

An Evaluation of the Light Output from 22 Contemporary Light Curing Units

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This study measured the radiant power (mW), irradiance (mW/cm²) and emission spectra (mW/cm²/nm) of 22 new, or almost new, light curing units (LCUs): - Alt Lux II, BioLux Standard, Bluephase G2, Curing Light XL 3000, Demetron LC, DX Turbo LED 1200, EC450, EC500, Emitter C, Emitter D, KON-LUX, LED 3M ESPE, Led Lux II, Optilight Color, Optilight Max, Optilux 501, Poly Wireless, Rádii cal, Rádii plus, TL-01, VALO Cordless. These LCUs were either monowave or multiple peak light emitting diode (LED) units or quartz-tungsten-halogen LCUs used in anterior and posterior teeth. The radiant power emitted by the LCUs was measured by a laboratory grade laser power meter. The tip area (cm²) of the LCUs was measured and used to calculate the irradiance from the measured radiant power source. The MARC-Patient Simulator (MARC-PS) with a laboratory grade spectrometer (USB4000, Ocean Optics) was used to measure the irradiance and emission spectrum from each LCU three times at the sensor located on the facial of the maxillary central incisors and then separately at the occlusal of a maxillary second molar. The minimum acceptable irradiance level was set as 500 mW/cm². Irradiance data was analyzed using two-way ANOVA and the radiant power data was analyzed by one-way ANOVA followed by Tukey test ($\alpha=0.05$). In general, the irradiance was reduced at the molar tooth for most LCUs. Only the Valo, Bluephase G2 and Rádii Plus delivered an irradiance similar to the anterior and posterior sensors greater than 500 mW/cm². KON-LUX, Altlux II, Biolux Standard, TL-01, Optilux 501, DX Turbo LED 1200 LCUs delivered lower irradiance values than the recommended one used in molar region, KON-LUX and Altlux II LCUs used at the maxillary incisors. Bluephase G2 and Optilight Max delivered the highest radiant power and KON-LUX, Altlux II and Biolux Standard delivered the lowest power. The emission spectrum from the various monowave LED LCUs varied greatly. The multi-peak LCUs delivered similar emission spectra to both sensors.

Key Words: light curing unit, radiant power, irradiance, emission spectrum, MARC patient simulator

Introduction

Use of light cured dental resins is now ubiquitous (1,2) and the light-curing unit (LCU) should be considered as an essential piece of equipment in every dental office. A significant volume of dental research and clinical procedures involve the use of composite resin and a dental curing light (3). To achieve the manufacturer's intended mechanical properties for light cured resin-based composites (RBCs), the material must receive from the LCU sufficient energy at the appropriate wavelengths (2,4-8).

Several different types of LCUs are available: quartz-tungsten-halogen (QTH), plasma arc (PAC), laser and different types of light emitting diode (LED) units (9). These LCUs range in price and unfortunately the cost of the unit is one of the first factors that some clinicians consider when purchasing a new curing light. However, when choosing a new LCU it is important to understand what it does and what its specifications mean. The use of a single "irradiance" value that manufacturers often quote to describe the output from the LCU should be interpreted with caution, as it implies that this single irradiance value describes the light that every part of the resin composite is receiving (2). However, this

irradiance (incident irradiance) value, expressed in milliWatt per square centimeter (mW/cm²), is derived from the total radiant power (Watts) delivered by the LCU onto a surface of known dimensions (cm²). It can only reflect an average value over the total surface area (2) and it does not take into account any non-uniformity in the light output across the tip of the LCU, or the distance from the tip.

The clinicians also need to know the emission spectrum of the light emitted from the LCU, so that they can match the light to the RBC they are using (4,5,10). The output from conventional single peak LED units is designed to activate the camphorquinone photoinitiator (1,5,11). Camphorquinone (CQ) is the traditional initiator used in most RBCs and it is mostly activated by blue light peaking at 468 nm wavelength. Several new photoinitiators have been developed as an alternative to CQ, e.g., trimethylbenzoyl-diphenylphosphine oxide (TPO, ranging from 375 to 410 nm) and 1-phenyl-1,2-propanedione (PPD, maximum wavelength \approx 410 nm) (12,13). Some broad-spectrum LED units include additional LED emitters that produce light at these lower wavelengths, which are in the 'violet' range, to make these LCUs compatible with a wider range of

photoinitiators (1,8,14). However, unless carefully designed, the addition of a variety of different wavelength LEDs within the light source can affect negatively the uniformity of the light beam from the LCU. This may then affect both the irradiance and wavelengths received at different locations

across the restoration and thus alter the polymerization of the RBC.

The sales of budget LCUs has increased substantially. Although it might seem attractive to purchase a budget LCU, the performance of this equipment may reduce the clinical

longevity of restorations. Several previous studies that have evaluated dental LCUs have used dental radiometers, but such devices are known to be inaccurate. In addition, they do not report the radiant power or the emission spectrum (15). Therefore, the aim of this study was to analyze the radiant power, irradiance and emission spectrum of a wide range of commercially available curing lights. As the ability of the LCU to access the restoration is also an important factor, the effect of the restoration's location in the mouth was also evaluated. Although previous studies have used a minimum acceptable irradiance value of 300 mW/cm², this was time when dentists used a curing light for 40 to 60 s per increment of RBC. Given today's norm of 10 to 20 s exposure time per increment, an irradiance value of 500 mW/cm² was defined in this study as the minimum threshold for adequate photocuring and producing adequate mechanical properties to the RBC. The null hypotheses were that: a) The QTH and the LED LCUs would deliver similar spectrum and irradiance to simulated restorations in the anterior and posterior teeth; b) The QTH and the LED LCUs would deliver similar radiant powers; c) The different light curing designs would not affect the irradiance delivered to simulated restorations in the anterior and posterior teeth.

Material and Methods

Twenty-two different commercially available LCUs (Figs. 1 and 2) were tested: 17 were monowave LED, 2 were multiple peak LED units and 3 were QTH units (Table 1).

Light Tip Area and Radiant Power

The tips of the LCUs were photographed (Fig. 3). The light tip internal and external diameters were measured. The tip area was calculated from the internal radius



Figure 1. A: Optilight; B: Optilight Color; C. Emitter D; D. High-Power 3M-ESPE; E. Led Lux II; F. DB 685; G. Emitter C; H. VALO Cordless; I. Bluephase G2; J. Radium-cal); K. Radium plus; L. Poly Wireless; M. EC500; N. DX Turbo Led 1200.

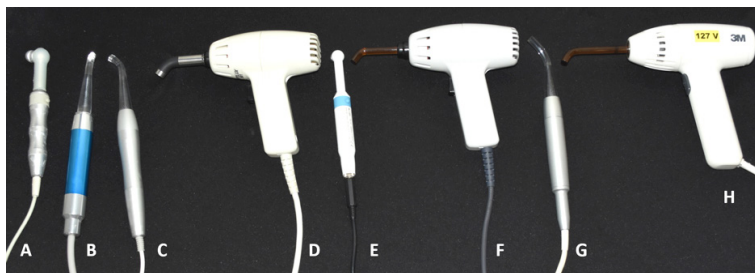


Figure 2. A: Kon-lux; B: Alt Lux II; C. BioLux Standard; D. Optilux 501; E. TL-01; F. Demetron LC; G. EC450; H. XL 3000.

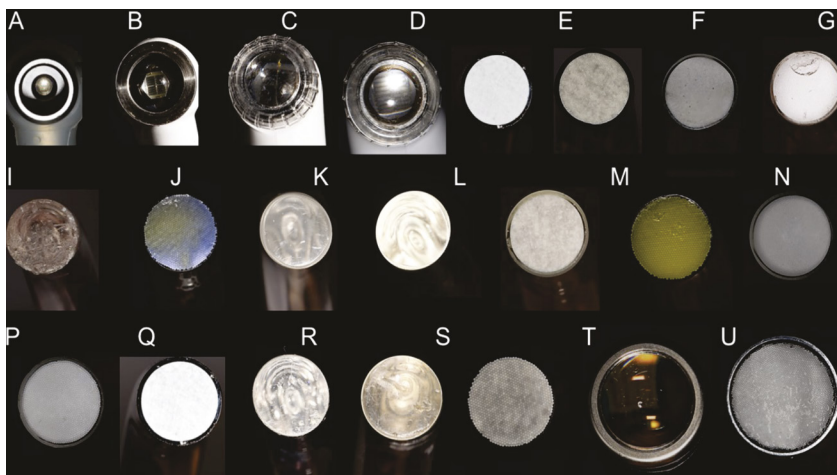


Figure 3. Images of the light tips from smallest to largest diameter: A: KON-LUX; B. TL-01; C. Radium plus; D. Radium cal; E. Optilight Color; F. High Power 3M/ESPE; G. DB 685; H. Led Lux II; I. DX Turbo LED; J. Demetron LC; K. EC500; L. EC450; M. Emitter D; N. XL 3000; O. Emitter C; P. Poly Wireless; Q. Optilight Max; R. Alt Lux II; S. BioLux Standard; T. Bluephase G2; U. Valo Cordeless; V. Demetron 501.

of the light tip in a standardized way using ImageJ software (National Institutes of Health, Bethesda, MD, USA).

The radiant power from the was measured using a 3-watt laboratory grade handheld photodiode power meter (Nova, Ophir Spiricon, Logan, UT, USA) that had a 10x10 mm measurement aperture (PD300-3W, Ophir Spiricon). Most of the LCUs were new or had been used for a very short time. The QTH LCUs were provided new halogen light bulbs before the test. Where appropriate, a fully charged battery was used for all the measurements. Three measurements were made with the tip of the LCUs positioned as close as possible to the surface of the sensor

without touching and the LCU was set to run for a 20 s exposure time. To provide an average reading, the radiant power output for each LCU was set as the power delivered at the tenth second of 20 s light exposure. This removed the effect of any spike in the light output when the unit was turned on in the first few seconds.

Irradiance

The design of the LCUs was very different, some were gun style, some were pen style, some used light guides and some had the LED light source located at the tip (Figs. 1 and 2). The light output from the LCUs was measured using

Table 1. Characteristics of the LCUs

| Light Curing Units/LCU | LCU serial number | LCU type/ wavelength emission | Battery/ Mains | Tip/light conductor | Manufacturer |
|------------------------|-------------------|----------------------------------|-------------------|-------------------------------|--|
| DX Turbo LED 1200 | 3871 | LED/monowave | Battery | Plastic/translucent | DX, Ribeirão Preto, SP, Brazil |
| EC500 | 1713 | LED/monowave | Battery | Plastic/translucent | Ecel, Ribeirão Preto, SP, Brazil |
| Poly Wireless | 2015114907 | LED/monowave | Battery | Plastic/translucent | Kavo Kerr, Joinville, SC, Brazil |
| DB 685 | 1072695 | LED/monowave | Battery | Optical fiber/ translucent | Dabi Atlante, Ribeirão Preto, SP, Brazil |
| Emitter C | L1541282C | LED/monowave | Battery | Optical fiber/ translucent | Schuster, Santa Maria, RS, Brazil |
| Emitter D | 7702023 | LED/monowave | Battery | Optical fiber/black | Schuster, Santa Maria, RS, Brazil |
| Optilight Color | 7000126059 | LED/monowave | Battery | Optical fiber/black | Gnatus, Ribeirão Preto, SP, Brazil |
| Optilight Max | 881778249 | LED/monowave | Battery | Optical fiber/black | Gnatus, Ribeirão Preto, SP, Brazil |
| High Power 3M-ESPE | 7000204142 | LED/monowave | Battery | Optical fiber/black | 3M-ESPE, St Paul, MN, USA |
| Radii plus | 52003 | LED/monowave | Battery | None | SDI, Basywater, Victoria, Australia |
| Radii cal | EA1015CL | LED/monowave | Battery | None | SDI, Basywater, Victoria, Australia |
| Alt Lux II | 2184 | LED/monowave | Mains | Plastic/translucent | Alt, Ribeirão Preto, SP, Brazil |
| BioLux Standard | 16192 | LED/monowave | Mains | Plastic/translucent | Alt, Ribeirão Preto, SP, Brazil |
| EC450 | EL003581 | LED/monowave | Mains | Plastic/translucent | Ecel, Ribeirão Preto, SP, Brazil |
| Led Lux II | 34512 | LED/monowave | Mains | Optical fiber/ translucent | Ortus, Campo Mourão, PR, Brazil |
| KON-LUX | KP3104676 | LED/monowave | Mains | None | Kondentech, São Carlos, SP, Brazil |
| TL-01 | 8039 | LED/monowave | Mains | None | Spring Health, Norristown, PA, USA |
| Bluephase G2 | 505212 | LED/multi-peak | Mains | Optical fiber/black | Ivoclar Vivadent, Schaan, Liechtenstein |
| VALO Cordless | C33856 | LED/multi-peak | Battery | None | Ultradent, South Jordan, UT, United States |
| Curing Light XL 3000 | 207723 | QTH | Mains | Optical fiber/black | 3M-ESPE, St Paul, MN, USA |
| Demetron LC | 62001338 | QTH | Mains | Optical fiber/black | Kerr, Orange, CA, USA |
| Optilux 501 | 53115507 | QTH | Mains | Optical fiber/black | Kerr, Orange, CA, USA |

a MARC patient simulator (MARC-PS, BlueLight Analytics, Halifax, NS, Canada). This device measures the irradiance (mW/cm^2), spectral emission (nm), and radiant exposure (J/cm^2) delivered from light-curing devices to simulated dental restoration sites on the facial of the maxillary central incisors and in the occlusal of a maxillary second molar in a dental mannequin head (16,17). The detectors were connected to a laboratory grade fiberoptic spectrometer (USB4000, Ocean Optics, Dunedin, FL, USA) inside the mannequin head. The anterior detector is located at the facial surface of the maxillary central incisors, simulating the surface of a class III restoration and the other detector is at the bottom of a 4 mm deep Class I preparation in the maxillary left second molar (16,18).

The LCUs were tested in their standard output mode for 10 s. The mouth opening at incisors region was fixed at 35 mm. One skilled operator made all the light exposures, following these three guidelines:

1. the LCU was placed directly over and as perpendicular

2. the LCU tip was stabilized as close as possible to the surface during the exposure time;
3. the operator wore appropriate blue light blocking glasses and correctly positioned the mannequin head to provide maximum visibility and access to the restoration (16,19).

The irradiance measurements were conducted independently at both anterior and posterior sensors, three times in a random order for each LCU (Fig. 4). The MARC software calculated the irradiance (mW/cm^2) received by the sensors from each LCU. The averages of the three measurements recorded for each LCU and from each sensor were obtained.

Statistical Analysis

Data were analyzed for normal distribution and homoscedasticity using the Shapiro-Wilk test and Levene's test, respectively. Two-way ANOVA (2x2) was used to compare the light output for two study factors: the LCU

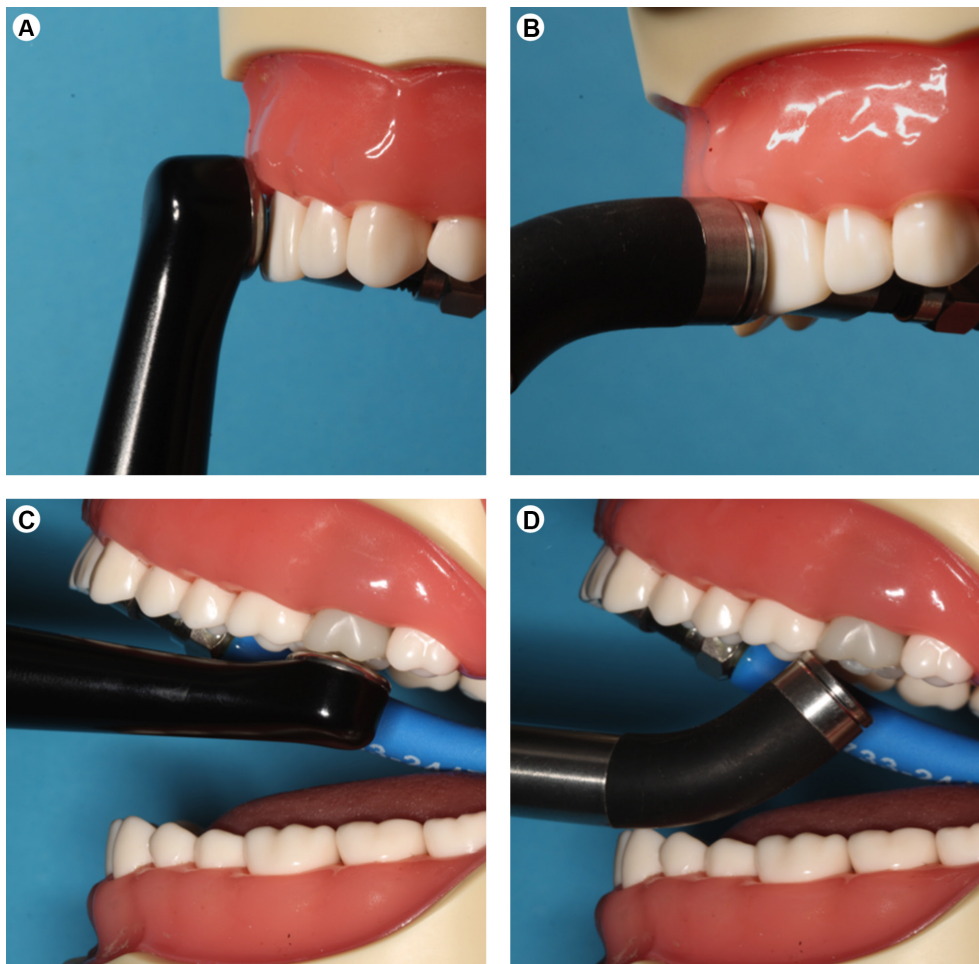


Figure 4. LCUs positioned at anterior sensor showing the ideal position of the tip parallel to the surface of the restoration, A: Valo Cordless and B: Demetron 501. LCUs positioned at posterior sensor showing that: C: Valo Cordless maintains ideal position of the tip parallel to the surface of the restoration, and D: Demetron 501 light tip could not be positioned parallel to the occlusal surface at the same inter incisal opening.

(22 LCUs) and the tooth region (anterior and posterior location). The power data was analyzed by one-way ANOVA. All tests were performed at a significance level of $\alpha=0.05$ and all analyses were performed by the Sigma Plot version 13.1 statistical package (Systat Software Inc., San Jose, CA, USA). The emission spectra (nm) were analyzed descriptively.

Results

The LCU emitted powers (mW) are in Table 2. One-way ANOVA showed that the radiant power values differed significantly among the LCUs ($p<0.001$). Tukey test showed that Bluephase G2 and Optilight Max delivered the highest radiant power, and KON-LUX, Altlux II and Biolux Standard delivered the lowest radiant power.

The internal diameter, external diameter and the area of the LCU tips are reported in Table 2. The designs of the LCU tips are shown in Figure 3. The external diameter of the LCU tips ranged from 7.9 to 13.5 mm. The internal diameter of the LCU tips ranged from 5.3 to 10.4 mm, thus

the area of the LCU tips ranged from 22.06 to 84.95 mm².

All LCUs could reach the anterior sensor equally well, however their ability to access posterior tooth varied considerably. Figure 4 illustrates the excellent ability of Valo Cordless to reach the posterior sensor whereas the light tip of the Demetron 501 could only reach the posterior sensor at an angle to the occlusal surface.

The irradiance and emission spectra emitted by LCUs are reported in Table 2 and Figures 5 to 8. Two-way ANOVA showed that the LCUs ($p<0.001$), the tooth position ($p<0.001$), and the interaction between LCUs and tooth position ($p<0.001$), significantly influenced the irradiance and the emission spectra from the LCUs. Tukey test showed that only Valo, Bluephase G2, Radium Plus, KON-LUX and Altlux II delivered a similar irradiance to both the anterior and posterior tooth locations. All other LCUs delivered a lower irradiance at posterior region compared at anterior location. KON-LUX and the Altlux II delivered an irradiance that was significantly lower than the 500 mW/cm² minimum

Table 2. Diameter of the light tips and radiant power

| Light curing units | Tip external diameter (mm) | Tip internal diameter (mm) | Tip Area (cm ²) | Power (mW) | Calculated irradiance (mW/cm ²) |
|----------------------|----------------------------|----------------------------|-----------------------------|---------------|---|
| Bluephase G2 | 9.8 | 8.4 | 0.55 | 1226.0 (6.1) | 2301.0 |
| Optilight Max | 8.0 | 7.4 | 0.43 | 1199.0 (25.2) | 2788.4 |
| Led Lux II | 7.8 | 7.1 | 0.40 | 894.3 (6.0) | 2235.7 |
| Emitter D | 8.2 | 7.2 | 0.41 | 858.7 (2.3) | 2094.4 |
| VALO Cordless | 13.1 | 9.6 | 0.72 | 842.0 (6.6) | 1169.4 |
| LED 3M ESPE | 7.9 | 6.9 | 0.37 | 834.0 (12.2) | 2254.1 |
| Radii cal | 12.4 | 6.0 | 0.28 | 684.0 (3.6) | 2442.9 |
| EC450 | 8.2 | 7.2 | 0.41 | 659.3 (22.7) | 1608.0 |
| Curing Light XL 3000 | 7.8 | 7.3 | 0.42 | 654.0 (10.4) | 1557.1 |
| Optilight Color | 7.9 | 6.6 | 0.34 | 618.3 (10.1) | 1818.5 |
| Optilux 501 | 12.2 | 10.4 | 0.85 | 612.3 (32.3) | 720.4 |
| Emitter C | 7.9 | 7.3 | 0.42 | 594.3 (11.0) | 1415.0 |
| Radii plus | 12.4 | 5.8 | 0.26 | 543.7 (18.3) | 2091.2 |
| DB 685 | 7.9 | 6.8 | 0.36 | 497.3 (9.6) | 1381.4 |
| Poly Wireless | 8.2 | 7.3 | 0.42 | 486.7 (6.1) | 1158.8 |
| DX Turbo LED 1200 | 8.3 | 7.1 | 0.40 | 469.7 (13.0) | 1174.3 |
| TL-01 | 9.2 | 5.7 | 0.26 | 367.3 (13.6) | 1412.7 |
| Demetron LC | 7.9 | 7.1 | 0.40 | 348.3 (2.1) | 870.8 |
| EC500 | 8.2 | 7.1 | 0.40 | 329.3 (15.5) | 823.3 |
| KON-LUX | 13.5 | 5.3 | 0.22 | 325.3 (4.2) | 1478.6 |
| BioLux Standard | 8.0 | 7.9 | 0.49 | 176.7 (7.8) | 360.6 |
| Alt Lux II | 8.2 | 7.6 | 0.45 | 175.7 (6.4) | 390.5 |

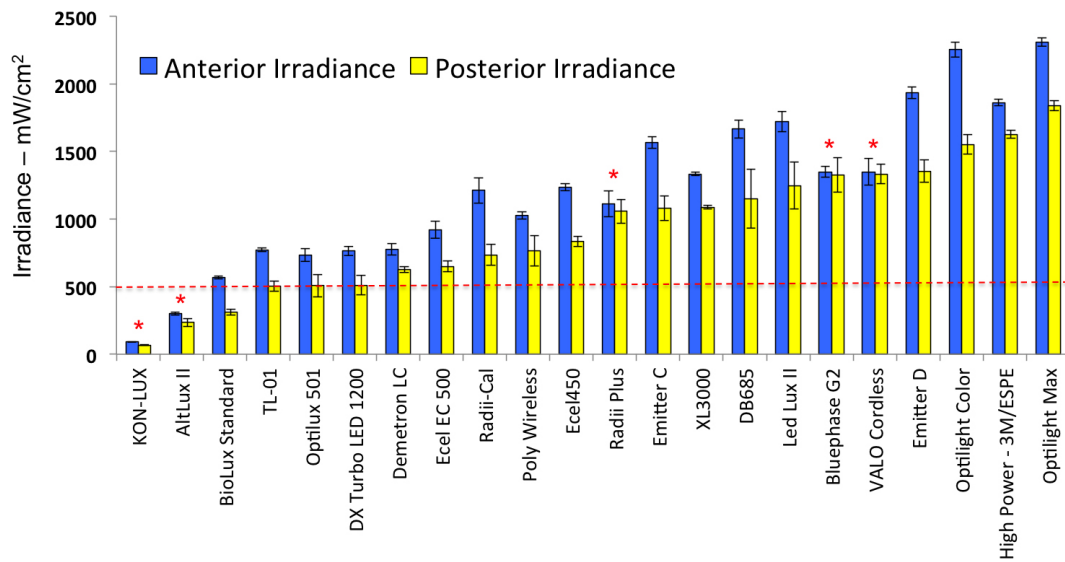


Figure 5. Irradiance values that were emitted for LCUs when used in anterior and posterior tooth sensor. *Lights that delivered similar irradiance in both locations.

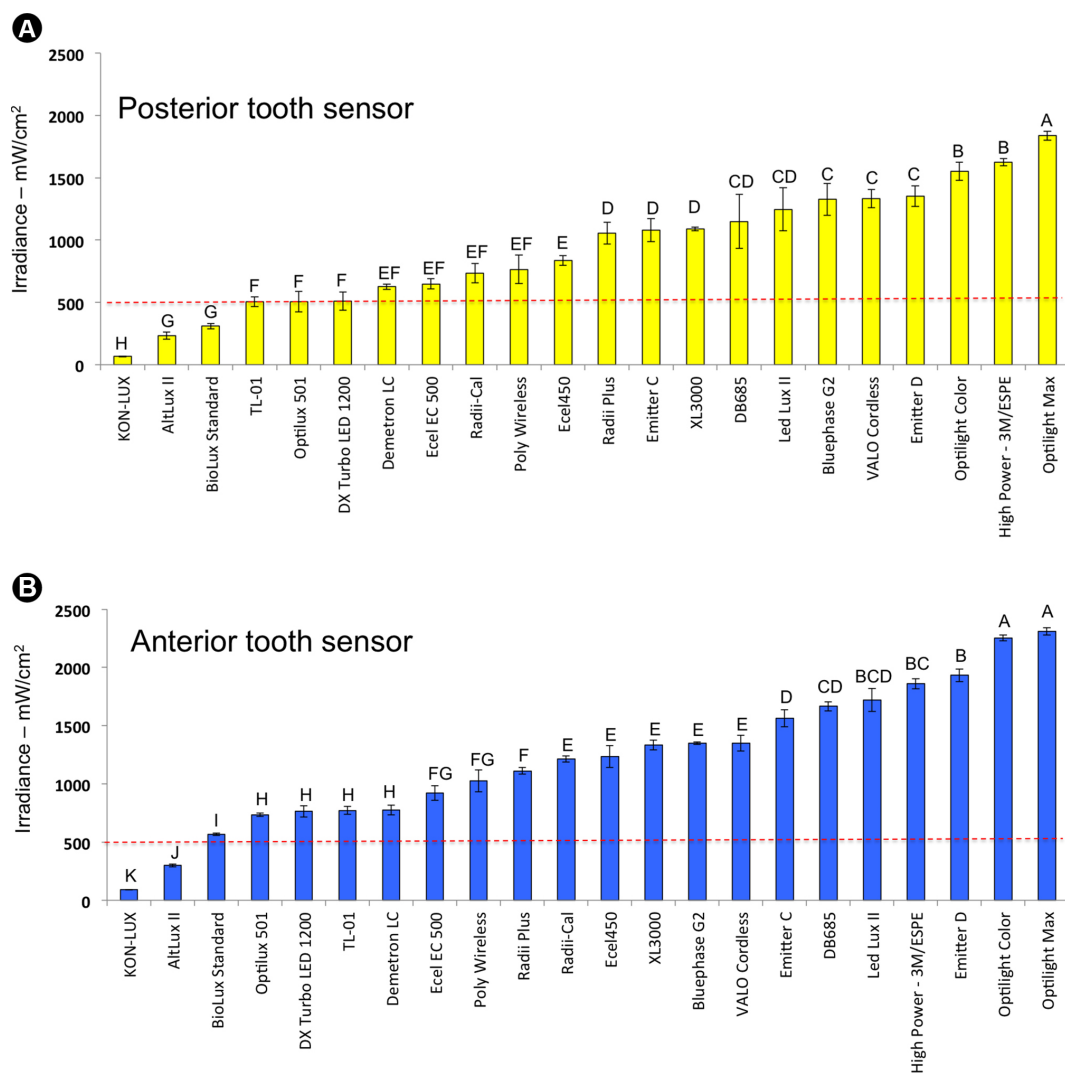


Figure 6. Irradiance values delivered by LCUs when used in: A: posterior sensor location; B: anterior sensor location. Different letters mean significant difference between LCUs at each tooth sensor.

irradiance to both the anterior and posterior sensors.

Tukey test showed that Optilight Max, Higher-Power 3M-ESPE delivered the highest irradiance and KON-LUX, Altlux II and Biolux Standard delivered the lowest irradiance to the posterior sensor. Six LCUs delivered an irradiance that was less than the one recommended when used in posterior region: KON-LUX, Altlux II, Biolux Standard, TL-01, Optilux 501, DX Turbo LED 1200. Tukey test showed that the Optilight Max, Optilight Color had the highest irradiance; KON-LUX and Altlux II had the lowest irradiance recorded at the anterior sensor. The KON-LUX and Altlux II LCUs also delivered an inadequate irradiance to the anterior sensor.

Figure 7A illustrates the different emission spectra by the QHT, monowave and multi-peak LED units. Figure 7B shows the difference in the spectrum emitted by two multi-peak LED LCUs tested in this study. The lower wavelengths reached different values for these two LCUs. The multi-peak LCUs delivered a similar irradiance (Fig. 8A) and spectra to both sensors (Fig. 8C). The irradiance (Fig. 8B) and spectral

radiant power values (Fig. 8D) of the monowave LED LCUs were lower when measured at the posterior location compared to the anterior location.

Discussion

The first hypothesis was rejected since the QHT and the LED LCUs delivered different irradiance and spectral radiant power values to the sensors in the anterior and posterior teeth. The shape of the different curing tips also affected the amount of light delivered at the two sensor locations (anterior and posterior).

The operator visibility and access was the worst in the posterior region, where the 35 mm interincisal opening negatively affected the irradiance results. This is not surprising, because as the distance from the light tip to the target surface increases, not all the light emitted from the light tip reaches the target and the RBC will receive less energy. This loss means that there is a risk that the RBCs will not be adequately light cured (1) Most LCUs showed

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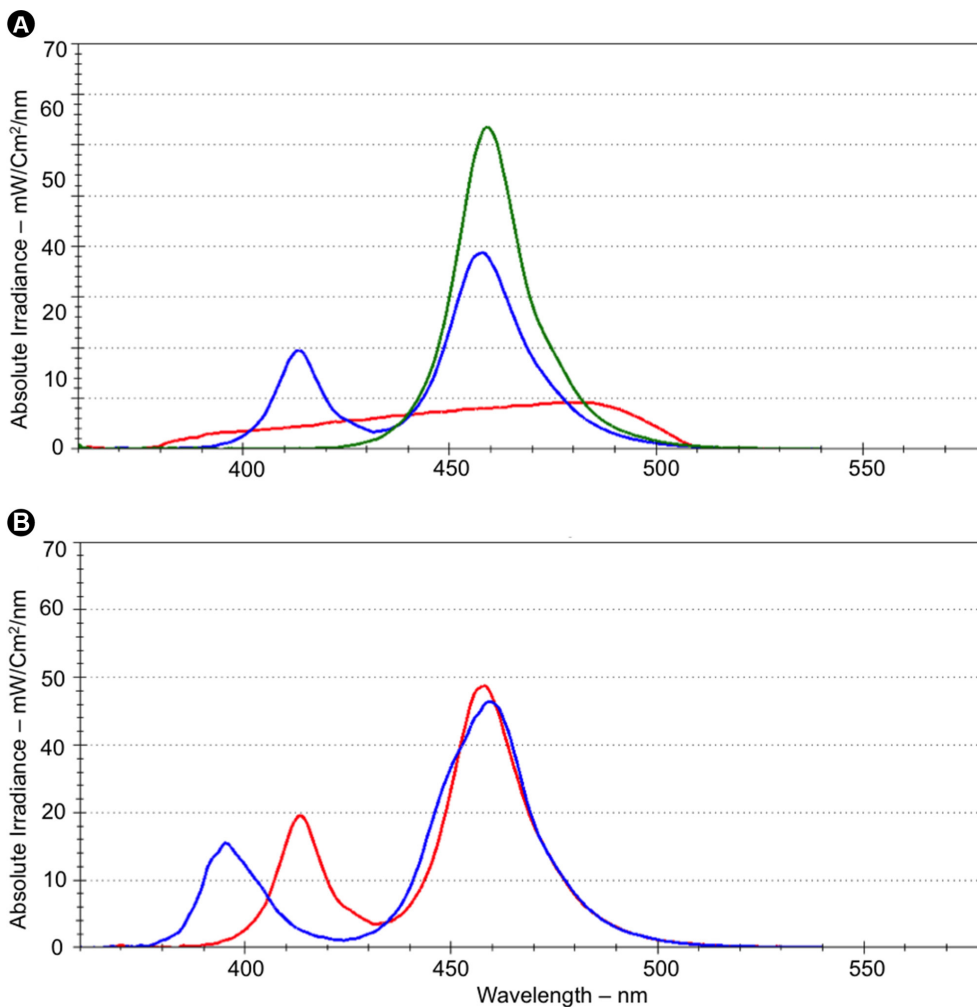


Figure 7. A: Emission spectrum showing the different wavelength peaks of a QHT LCU (red line); a monowave LED LCU (green line) and a multi-peak LED LCU (blue line); B: Emission spectrum and wavelength peaks of two multi-peak LED LCUs.

a significant decrease in the irradiance when the light was delivered to the posterior sensor compared with the anterior sensor. Although the operator was skilled and used eye protection when using the LCU, it was difficult to position the light tip directly over the posterior sensor. Despite this difficulty, the operator kept the LCU over the tooth and the irradiance delivered remained steady in all cases.

A previous study has also reported that access to the Class I sensor at the posterior location is more difficult than to the Class 3 sensor at the anterior location (18). The optic design and the ability of the operator to effectively position the LCU in the oral cavity may be possible factors that affect this difference (19). In this study, Valo, Bluephase G2, Radium Plus, KON-LUX and Altlux II delivered similar irradiance values to the anterior and posterior sensor tooth. On the other hand, KON-LUX e Altlux II delivered less than 500 mW/cm² to both sensors, which was considered to be inadequate.

The irradiance value of 500 mW/cm² was the minimum threshold set in this study for adequate photocuring and achieving adequate mechanical properties for the RBCs. Given that dentists wish to reduce the time spent light curing, this value was considered to be the minimum

irradiance necessary to adequately polymerize a 2 mm increment of composite (20,21). Six LCUs delivered inadequate irradiance in posterior region: KON-LUX, Altlux II, Biolux Standard, TL-01, Optilux 501, DX Turbo LED 1200. In the anterior region, only two LCUs delivered an irradiance less than 500 mW/cm². Incomplete polymerization of dental RBCs can lead to a multitude of clinical problems. For example: increased discoloration, lower bond strengths, more gingival marginal defects, decreased hardness, decreased flexural strength, pulp irritation, greater post-operative sensitivity, lower fracture strengths, decreased dynamic elastic modulus, lower resistance to abrasive wear and eventual failure of the restoration (22,23).

Clinicians often light cure the entire adhesive systems in MOD preparations just once and then also light cure the entire restoration using only one light exposure. This and other studies show that the orientation of the LCU tip over the tooth in some areas, such as the proximal boxes, will influence the received irradiance (22). The angled design of the light tip means that it creates an angle when placed over the molar that may well result in a lower irradiance being delivered to the distal proximal box of a MOD restoration. This may result in the resin being inadequately polymerized

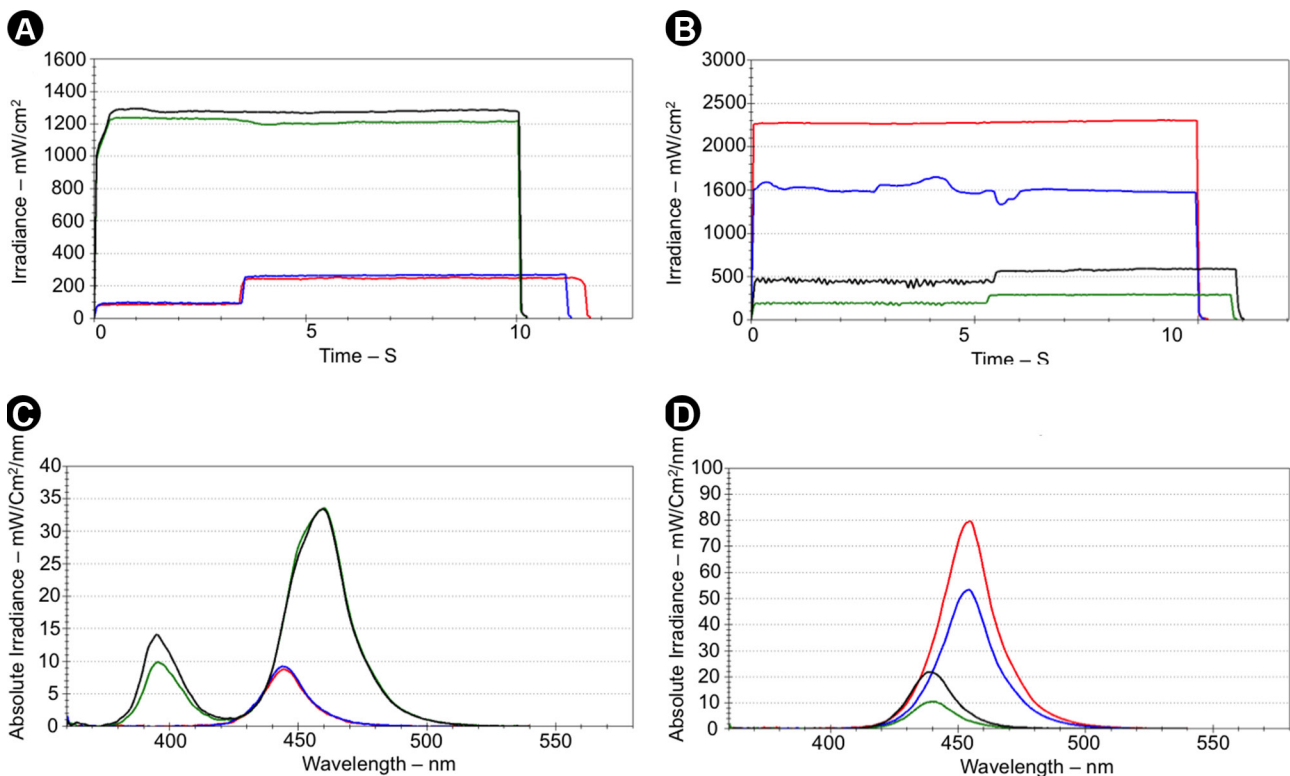


Figure 8. Effect of sensor location on the irradiance and emission spectrum of representative LCUs; A: Example of a LCU that delivered similar high irradiance (black and green lines) to both the anterior and posterior sensor and a LCU that delivered low irradiance (red and blue lines) to the same sensors); B: Example of LCUs that delivered higher irradiance at anterior sensor (red and black lines) and lower irradiance at posterior sensor (blue and green lines); C: Example of a multi-peak emission spectrum delivered (black and green lines) and low irradiance (red and blue lines) that delivered a similar spectrum and irradiance to both the anterior and posterior sensors; D: Example of LCUs that emitted higher spectrum and wavelength peaks to the anterior sensor (red and blue lines) but a lower irradiance to posterior sensor (black and green lines).

at the bottom of the proximal box. Another aspect that affects the performance of the LCU is the area of the tip. Even if the LCU has a homogeneous light output and has a wide 10 mm outside diameter tip, if the tip diameter does not cover the restoration, then the polymerization process can be compromised. Since the molar teeth have in average 10 mm in medial-distal dimension; only 3 LCUs (Demetron 501, Valo Cordless and Bluephase G2) are able to cover the area of the entire MOD restoration with the tip of the LCU. The tested scenario in this study would be even worse if the irradiance had been measured at the gingival floor of a proximal box, where the effects of an increased distance and the tip inclination will further reduce the irradiance. Thus despite some advertising claims that the dentist need light cure a bulk-fill RBC only once, the clinician may still have to light cure a bulk-fill RBC restoration more than once so that all of the restoration receives sufficient light (20)

Manufacturers and researchers should provide detailed information about the radiant power (mW), irradiance, the effect of distance on the irradiance, and the emission spectrum across the light tip when describing the LCU (2), so that the dentist can make an informed decision about the choice of LCU, the exposure time and photoactivation technique (20). Clinicians should periodically check their LCUs by measuring the irradiance and they should consider the effect of different shades and opacity of the RBC on the exposure time. If the LCU delivers an irradiance close to 500 mW/cm², longer exposure times (40 to 60 s) and multiple exposures to the occlusal, lingual and buccal surfaces are recommended. Alternately, the clinicians should seriously consider replacing the LCU.

Further studies are required to characterize the active area of the LCU optic tip from where light is emitted, and to correlate the irradiance across the light tip with the hardness values of various RBCs and determine the effects of any non-uniformity in the irradiance on the RBC. At present, it is recommended that clinicians use an LCU with large tip area that emits a homogeneous irradiance across the tip greater than 500 mW/cm². The effects of distance up to 8 mm away on the irradiance should be small and the LCU should be able to deliver the same irradiance to both anterior and posterior sensors.

Resumo

Este estudo mediu a potência (mW), irradiância (mW/cm²) e espectro da luz (mW/cm²/nm) emitida por 22 fontes de luz (Alt Lux II, BioLux Standard, Bluephase G2, Curing Light XL 3000, Demetron LC, DX Turbo LED 1200, EC450, EC500, Emitter C, Emitter D, KON-LUX, LED 3M ESPE, Led Lux II, Optilight Color, Optilight Max, Optilux 501, Poly Wireless, Radii cal, Radii plus, TL-01, VALO Cordless) disponíveis comercialmente. A potência emitida pelas fontes de luz foi medida usando um medidor laboratorial de potência com grade a laser. A área (cm²) da ponta ativa efetiva das fontes de luz foi medida com paquímetro digital e utilizada para calcular a irradiância

emitida. O simulador de paciente-MARC (MARC - PS) com espectrômetro (USB4000, Ocean Optics) foi usado para medir a irradiância e o espectro de luz emitida por cada fonte de luz na região anterior e posterior. Esta medição foi repetida por três vezes em dois sensores localizados na região anterior e posterior da arcada dentária. Os dados de irradiância foram analisados utilizando análise de variância em dois fatores, e os dados de potência foram analisados com análise de variância em fator único seguido pelo teste de Tukey ($\alpha=0,05$). As fontes de luz Valo, Bluephase G2, Radii Plus emitiram irradiância semelhante tanto na região anterior como posterior com valores superiores ao mínimo de 500 mW/cm². Seis fontes de luz emitiram irradiância menor que o recomendado (500 mW/cm²) quando usadas na região posterior: Kon-lux, Altlux II, Biolux Standard TL-01, Optilux 501, DX Turbo LED 1200 e duas quando usadas na região anterior: Kon-lux e Altlux II LCUs. As fontes Bluephase G2, Optilight Max emitiram os maiores valores de potência e as fontes de luz Altlux II e Biolux Standard emitiram os menores valores de potência. O espectro de luz das fontes LED de espectro único variou de forma evidente entre as fontes. As fontes LED multi pico de espectro emitiram espectros de luz similar para ambos os sensores. A fotoativação na região posterior tende a reduzir substancialmente a irradiância da maioria das fontes de luzes testadas.

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