

# LED Technology

*Here to stay*

A **dentist's** guide to understanding  
the latest advances in **curing technology**

## WHAT'S INSIDE:

- Defining LED technology
- The science behind LED
- LED research
- Restorative materials and curing lights

**ARE YOU UP TO SPEED ON LED?**

By all accounts, dentistry's use of light curing technology continues to rise sharply. A recently released study from the American Dental Association notes that nearly 86 million composite resin fillings were placed in 1999—up about 80 percent from 1990.



**Bob Kehoe**  
Editorial Director

Sales of composite resins in 2001 totaled an estimated \$119 million, up 13 percent from the prior year.

Recently, we've witnessed a rapid rise in new curing light system offerings in various categories, including plasma arc, quartz tungsten halogen, high-speed halogen, laser and light-emitting diode (LED). The main premise behind many of these newer systems is to accelerate the polymerization process, or to at least make it less tedious for practitioners, while at the same time ensuring adequate depth of cure.

Various scientific and clinical researchers have hotly debated the merits and limitations of many newer curing light media. However, there seems to be universal consensus on one point: LED technology is here to stay.

The question is: How well acquainted are clinicians with this technology? A survey conducted in the first quarter of this year by our sister publication, Dental Products Report, indicates many of you want to know more about the science, safety and efficacy behind light curing technology in general and LED systems specifically.

This supplement will help acquaint you with the fundamentals of LED technology. It provides you with important information about the science of how this technology works, research findings and how LED compares with other categories of curing light systems. Finally, this report will give you a sense of the historical development and evolution of LED technology in dentistry and what you can look for in the future development of LED curing lights.

*Bob Kehoe*  
Dental Practice Report

# Curing lights at a glance

**C**uring light technologies have expanded a great deal in the past few years, offering more options—and more confusion—for the dentist. Halogen lights have been the standard in the industry for many years, but recent introductions of plasma arc (PAC), laser and light-emitting diode (LED) curing lights have added a new dimension to curing dental materials. Despite their differences, the commonality of these lights is that they all provide blue light, the kind of light that is appropriate for curing dental materials today. But do you really know the differences in how these lights operate? What makes one better than the other? Ultimately, which is right for your needs? Many factors play into the answers to these questions. Understanding the technology behind each curing light is a valuable first step in finding the answers and making an informed decision about which curing light is right for you and your practice.

## Chemistry 101

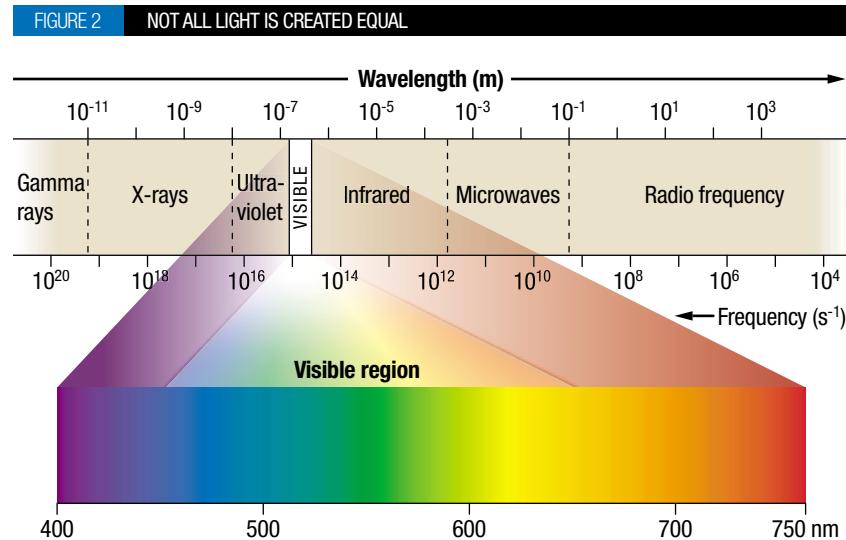
The first step in understanding how curing lights work is identifying the key principles behind light curing. As you likely remember from dental school, photoinitiators are the chemicals in dental materials that allow them to change properties and harden upon light curing. All photoinitiators utilized in dental materials absorb light in the 400-500 nanometer (nm) range. The light that exists in that range is blue by

nature, so all dental photoinitiators utilize blue light. (See Figures 1 and 2.)

The most prominent photoinitiator in dentistry is camphorquinone (CPQ), utilized in more than 90 percent of materials on the market today. Knowing which photoinitiator is in your dental materials is the difference between a properly cured material and scheduling another appointment to fix an under-cured composite. Manufacturers should be able to tell you what photoinitiator is used in their materials. Each photoinitiator has an absorption spectrum, measured in nanometers. CPQ, for example, has an absorption spectrum between 400 and 500 nm, which matches with blue light, with its maximum efficiency achieved between the 460 and 480 nm range. Once you've identified the photoinitiator in your material and know its effective absorption range, it's time to look at the wavelengths of your curing light.

Light is delivered from your curing light over a range of wavelengths. The range of these wavelengths varies among types of lights. Your goal should be to match the wavelength of the curing light with the absorption spectrum of the photoinitiator of the composite material. (See Figure 3.)

We've discussed half the answer to this all-



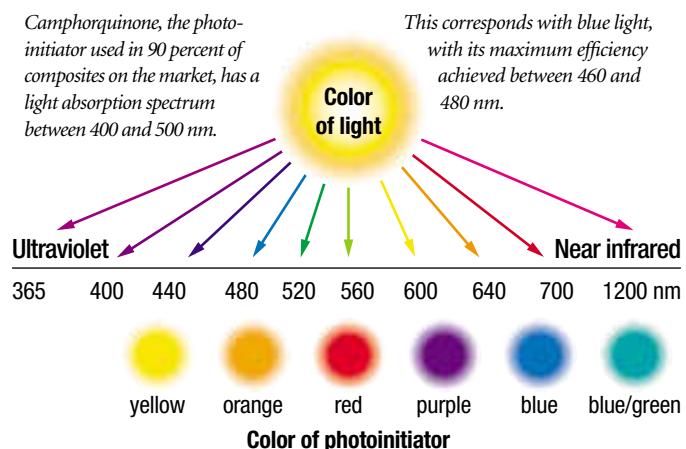
important equation already. If a material uses CPQ as the photoinitiator, then the optimal efficiency of light absorption is from 460 to 480 nm. Does your curing light's wavelength match this number? If you're outside the photoinitiator's absorption spectrum even a little, you're wasting light and any extra energy is being diverted uselessly. High-intensity curing lights with wavelengths less than 400 nm or greater than 500 nm, ranges outside CPQ's optimal 460-480 nms, are generating a significant amount of wasted light energy because it doesn't match the photoinitiator. Bringing this information together results in under-

standing how much "total useful light" you are getting from your curing light.

## Total useful light

Dentists evaluate curing lights by using a light meter, which measures total energy over a given spectral range. Curing light intensity is measured in milliwatts per square centimeter [mw per cm<sup>2</sup>]. For example, 3M ESPE's Elipar™ FreeLight curing light measures near the 400 mw per cm<sup>2</sup>. A typical halogen light provides blue light output between 400 to 800 mw per cm<sup>2</sup>. A dentist could potentially have a curing light with a high-energy output, such as 1,000 mw per cm<sup>2</sup>, but the light's wavelength may not match up well with the absorption spectrum of CPQ. If that happens, the dentist has been deceived into thinking he or she has more useful light. What they really have is more intensity, but they are wasting it by not matching the wavelength to the absorption spectrum. It's not always how much light you have, but rather how effectively the light's

**FIGURE 1 LIGHT AND LIGHT ABSORPTION**



**FIGURE 3 LIGHT WAVELENGTH AND CAMPHORQUINONE ABSORPTION**

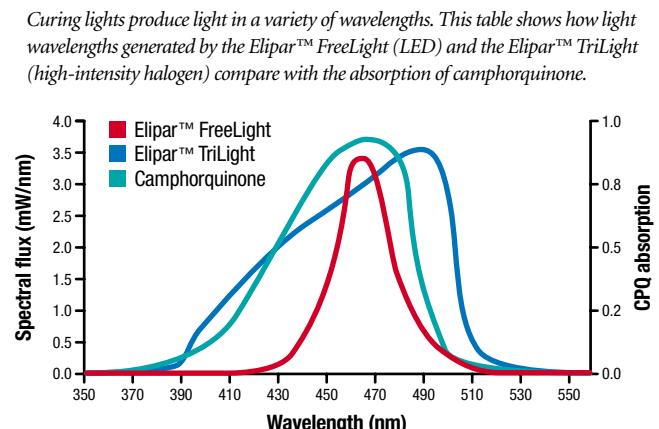
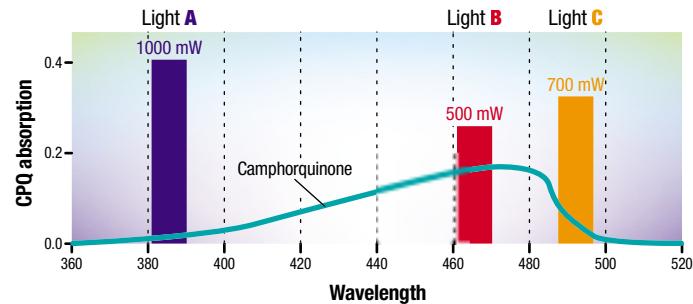


FIGURE 4 WHICH LIGHT WOULD YOU CHOOSE FOR CAMPHORQUINONE?

As this figure illustrates, more power doesn't always result in greater curing efficiency.



wavelength matches with the photoinitiator's absorption spectrum. (See Figure 4.)

A lower-powered light, such as an LED curing light, may be a better fit because it more closely matches the photoinitiator in the material. Matching the wavelength of the curing light to the absorption spectrum of the photoinitiator is one of the most important factors in curing dental materials. Only

when this is done correctly will intensity change the outcome of the cure. However, intensity is clearly an important factor in successfully curing dental materials. Higher intensity at the desired absorption wavelengths is likely to be better than an equivalent light with lower intensity within the desired absorption spectrum. Understanding this principle is the key to understanding the different types of curing lights. ■

## COMMON MISCONCEPTIONS

**MYTH:** Intensity is the most important factor in choosing a curing light.

**FACT:**

Actually, matching the wavelength of the curing light to the absorption spectrum of the photoinitiator is the most important factor in curing dental materials. Only when this is done correctly will intensity change the outcome of the cure. For example, it is possible for a curing light to be more intense than another but leave a material uncured because the wavelength didn't match the photoinitiator.

FIGURE 5	SO MANY CURING LIGHTS, SO MANY CHOICES — PROS	CONS
<b>Halogen</b>	<ul style="list-style-type: none"> <li>▶ Low-cost technology</li> <li>▶ Longest history in dental industry</li> </ul>	<ul style="list-style-type: none"> <li>▶ Low efficiency</li> <li>▶ Short service life</li> <li>▶ High temperatures (lamp must be cooled by ventilating fan)</li> <li>▶ Continuous spectrum must be narrowed by filter systems</li> </ul>
<b>PAC</b>	<ul style="list-style-type: none"> <li>▶ Shorter polymerization times (no unambiguous scientific data to confirm this)</li> </ul>	<ul style="list-style-type: none"> <li>▶ Very low efficiency</li> <li>▶ High temperature development (lamp is situated in the base unit and cooled by a ventilating fan)</li> <li>▶ Continuous spectrum must be narrowed by filter systems</li> <li>▶ High price</li> </ul>
<b>Laser</b>	<ul style="list-style-type: none"> <li>▶ Low heat generation</li> </ul>	<ul style="list-style-type: none"> <li>▶ Negative perception about curing quality due to high curing speeds</li> <li>▶ Incompatible with some adhesives and composites</li> <li>▶ Large base needed for power suppliers and cooling</li> <li>▶ High price</li> </ul>
<b>LED</b>	<ul style="list-style-type: none"> <li>▶ No need for filter systems</li> <li>▶ High efficiency leads to minimal heat (no ventilation fan required) and low power consumption (battery operation is possible)</li> <li>▶ Frame can be easily cleaned, since no slots for a ventilation fan are needed</li> <li>▶ Long service life</li> <li>▶ Consistent output, with no bulbs to change</li> <li>▶ Quiet</li> </ul>	<ul style="list-style-type: none"> <li>▶ Due to their narrow emission spectrum, LEDs can only polymerize materials with an absorption maximum between 440 and 480 and CPQ as the photoinitiator</li> <li>▶ Relatively new technology in the dental industry</li> </ul>

# LED

## under the microscope

Light-emitting diode technology has been around for decades. You probably have encountered electronic devices in your home or office that contain red or green light indicators utilizing LED technology. The keyboard for your computer, for example, most likely utilizes LED lights to let you know the 'Caps Lock' key has been pushed. Even laser pointers utilize LED technology, though a different version. Slightly different than these two examples is blue LED light, which has entered the den-



tal market recently but is poised to take off as the next industry-changing technology. Why? Because blue LED wavelengths are matched to the absorption spectrum of the most popular photoinitiator in composites today, CPQ, making this technology incredibly efficient and consistent in curing dental materials. ■

## COMMON MISCONCEPTIONS

**MYTH:** The more LEDs that a curing light contains, the better it is at curing materials.

**FACT:**

The number of LEDs in a curing light doesn't necessarily have any bearing on the spectral output of the unit, no matter if it has 64, 19 or one LED. In a culture where more is better, this can be a difficult principle to understand, but there are multiple types of LEDs and each is unique in its performance. Different LEDs have different intensities, so a curing light with one very intense LED could be more powerful than a curing light with 64 less-intense LEDs. Curing light output depends on three things: spectral output of the LEDs' wavelength, intensity of the LEDs and optical light delivery. Judging an LED curing light by the number of LEDs doesn't make sense.

## Prove it!

At the 2002 meeting of the International Association for Dental Research (IADR), researchers spent considerable time discussing recent findings related to LED technology. Summarizing the acceptance of the new technology into the dental community, IADR researchers stated: "LED technology is a viable alternative to polymerize adhesives and composites."

Researchers demonstrated the principles behind why LED technology performs at the level of other current curing lights, and with better efficiency. "Data indicates the LED light tested had least power, lowest intensity, narrowest spectral output, created least pulp temperature rise, and required cure times comparable to the representative conventional halogen light tested. LED technology can be successfully applied to polymerization of dental restoratives."

Yet, the IADR is not the only researching body that recognizes the value of LED technology. In the March issue of the CRA Newsletter, it is stated, "When cure time and resin are standardized, LED lights have a depth of cure similar to conventional halogen lights. This depth of cure is possible with LED intensity measurements 40-60 percent lower than halogen lights due to output that is very specific to the chemical initiator camphorquinone used in most resins." As you'll remember from the early part of this article, the link between the photoinitiator's absorption spectrum and the curing light's wavelength is where the first test of a curing light must come in.

These research results push LED technology to the forefront of curing light technology. More studies will continue to validate the principles addressed in the preceding paragraphs, and new developments in this exciting technology will continue to improve the curing of dental materials. ■

## 3M ESPE ELIPAR™ FREELIGHT

3M ESPE's own entry into the world of LED technology is the **Elipar™ FreeLight** curing light. The light requires less than 10 percent of the electrical power consumed by conventional halogen lights. The small, cordless handpiece is designed for user comfort and flexibility.

The performance of the Elipar FreeLight curing light provides polymerization results and cure times similar to conventional halogen units. Blue LEDs generate a light that closely matches the absorption spectrum of the photoinitiator systems most frequently used in dental materials, and the LEDs are very long-lived.

According to research presented at the International Association of Dental Research (Abstract 1935), "3M ESPE Elipar™ FreeLight Curing Light, with less than half the light output than a halogen light, is able to produce acceptable curing depths for all the composites."



# Restoratives

## *and curing lights*

Composite materials were introduced to the marketplace in the 1950s and 1960s, developed as a more esthetic option than amalgam for restorations. In 1964, 3M introduced Addent™, the first commercial polymerizable resin composite dental restorative on the market. At this time, restoratives were chemically cured, requiring separate pastes mixed together before applying to the prepared tooth. During the late 1970s, the concept of photopolymerizing dental restorative materials with

UV light activation was first introduced to the dental community. This concept served as a major advance over conventional chemically cured composites by providing premixed, shelf-stable materials with infinite working time and cure-on-demand ability. For the first time, curing restorative materials required no mixing, provided adequate time for placement and preparation of anatomy, and delivered instantaneous results. This gave more control to the dentist and reduced the stress involved with restorative dentistry.

### Future outlook

LED technology is certain to play a crucial part in the future of dentistry. Impressive debuts by first-generation models, such as 3M ESPE's Elipar™ FreeLight Curing Light, have cemented LED technology's status in the industry. By matching the curing light's spectral output, or wavelength, to the photoinitiator's absorption spectrum, LED technology has completed the most important first step in efficient, consistent light curing. Continued research into the LED arena will offer the same efficient technology with higher intensity lights and decreased cure times. Future curing lights could be pen-sized and cure materials in half the time it takes currently. The bottom line is, LED technology is here to stay, and the sky's the limit.

UV photocuring dramatically changed the direction of dentistry; however, it still had several limitations including limited depth-of-cure due to light absorption of the resins, pigments and fillers in the composites, and also significant safety considerations due to the nature of higher energy UV light. The early 1980s led to further advances in the photocuring of dental materials. The key advance was in the area of visible light curing and the identification of CPQ as an ideal photoinitiator. The advent of visible light curing and photoinitiator use in composite materials began changing the world of restorative dentistry. Blue light in the form of quartz-tungsten halogen curing lights became the standard for light curing, offering better depth of cure and a safer means of curing versus UV light.

Restorative materials and curing light technologies continued to advance. Manufacturers continued to improve upon the physical and esthetic properties of composites while curing lights increased in intensity in an attempt to direct more light toward the restoratives to cure them faster and

#### COMMON MISCONCEPTIONS

**MYTH:**  
LED curing lights are a very **slow** way to cure materials.

**FACT:**  
LED curing lights are able to cure materials in times comparable to conventional halogen lights. They can do this by utilizing a narrow wavelength that most closely matches CPQ, the photoinitiator chiefly used in composite materials. This narrow and well-matched wavelength overlap allows LED curing lights to efficiently cure materials with little wasted light output.

deeper. Restoratives branched out into categories such as hybrids, known for their strength with some esthetic quality. Microfills were still used for their exceptional esthetics. Plasma Arc and Laser curing lights entered the market, promising faster cures by producing more light.

Manufacturers still are attempting to capture the strength of a hybrid and the esthetics of a microfill. So far, no one material has captured both qualities to the fullest extent possible. On the curing light side, light emitting diode (LED) curing lights are the latest advancement, coming to market with numerous benefits to traditional curing lights, including low energy consumption with the light output fine-tuned to CPQ.

In the near future, 3M ESPE will be introducing a new addition to the restorative market that finally attains the goal of offering both excellent strength and outstanding esthetic qualities. And we can be watching for higher intensity LEDs to bring curing lights into the next generation of dentistry. ■

## It's Good To Be King!



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