Visible Light-Curing

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Visible light-curing of resin-based materials is a routine but very important process in restorative dentistry. New light-curing technologies have emerged in recent years, particularly the development of light-emitting diode (LED)-based devices. In addition, our understanding of light-curing has improved greatly, as research has revealed aspects of the process that were unknown or poorly understood in the past. This Critical Appraisal presents some of the better research on the subject that has appeared in the recent literature.

Comparison of Manufacturer-Recommended Exposure Durations with Those Determined Using Biaxial Flexure Strength and Scraped Composite Thickness Among a Variety of Light-Curing Units

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ABSTRACT

Objective: This study compared composite depths of cure as: (1) recommended by the manufacturer, (2) determined by measuring flexural strength, or (3) determined by a composite scrape test.

Materials and Methods: A single hybrid composite resin restorative material (Prodigy shade A3, Kerr, Orange, CA, USA) was light-activated using three different units: Optilux 501 (traditional quartz-tungsten-halogen [QTH]), LE Demetron 1 (an early or conventional LED unit), or Demi (a newer, high intensity LED unit). All of these devices are produced by Kerr Demetron (Orange, CA, USA). The irradiance of each unit was measured using a spectral radiometer.

A custom specimen fabrication device was used to form 3-mm stacks of composite resin separated into 0.5-mm layers. The composite was light-activated from the top surface of the stack for various exposure times—10, 20, 30, 40, and 60 seconds for the QTH light and 5, 10, 15, and 20 seconds for both LED devices. Curing times recommended by the manufacturer were 20 seconds for the QTH, 10 seconds for the conventional LED, and 5 seconds for the high intensity LED. The individual layers of composite were removed from the stack and their biaxial flexure strength was determined using a standard test fixture in a universal testing machine (Instron Corporation, Norwood, MA, USA). The monomer conversion of each specimen was measured using a Fourier transform infrared (FTIR) spectrometer.

Compules of the same composite were modified for use as plastic cylinders holding the uncured composite paste. The plunger was removed and the curved spout was cut from the main cylindrical body of the compule. The composite within the compule was light-activated from the top surface using the three curing devices for various exposure times. The cured composite was removed from the compule and uncured paste was scraped from the bottom. The thickness of the hard composite was measured with a digital micrometer. A spreadsheet program was used to plot the thickness of the composite as a function of exposure duration for each unit. The

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same software was used to perform a regression analysis to determine optimal exposure times.

Results: The power density of the QTH device was 602 mW/cm^2, with a broad spectrum (370–510 nm) output. The LE Demetron 1 had a power density of 593 mW/cm^2 with a 65 nm spectrum peaking at 460 nm. The Demi provided a shifting output, with intensities of 1,434 and 1,183 mW/cm^2. Its emission spectrum was 420 to 500 nm, with a peak of 456 nm.

Flexural strength of the composite increased with exposure time for each of the three curing devices. Flexural strengths values at a 2.5-mm depth equivalent to those at the top irradiated surface were achieved with 15- to 20-second exposures for the conventional LED, 20 seconds for the high intensity LED, and 30 to 40 seconds for the QTH. Regression analysis of the scraping method showed that optimal polymerization of the composite using the three different devices occurred at 15, 17, and 25 seconds, respectively. Results determined by simple scraping correlated well with those determined by biaxial flexure testing.

Conclusions: In all cases, the exposure times recommended by the manufacturer resulted in lower flexural strengths and smaller scraped composite thicknesses than those achieved using longer exposure times. A simple in-office scraping test can provide accurate information regarding depth of cure provided by combinations of light-curing units, exposure durations, and composite brand and shade.

COMMENTARY

This is a lengthy and rather technical treatment of exposure times required to adequately cure a composite resin restorative material. It presents two major findings of interest to the clinician. First, it suggests that the curing times recommended by a manufacturer might not deliver the amount of energy required to adequately cure composite, even under the ideal laboratory conditions used in the study. Longer exposure times are almost certainly better, especially under clinical conditions that are rarely if ever ideal. Second, a very simple scraping test was shown to provide information about depth of cure that was almost identical to that obtained by a more sophisticated laboratory test. This scraping method could easily be used by any clinician who wished to determine specific curing times for a combination of light and composite used in his or her practice.

Knoop Microhardness Mapping Used to Compare the Efficacy of LED, QTH, and PAC Curing Lights

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ABSTRACT

Objective: This study was designed to test the ability of 21 curing lights (three each of seven different brands) to polymerize composite at distances of 4 and 8 mm from the light guide.

Materials and Methods: The study evaluated curing of five composite resin restorative materials by these curing devices: Optilux 501 (Kerr Demetron), Sapphire (Den-Mat, Santa Maria, CA, USA), Allegro (Den-Mat), bluephase 16i (Ivoclar Vivadent, Amherst, NY, USA), LE Demetron II (Kerr Demetron), SmartLite iQ (Dentsply Caulk, Milford, DE, USA), and UltraLume 5 (Ultradent, South Jordan, UT, USA). The Optilux 501 is a quartz-tungsten-halogen (QTH) light, the Sapphire is a plasma arc curing (PAC) light, and the other are LED units. Of the LED devices, the UltraLume 5 provides a dual-peak output, whereas the other devices emit light within a single wavelength band. The light output (intensity and spectrum) from each device was measured using a laboratory-grade spectroradiometer at distances of 0, 4, and 8 mm.

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Composite specimens were formed in 2-mm-thick aluminum molds using the light guides at these same distances, generally with curing times recommended by the manufacturers. At 24 hours, multiple Knoop microhardness measurements were made across the top and bottom surfaces of the specimens using an automated hardness tester (a good correlation has been reported between Knoop hardness and degree of conversion). The Knoop hardness numbers were exported into a graphing program for statistical analysis and production of color-coded hardness maps.

Results: The spectral emission of the PAC light was the broadest, covering 375 to 515 nm, The QTH also had a broad spectrum, but not as much as the PAC light. As expected, four of the LED devices had single peak emission spectra and the UltraLume 5 had a dual-peak spectrum.

At the 0-mm distance, the mean irradiance values ranged from 782 to 2,693 mW/cm^2. The mean energy densities at that distance ranged from 7.3 to 22.9 mJ/cm^2. Energy densities are a product of intensity and exposure time, so a light with lower intensity can deliver a higher energy density than a more intense light that has a shorter exposure time. In this study, curing times varied among the different curing lights, and were either 5, 10, or 20 seconds. The mean irradiance values decreased with increasing distance from the light guide. They ranged from 325 to 2,327 mW/cm^2 at 8 mm. Energy densities declined in a similar fashion. The PAC light was by far the least affected by distance.

Overall, the PAC light also produced the greatest hardness values. Representing those as 100%, the other mean hardness values were 94% for the QTH light and ranged from 72% to 91% for the LED units. With the exposure times and composites used, the curing ability of the various lights, was ranked from best to worst: Sapphire, Optilux 501, Allegro, UltraLume 5, LE Demetron II, and bluephase 16i.

Conclusions: When used with some manufacturers' suggested curing times and clinically relevant distances, some curing lights deliver much less energy than is recommended for thorough resin polymerization and produce softer composites.

COMMENTARY

The LED curing lights tested in this study were used for exposure times of only 5 or 10 seconds. The two LED devices ranked as the least able to cure composite thoroughly were the ones that used 5-second exposures. Even at a 0-mm distance from the light guide, the energy densities delivered were less than desirable in some cases. Undoubtedly, these LED devices would have performed better with longer exposure times. However, manufacturers claim that these short exposure durations are acceptable. The results of this study suggest that very short curing times are not a good idea in most clinical situations except for PAC lights.

Pulpal Temperature Rise and Polymerization Efficiency of LED Curing Lights

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ABSTRACT

Objective: The purpose of this study was to evaluate the polymerization efficiency of four LED light-curing units and their thermal effects on the pulp chamber at different exposure times.

Materials and Methods: The LED curing devices used in this study included two single-peak devices (bluephase 16i and Freelight 2 [3M ESPE, St. Paul, MN, USA]) and two multiple-peak devices (bluephase G2 [Ivoclar Vivadent] and G-Light [GC America, Alsip, IL, USA]). A conventional QTH unit (XL3000 [3M ESPE]) was

used as the control. The spectral emission of each device was measured using a spectroradiometer and irradiance was measured using a handheld dental radiometer (Ivoclar Vivadent).

All of the devices were used to light-activate Tetric EvoCeram (Ivoclar Vivadent) composite shade A2 (with camphorquinone, or CQ, as the dominant photoinitiator) and Bleach XL (with Lucirin TPO as the dominant photoinitiator). The composite was cured in 2-mm-deep molds using the LED units at exposure times of 10, 20, and 40 seconds. The halogen light was used at 40 seconds. Vickers hardness (VHN) of top and bottom surfaces was measured using a microhardness tester.

To measure temperature changes within the pulp chamber under the various curing conditions, a thermocouple was placed inside the water-filled pulp chamber of an extracted molar. The remaining dentin thickness between composite cured on the tooth surface and the pulp was 2 mm. A 2-mm-thick Teflon mold was placed over the flattened occlusal surface of the tooth before irradiation. Temperature readings were done using both an empty mold and with the mold filled with either of the two tested composites. Temperature was recorded during irradiation and extended until ambient temperature had been regained.

Results: Measured irradiance values (mW/cm^2) were 544 for the QTH light, 644 for the FreeLight 2, 1,050 for the bluephase G2, 1,166 for the G-Light, and 1,622 for the bluephase 16i. The measured emission spectra suggested that the FreeLight 2 and the bluephase 16i should be ineffective for stimulating the TPO photoinitiator.

For the A2 composite, VHN values at the bottom surfaces of the specimens were at least as high as those for the control (40-second exposure of QTH light) with only one exception. Although there was more statistical overlapping of the results for the Bleach XL shade composite, the pattern was similar. In both cases, irradiation time played a significant role in the results.

Temperature increases within the pulp chamber were as much as 6°C. These tended to be higher using the more powerful lights, longer curing times, and A2 composite.

Conclusions: A perfect correspondence between curing light and composite is important to provide optimal polymerization of the composite and limit heating in the pulp chamber. Also, reduced curing times are possible with high intensity LED curing units, but optimal curing times are longer than those recommended by manufacturers and can depend on the type of photoinitiator present in the composite.

COMMENTARY

The stated conclusions summarize this study very well. With mismatched emission spectra of the curing light and absorption spectra of the photoinitiators, longer curing times are required. With higher intensity lights, this can come at the expense of undesirable heating of the pulp chamber.

Irradiance Uniformity and Distribution from Dental Light Curing Units

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ABSTRACT

Objective: The purpose of this study was to quantify and qualify the distribution and uniformity of irradiance from a variety of commercial light-curing units and to evaluate the effects of different light guide designs.

Materials and Methods: The curing devices tested in this study, including type of light source and light guide were the Sapphire (PAC; “reverse turbo” 5.5–9 mm light guide), Optilux 501 (QTH, standard 11 mm), bluephase 16i (LED, 13–8 mm turbo and standard 11 mm), SmartLite iQ (LED, 13–8.5 turbo), and FLASHLite

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Magna (LED, which uses no light guide [Discus Dental, Culver City, CA, USA]). The power of each light was measured by multiple exposures on two different meters. Irradiance values were calculated by dividing mean power values by the light tip area. Irradiance across the tips was determined by using a special apparatus (beam profiler) designed to accurately characterize light beams.

Beam analyzer software color-coded irradiance in both two and three dimensions. Another software package was used to generate histograms of the irradiance levels at different locations of the beam. To determine the effect of light guide type on power output and irradiance distribution, the same curing device (bluephase 16i) was tested using both standard and turbo light guides.

Results: The mean irradiance values for the tested lights at tip end (in mW/cm^2) were 2,208 for the PAC light, 1,714 for the bluephase 16i/turbo, 1,120 for the FLASHLite, 786 for the halogen, 725 for the bluephase/standard, and 570 for the iQ. "Top hat factors" (THF) were calculated for each light (a perfect distribution of emitted light forms a cylinder with a flat top, i.e., resembling a top hat). The FLASHLite, which has a different configuration from the other units tested and does not use a light guide had the lowest THF at 0.32; the SmartLite iQ had the highest THF at 0.74. For the LED device using both standard and turbo light guides, the standard light guide produced a higher THF (0.60) than the turbo (0.50). A "perfect" light beam would have a THF of 1.0, so higher values are better, indicating a more uniform beam.

All of the tested lights had varying irradiance levels at different locations across the beam. Coefficients of variation (standard deviation divided by mean) for irradiance differences within a beam tended to be in the 40% range. Essentially, this means that light output was not uniform across the face of a light guide. As one example, the SmartLite iQ produced a beam that was less than 500 mW/cm^2 in 15% of its area and more than 500 mW/cm^2 in 85% of its area, with a small percentage of the latter exceeding 1,000 mW/cm^2.

Conclusions: Using different light guides on the same light-curing unit significantly affected its power output, irradiance values, and beam homogeneity.

COMMENTARY

This study found that light emitted from LED curing devices is not uniformly distributed within a beam; there are more and less intense areas. Localized differences in light intensity could result in differences in the physical properties of composite, but the clinical implications of such small-area differences are unknown. From a clinical standpoint, the most important finding was that turbo tips significantly reduce homogeneity of the light beam. Previous studies have reported that turbo tips have a focusing effect that causes dispersion of the light beam as the distance between the light guide and composite "target" increases beyond a certain distance such as 5 mm. Therefore, at greater distances, turbo tips deliver less energy than regular tips.

SUGGESTED READING

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THE BOTTOM LINE

- LED curing devices represent the state of the art in dental light-curing technology. These generally have emission spectra well suited to absorption by camphorquinone, the primary photoinitiator used in dentistry. LED devices also require less energy than traditional curing units. They are expected to have a long service life, and many are lightweight portable units.
- PAC and QTH technologies are proven technologies that provide broad spectra of light capable of stimulating all dental photoinitiators. PAC lights can adequately cure composite with very short exposure times.
- Some manufacturers claim that their high-intensity LED curing lights can be used to cure many composites with exposure times as brief as 5 seconds. Independent research has failed to verify such claims.
- Appropriate curing times are influenced by various factors related to the light being used and the composite being cured. More information on this will be presented in a future "Contemporary Issues" article by Dr. Kraig Vandewalle.
- A few materials (such as certain bleach shade composites) contain little camphorquinone and may not cure well using single-peak LED devices. This is not a concern for PAC, QTH, and dual- or multipeak LED devices.
- High-intensity curing lights, including LEDs, can heat the pulp. Shorter curing times cause less heating.
- Light emission from light guides is not uniform across the diameter of the beam or with distance. Beam uniformity is better with standard light guides than with turbo tips.

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