Announcement: An Evaluation of a New Portable Spectrometer System (checkMARC)

The current American Dental Association’s light curing guideline for practitioners recommends that the irradiance exitance from any dental light-curing unit LCU should be regularly monitored and recorded over time to ensure that the LCU meets its manufacturer’s specifications and functions. Having a radiometer that can accurately and consistently measure and monitor the LCU’s outputs is therefore a quality assurance requirement for adequately photo-polymerizing resin composites. For more information, [Click Here](#).
Background:

The quality of resin-based restorations is greatly influenced by the curing efficiency of a light-curing unit (LCU). The current American Dental Association’s light curing guideline for practitioners recommends that the irradiance exitance from any dental LCU should be regularly monitored and recorded over time to ensure that the LCU meets its manufacturer’s specifications and functions [1]. Having a radiometer that can accurately and consistently measure and monitor the LCU’s outputs is therefore a quality assurance requirement for adequately photo-polymerizing resin composites. Past studies have revealed most commercial radiometers are relatively inaccurate – some are even erroneous, especially for determining those LCUs with irradiance greater than 1500 mW/cm² – when compared to the “gold standard,” laboratory-grade spectrophotometers (e.g., thermopile and integrating sphere) [2-5]. For example, commercial handheld dental radiometers such as Demetron LED radiometer (Kerr, Orange County, CA, USA), Cure Rite radiometer (Dentsply, York, PA, USA), and SDI LED radiometer (SDI, Bayswater, Australia) have measured irradiance inconsistently and do not have the ability to record spectral radiant power emitted between 350nm and 600nm wavelengths in real time, a critical measure to determine whether the LCU’s spectral wavelength overlaps or matches that of the photoinitiator’s absorption wavelength [2-5]. The errors in measuring irradiance are predominately associated with the designs of handheld radiometers. Most handheld radiometers have smaller windows for collecting light outputs than most areas of the light guides, contain diffusers that homogenize the entrance beam rather than capturing the true nature of beam inhomogeneity across a light tip, and have filters that do not match the range of wavelengths emitted by the LCU, such that the violet range is typically filtered.
Recently, checkMARC (BlueLight Analytics, Halifax, Canada) was introduced as a new LCU testing service that can provide practitioners with a more accurate LCU output measurement than hand-held radiometers [6]. The checkMARC system includes a portable spectrometer device and a proprietary web-based software application that offers up-to-date curing specifications on more than 150 LCUs and 130 dental resin-based composites, enabling the accurate curing light measurement to be immediately compared to the manufacturer’s specification. Also, like the laboratory-grade meter checkMARC is able to provide spectral radiant power as a function of LCU’s emitted wavelengths. This real-time analytics of reporting the spectral radiant power versus LCU’s emitted wavelength are supported by submission of the collected data through the web-based software. Currently, the checkMARC light curing testing service is also offered by 3M ESPE. According to 3M ESPE, this service, which includes the checkMARC system, its web-based software suite, and any training to improve operator curing light technique is free for any military clinic.

Product Information (checkMARC system):
- Portable spectrometer based assembly (STS, Ocean Optics)
- Light collecting sensor’s diameter = 16 mm
- Diffuser window = Teflon
- Calibrated against National Institute of Standards & Technology (NIST) reference light source (HL 2000, Ocean Optics)

Objective:

We compared the irradiance outputs of various dental office light-curing units (LCUs) measured with a new spectrometer system (checkMARC) and a commercial handheld radiometer (Bluephase Meter, Ivoclar Vivadent, Schaan, Liechtenstein) against the irradiance values determined from two laboratory-grade (“gold standard”) spectrophotometer systems (thermopile and integrating sphere).

Materials and Methods:

A total of 21 LCUs (e.g., 3 LCUs per brand and 7 different brands) were utilized. The 7 LCU brands were: Bluephase Style, Demi Ultra, Elipar S10, Paradigm, SmartLite Focus, SPEC3, and Valo Cordless. Standard curing mode for all brands was selected. The irradiance outputs for the 21 LCUs were measured using the following devices without any filter:

- **checkMARC**: First, the type of curing light was entered into the checkMARC software (BlueLight Analytics). Then, each LCU’s output was collected. Finally, based on the type of curing light and collected light output, the checkMARC software computed the LCU’s irradiance (mW/cm²).
- **Bluephase Meter I (Ivoclar Vivadent)**: each LCU’s irradiance was directly read from the radiometer (note: the exit apertures at the end of the LCUs were often larger than the diameter of radiometer sensor window). Bluephase Meter I was used in this evaluation because Bluephase Meter II was not yet commercially available for testing during the times that this study was conducted.
- **Thermopile (10A-SH-V1.1ROHS, Ophir)**: Per ISO 10650-2 [7], the power per LCU (optic-to-sensor distance = 0 mm) was recorded. The power was converted to irradiance via the formula: power divided by each tip’s cross-sectional active area, cm². For each LCU, three measurements were made. Since there are three LCUs per brand, 9 measurements per brand were used to calculate an average irradiance and standard deviation for any specific brand.
- **Integrating sphere [sphere ø = 15 cm & entrance port ø = 19 mm (Labsphere) from which port was linked to a calibrated spectrophotometer (USB 4000, Ocean Optics)]**: each LCU’s
power spectrum (optic-to-entrance distance = 0 mm) was integrated from 360-540 nm range (Figure 1) and then converted to average irradiance (i.e., power / each tip’s cross-sectional active area, cm²).

- Statistics: Data were analyzed with linear regression and ANOVAs/Tukeys (α = 0.05).

Results:

Significant differences in mean irradiance were found between the 4 systems depending on the LCU brand (Table 2). Bivariate regression analysis demonstrated that the irradiances correlated better between the checkMARC and integrating sphere ($r^2 = 0.894$) than between the commercial handheld radiometer and the integrating sphere ($r^2 = 0.274$). See Figure 2.

Conclusion and Recommendation:

The new checkMARC spectrometer system provided a lower overall percent deviation in irradiance than the commercial handheld radiometer when compared to thermopile or integrating sphere. The irradiance values measured by the checkMARC spectrometer system were better matched to the “gold standard” method than most commercial handheld radiometers [3, 6].

Very importantly, LCU irradiance (mW/cm²) is defined as the emitted power divided by the emitting light tip area. In general for calculating irradiance, most commercial handheld radiometers do not take into consideration the different areas of the LCU tips. This is because the entrance apertures for measuring light outputs for most commercial handheld radiometers are typically smaller than most of the light tips. Furthermore, most handheld radiometers calculate the irradiance of a LCU that is based on the area of the diffuser-window area of the radiometer rather than the LCU tip area; thereby, calculation of the LCU irradiance can be erroneous in comparison to a laboratory-grade meter [2, 3]. Of the systems mentioned here, only checkMARC and Bluephase Meter II take the consideration of light tip area into calculating irradiance. Furthermore, the ability to accurately measure light tip area is critical in irradiance calculation. This is because irradiance is the quotient of power over area, and a small change in the quotient’s denominator can have a significant change in the overall irradiance.

Since LCUs are integral components of modern operative dentistry, their repetitive usages are often associated with routine wear and tear and damages, possibly caused by chemical disinfectants, light-guide autoclaving, accidental dropping, or restorative material adhering to the LCU’s light guide. DECS recommends that the irradiance exitance from any dental LCU should be monitored quarterly per year and keep a log record over time to ensure that the LCU meets its manufacturer’s specifications and functions.

Table 1: Comparison of salient features amongst various popular radiometers:
<table>
<thead>
<tr>
<th>Brand</th>
<th>Manufacturer</th>
<th>Radiometer Spectrometer</th>
<th>Accuracy in comparison to &quot;gold standard&quot;</th>
<th>Display</th>
<th>Light entrance aperture (diameter, mm)</th>
<th>Measurable wavelength (nm)</th>
<th>Measurable output (mW/cm²)</th>
<th>Ability to provide manufacturer recommended curing times</th>
<th>Price ($) Civ.</th>
<th>Price ($) Gov.</th>
<th>Warranty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluephase Meter II</td>
<td>Ivoclar Vivadent</td>
<td>Yes</td>
<td>No</td>
<td>+++</td>
<td>digital</td>
<td>12</td>
<td>380-550</td>
<td>300 - 12000</td>
<td>No</td>
<td>380</td>
<td>285</td>
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<tr>
<td>checkMARC</td>
<td>BlueLight Analytics</td>
<td>No</td>
<td>Yes</td>
<td>+++</td>
<td>web-linked software</td>
<td>16</td>
<td>300-700</td>
<td>&lt;10000</td>
<td>Yes</td>
<td>400/month</td>
<td>400/month</td>
</tr>
<tr>
<td>Cure Rite</td>
<td>Dentsply</td>
<td>Yes</td>
<td>No</td>
<td>++</td>
<td>digital</td>
<td>6.5</td>
<td>400-525</td>
<td>&lt;2000</td>
<td>No</td>
<td>231.75</td>
<td>237.75</td>
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<tr>
<td>Demetron LED</td>
<td>Kerr</td>
<td>Yes</td>
<td>No</td>
<td>++</td>
<td>analog</td>
<td>7</td>
<td>400-500</td>
<td>&lt;2000</td>
<td>No</td>
<td>292.32</td>
<td>175.4</td>
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<tr>
<td>SDI LED</td>
<td>SDI</td>
<td>Yes</td>
<td>No</td>
<td>+++</td>
<td>digital</td>
<td>12</td>
<td>380-515</td>
<td>&lt;2000</td>
<td>No</td>
<td>191</td>
<td>136.56</td>
</tr>
</tbody>
</table>

**Figure 1**

![Graph showing spectral radiant power (mW/nm) against wavelength (nm)](image)

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**Table 2: Irradiances of various LCU brands measured with spectrometer, radiometer, and 2 spectrophotometers**

<table>
<thead>
<tr>
<th>Light Curing Unit Brand</th>
<th>CheckMARC Mean Irradiance (mW/cm²)</th>
<th>SD</th>
<th>Radiometer Mean Irradiance (mW/cm²)</th>
<th>SD</th>
<th>Thermopile Mean Irradiance (mW/cm²)</th>
<th>SD</th>
<th>Integrating Sphere Mean Irradiance (mW/cm²)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluephase Style</td>
<td>1101</td>
<td>17 ab</td>
<td>1033</td>
<td>56 b</td>
<td>1047</td>
<td>17 b</td>
<td>1145</td>
<td>35 a</td>
</tr>
<tr>
<td>Demi Ultra</td>
<td>1325</td>
<td>39 a</td>
<td>861</td>
<td>131 b</td>
<td>1374</td>
<td>51 a</td>
<td>1517</td>
<td>87 a</td>
</tr>
<tr>
<td>Elipar S10</td>
<td>1250</td>
<td>12 a</td>
<td>1138</td>
<td>44 b</td>
<td>1123</td>
<td>26 b</td>
<td>1261</td>
<td>13 a</td>
</tr>
<tr>
<td>Paradigm</td>
<td>1262</td>
<td>48 a</td>
<td>1089</td>
<td>60 b</td>
<td>1123</td>
<td>39 b</td>
<td>1272</td>
<td>28 a</td>
</tr>
<tr>
<td>SmartLite Focus</td>
<td>1035</td>
<td>50 b</td>
<td>534</td>
<td>8 c</td>
<td>1080</td>
<td>28 b</td>
<td>1221</td>
<td>58 a</td>
</tr>
<tr>
<td>SPEC3</td>
<td>2078</td>
<td>68 a</td>
<td>1482</td>
<td>149 b</td>
<td>1786</td>
<td>214 ab</td>
<td>1939</td>
<td>117 a</td>
</tr>
<tr>
<td>Valo Cordless</td>
<td>1028</td>
<td>49 a</td>
<td>1002</td>
<td>7 a</td>
<td>1028</td>
<td>59 a</td>
<td>1037</td>
<td>66 a</td>
</tr>
</tbody>
</table>

Row with the same lower case letter per LCU brand is not significantly different (p > 0.05)

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