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Characterizing the output settings of dental curing lights

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ABSTRACT

Objectives: For improved inter-study reproducibility and ultimately improved patient care, researchers and dentists need to know what electromagnetic radiation (light) is emitted from the light-curing unit (LCU) they are using and what is received by the resin. This information cannot be obtained from a dental radiometer, even though many studies have used a dental radiometer.
Methods: The light outputs from six LCUs (two QTH and four broad-spectrum LED units) were collected in real-time using an integrating sphere connected to a fiberoptic spectrometer during different light exposures.
Results: It was found that the spectral emissions were unique to each LCU, and there was no standardization in what was emitted on the various ramp (soft-start) settings. Relative to the normal use setting, using the ramp setting reduced the radiant energy (J) delivered from each LCU. For one of the four broad-spectrum LED LCUs, the spectral emissions in the violet range did not increase when the overall radiant power output was increased. In addition, this broad-spectrum LED LCU emitted no light from the violet LED chip for the first 5 s and only emitted violet light when the ramp phase finished.
Conclusions: A single irradiance value derived from a dental radiometer or from a laboratory grade power meter cannot adequately describe the output from the LCU. Manufacturers should provide more information about the light output from their LCUs. Ideally, future assessments and research publications that include resin photopolymerization should report the spectral radiant power delivered from the LCU throughout the entire exposure cycle.

1. Introduction

When using a light-curing unit (LCU), the dentist should aim to deliver sufficient energy at the correct wavelengths to polymerize the target resin. For improved inter-study reproducibility and ultimately improved patient care, researchers and dentists need to know the electromagnetic radiation (light) emitted from the LCU they are using. Many LCUs have multiple light settings that offer the dentist different power outputs, and sometimes different spectral emissions, that are claimed to provide unique clinical benefits [1]. These light output options may be classified broadly into either continuous or discontinuous light curing techniques. The manufacturers give a variety of proprietary names for continuous power output techniques that include standard or normal output, low power or 'adhesive setting', high power, boost, Xtra power, Turbo, Plasma Emulation, etc. Similarly discontinuous or modulated curing modes include terms such as step, ramp, pulse, and pulse delay. These modulated curing modes were introduced in an attempt to reduce the adverse effects of polymerization contraction stress on the tooth/restoration complex by starting, and sometimes finishing, the light exposure at a reduced light output level [1–12]. Some of these pulsed light modes slow the rate of energy delivery by switching the light on and off repeatedly, while others alternate between a high and low output. This pulsing is intended to reduce adverse heating effects on both the light emitting diode (LED) chip and the oral tissues, and to reduce polymerization shrinkage stress within the resin based composite (RBC). The pulse delay modes typically deliver a low power level for a few seconds followed by a delay of one to three minutes before delivering a final light exposure at higher output levels [3,11]. One Quartz–Tungsten–Halogen (QTH) unit offered a pulse mode that started with a ramped output and ended with a continuous pulsing where the LCU oscillated between low and high

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output [13]. Soft Energy Light Release is a mode where the light output ramps up to full power and then declines in a similar manner at the end of the light exposure cycle [14]. These light output terms are often reported by manufacturers and researchers alike in terms of a single irradiance value that was either measured using unreported methods [3,5–7,12,15], or using dental radiometers [9,10,16] that are known to misreport the LCU output [17–21].

The electromagnetic radiation from the LCU and requirements of the RBC should be spectrally compatible [16,22–27]. That is to say, the operator should ensure that the LCU emits photons at the wavelengths required to activate the photoinitiators used in the RBC. This information cannot be obtained from a conventional dental radiometer. Previously, a QTH bulb was the most commonly used light source in a curing light. These QTH units emit a broad spectral emission of violet and blue light that activates all photoinitiators present in current RBCs, and it was not necessary to know the exact emission spectrum of the LCU. Conventional, single-peak LED curing lights deliver limited spectral coverage that has likely been chosen to activate the camphorquinone (CQ) photoinitiator used in most RBCs [25,28]. However, some LED curing lights include additional LED chips that emit light at lower wavelengths, in the 'violet' range, to make these LCUs compatible with a wider range of photoinitiators [25,28]. The number and location of the spectral emission peaks vary between manufacturers, as does each peak's relative contribution to the total power output during light exposure [29,30]. *Polywave®* is a registered trademark of Ivoclar Vivadent and indicates that their LED curing light delivers a light output with two or more wavelength peaks. This gives their LCUs a wider spectral emission range that is comparable to QTH lights. It is assumed that a *Polywave®* light will deliver this wider spectral emission range on all output settings. Although some manufacturers do provide detailed information on the light output from their LCU [31], usually the details provide only the entire wavelength range from the LCU and do not always specify how the spectral radiant power is affected when the settings are changed [30].

1.1. Objective

This study used laboratory grade equipment to characterize the real-time spectral radiant power and spectral emissions from two QTH lights and four broad-spectrum blue LED lights. The hypotheses were:

(a) The two QTH units and the four LED units would deliver similar spectral power outputs.
(b) Changes in the output settings would not change the shape of the emission spectrum from each LCU.
(c) The ramp settings would deliver similar light outputs from each LCU.

2. Materials and methods

This study examined six light-curing units: two were QTH lights and four were broad-spectrum LED lights. The two QTH lights selected were the Optilux 501 (SDS Kerr, Middleton, WI, USA) and the Elipar TriLight (3 M ESPE, St Paul, MN, USA). The broad-spectrum LED lights selected were the: Translux 2Wave (Heraeus Kulzer, South Bend, IN, USA), SmartLite Max (DENTSPLY, York, PA, USA), Bluephase G2 (Ivoclar Vivadent, Amherst, NY, USA), and Valo (Ultradent, South Jordan, UT, USA). For each light, the optical light tip diameter was measured to the nearest 0.1 mm using digital callipers (Mitutoyo Canada Inc., Mississauga, ON, Canada). Although not new, these LCUs had been well maintained and had only been used in a laboratory. Wherever possible, the LCUs were used for 20 s, or as programmed by the manufacturer (Table 1).

2.1. Real-time spectral radiant power

The light output was collected using a 6-inch integrating sphere (Labsphere, North Sutton, NH, USA) connected to a fiberoptic spectrometer (USB 4000, Ocean Optics, Dunedin, Fla, USA). Before the experiment was started, the equipment was calibrated using a

Table 1

Radiant power and the average irradiance delivered from each LCU. The oval tip area of the SmartLite Max was specified by the manufacturer to be 49 mm^2. The area under the real-time power (mW) curves was integrated to determine the radiant energy (J) delivered during one exposure.

Curing light and external tip diameter	Setting	Optical tip area (mm^2)	Radiant power (mW)	Average irradiance received and [*Manufacturer's values*] (mW/cm^2)	Exposure time (s)	Radiant energy delivered (J)
Optilux 501	Standard	106	586	553 [*850*]	20	12.1
[14 mm]	Ramp		685	646 [*1000*]	20	9.1
	Boost		709	669 [*1000*]	10	7.2
Elipar TriLight	Standard	57	458	804 [*800*]	20	9.3
[10 mm]	Exponential (Ramp)		455	798 [*800*]	40	13.3
	Medium		262	460 [*450*]	20	5.4
Translux 2Wave	Standard	44	560	1273 [*1400*]	20	11.2
[8 mm]	Soft-Start (Ramp)		559	1270 [*1400*]	20	10.7
SmartLite Max	Standard	49	764	1559 [*2200*]	20	15.6
	Ramp		758	1547 [*2200*]	20	14.2
Bluephase G2	High	63	885	1405 [*1200*]	20	17.5
[10 mm]	Soft (Ramp)		883	1402 [*1200*]	20	14.7
	Low		499	792 [*650*]	20	9.9
Valo	Standard	69	675	978 [*1000*]	20	13.6
[10 mm]	High		966	1400 [*1400*]	4	3.8
	Xtra		1590	2304 [*3200*]	3	4.7