely cured composite resins. J Prosthet Dent 1984;52:626-31.
17. de Lange C, Bausch JR, Davidson CL. The curing pattern of photo-initiated dental composites. J Oral Rehabil 1980;7:369-77.
18. Yearn JA. Factors affecting cure of visible light activated composites. Int Dent J 1985;35:218-25.
19. Mills RW, Jandt KD, Ashworth SH. Dental composite depth of cure with halogen and blue light emitting diode technology. Br Dent J 1999;186:388-91.
20. Cacciafesta V, Sfondrini MF, Scribante A, Boehme A, Jost-Brinkmann PG. Effect of light-tip distance on the shear bond strengths of composite resin. Angle Orthod 2005;75:386-91.
21. Arici S, Caniklioglu CM, Arici N, Ozer M, Oguz B. Adhesive thickness effects on the bond strength of a light-cured resin-modified glass ionomer cement. Angle Orthod 2005;75:254-9.
22. Radzi Z, Abu Kasim NH, Yahya NA, Abu Osman NA, Kassim NL. Standardization of distance and angulation of light curing unit tip using distometer. 3rd Kuala Lumpur International Conference on Biomedical Engineering; 2006.
23. Caldas DB, de Almeida JB, Correr-Sobrinho L, Sinhoreti MA, Consani S. Influence of curing tip distance on resin composite knoop hardness number, using three different light curing units. Oper Dent 2003;28:315-20.
24. Meyer GR, Ernst CP, Willershausen B. Decrease in power output of new light-emitting diode (LED) curing devices with increasing distance to filling surface. J Adhes Dent 2002;4:197-204.
25. Yoshida S, Namura Y, Matsuda M, Saito A, Shimizu N. Influence of light dose on bond strength of orthodontic light-cured adhesives. Eur J Orthod 2012;34:493-7.
26. Carvalho PE, dos Santos VM, Isber H, Cotrim-Ferreira FA. Halogen light versus LED for bracket bonding: Shear bond strength. Dental Press J Orthod 2013;18:31.e1-6.
27. Shortall AC, Palin WM, Jacquot B, Pelissier B. Advances in light-curing units: Four generations of LED lights and clinical implications for optimizing their use: Part 2. From present to future. Dent Update 2012;39:13-7, 20-2.
28. Janowalla Z, Porter K, Shortall AC, Burke FJ, Sammons RL. Microbial contamination of light curing units: A pilot study. J Infect Prevent 2010;11:216-21.