Optical hazard evaluation of dental curing lights*

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Abstract – The potential ocular hazards associated with the use of dental curing lights were evaluated. Recommendations are provided for precluding exposure of personnel to hazardous levels of optical radiation. Users should not stare directly into the dental curing lights at distances shorter than 25 cm (which would not be a likely event). Eye protectors which filter wavelengths below 500 nm may be desired by individual users to reduce discomfort or if surface lamination is applied.

Key words: curing lights; dental resins; optical hazards

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Dental curing (photopolymerization) lights are used to cure resins used for dental restorations (tooth "fillings") and are now found in most dental clinic offices. The first photosensitive resins developed were cured with near-ultraviolet (UV-A) radiation. Now, most resins are cured with blue-violet light. The dental curing lights examined in this study consisted of an enclosed light source (and power supply), which was coupled to a handheld "gun" by a fiber-optic cable or light-guide. From the fiber-optic cable or the protruding tip of the "gun", light was directed to the resin to be cured. Fig. 1 shows a representative curing light in use.

A total of 12 units were evaluated at several Army Dental Clinics. A list of the evaluated units, their identification, and their manufacturer can be found in Table 1.

Material and methods

A spectroradiometer [employing an Oriel double monochromator (2.5 nm bandwidth), a Hamamatsu R212 photomultiplier, an Oriel High Voltage power supply, and a Keithley Model 614 Electrometer] was used for the measurements of spectral irradiance. The spectroradiometer was calibrated against a 1000-W FEL-type standard lamp, with calibration traceable to the National Bureau of Standards.

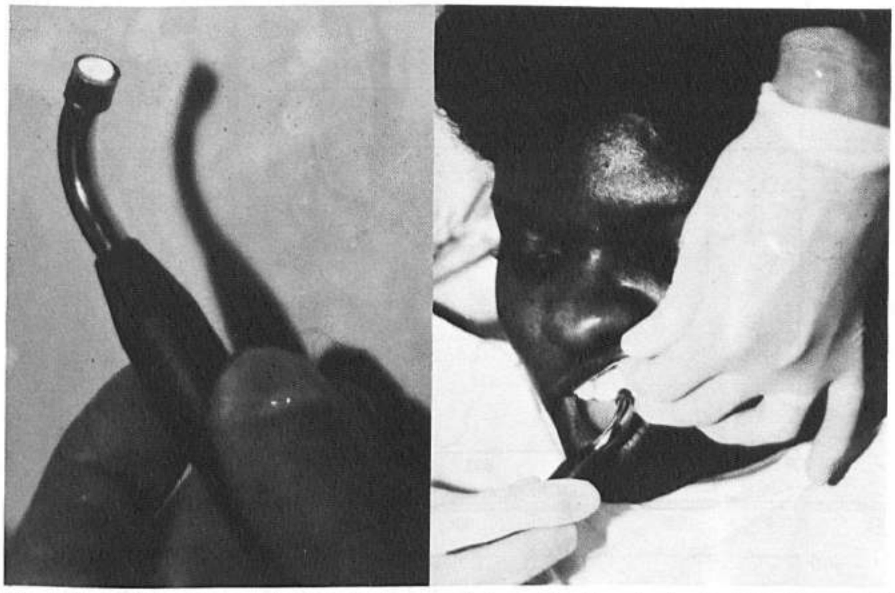

Fig. 1. Uses of dental curing light. Left photograph shows tip of applicator. In right photograph the dentist stands behind dental technician to demonstrate applicator in use.

Table 1. Identification of evaluated units

Unit	Model	Manufacturer/Agent
Caulk (1), (2), (3)	Pr-1 (Prisma-Lite)	L. D. Caulk Co., Milford, DE
Caulk NUVA-Lite	NUVA-Lite	L. D. Caulk Co., Milford, DE
Command (1), (2), (3)	Command	Kerr Div. of Sybron Corp., Romulus, MI
Spectra Lite	Spectra Lite	Peatron Corp, Walinford, CT
Norland Opticure	Light Gun UVC	Norland Prod., New Brunswick, NJ
Western Electric	Simplex	A. Solomon Mfg. Corp., Roswell, GA
Midwest Insite	Insite	Adm. Midwest, Des Plains, IL
Elipar	Elipar Curing Light	Elipar, Seefeld/Overbau, FRG

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The opinions or assertations herein are those of the authors and should not be construed as official positions of the Department of the Army or Department of Defense.

Use of Company names does not imply endorsement by the US Army, but is intended only to assist in identification of a specific product.

Results

The measured spectral irradiance for 12 of the different types of dental lights is plotted in Figs. 2–4. From these spectral measurements, the following quantities used for the hazard evaluation (1, 2) were derived: total irradiance (E), effective UV irradiance (E_{eff}), UV-A irradiance (E_{UVA}), the blue-light radiance (L_B), thermal-hazard radiance (L_R) and the luminance (L_V) were calculated using the source diameter (D) and the measurement distance (0.3 m). The results are shown in Table 2.

Discussion

During a curing procedure, the dentist is normally not exposed to the light source directly. The light source is a tungsten-halogen lamp whose output is transmitted via a quartz rod or a fiber-optic cable to the tooth under treatment. The dentist can be exposed to reflected light from the tooth or to light that has been transmitted through the transilluminated tooth. Occasionally, if the dentist is curing a preparation on the front teeth from behind, he can view the exposed area of the tip. The calculations in this report assume worst-case conditions: direct exposure to the tip of the curing device within a viewing distance such that the source subtends an angle greater than 11 milliradians. It must be emphasized that the dentist is only occasionally exposed to the tip directly. During the normal course of a photopolymerization the operator is only exposed to the reflected or transmitted source (see Fig. 1).

Some units had timers. The Caulk Prisma-Lite units emitted an audible tone every 10 s while the light was on. The Command units were equipped with a timer, adjustable for an on-time between 1 and 30 s. There were not warning labels indicating a need to avoid staring into the light source attached to any of the units.

The output of a specific type of curing light was shown to vary within a factor of two, depending on the age of the light source. Some units emitted a relatively large portion of their output in the UV-A spectral region. Earlier types of curing lights were UV-A sources with very little visible output, whereas the currently used resins are best cured with blue-violet light. The advantage with blue-light-cured (polymerized) resins is a greater and more consistent depth of cure, whereas UV-A radiation provides a more shallow (albeit harder) depth of cure (3). Generally, a complete curing of a resin takes 30–50 s.

Hazard criteria

At present, guidelines exist only for limiting occupational exposure to bright light (other than for lasers). However, ACGIH has had *proposed* TLV*'s on the "Notice of intent to establish"-list (4) for several years, and these were used in this study.

*TLV – Threshold Limit Value established by the American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio. Use of trademarked names does not imply endorsement by the US Army but is intended only to assist in identification of a specific product.

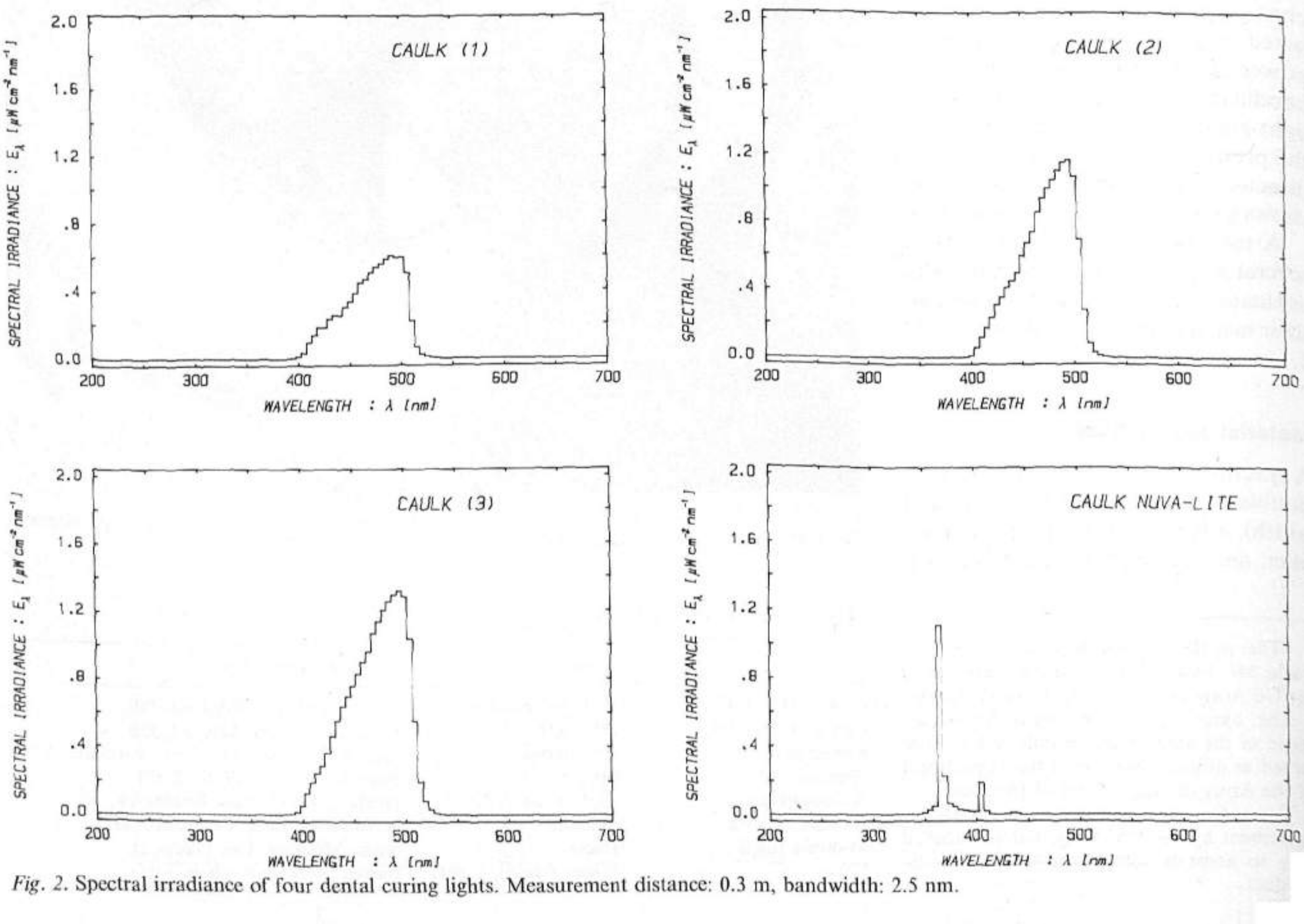

Fig. 2. Spectral irradiance of four dental curing lights. Measurement distance: 0.3 m, bandwidth: 2.5 nm.

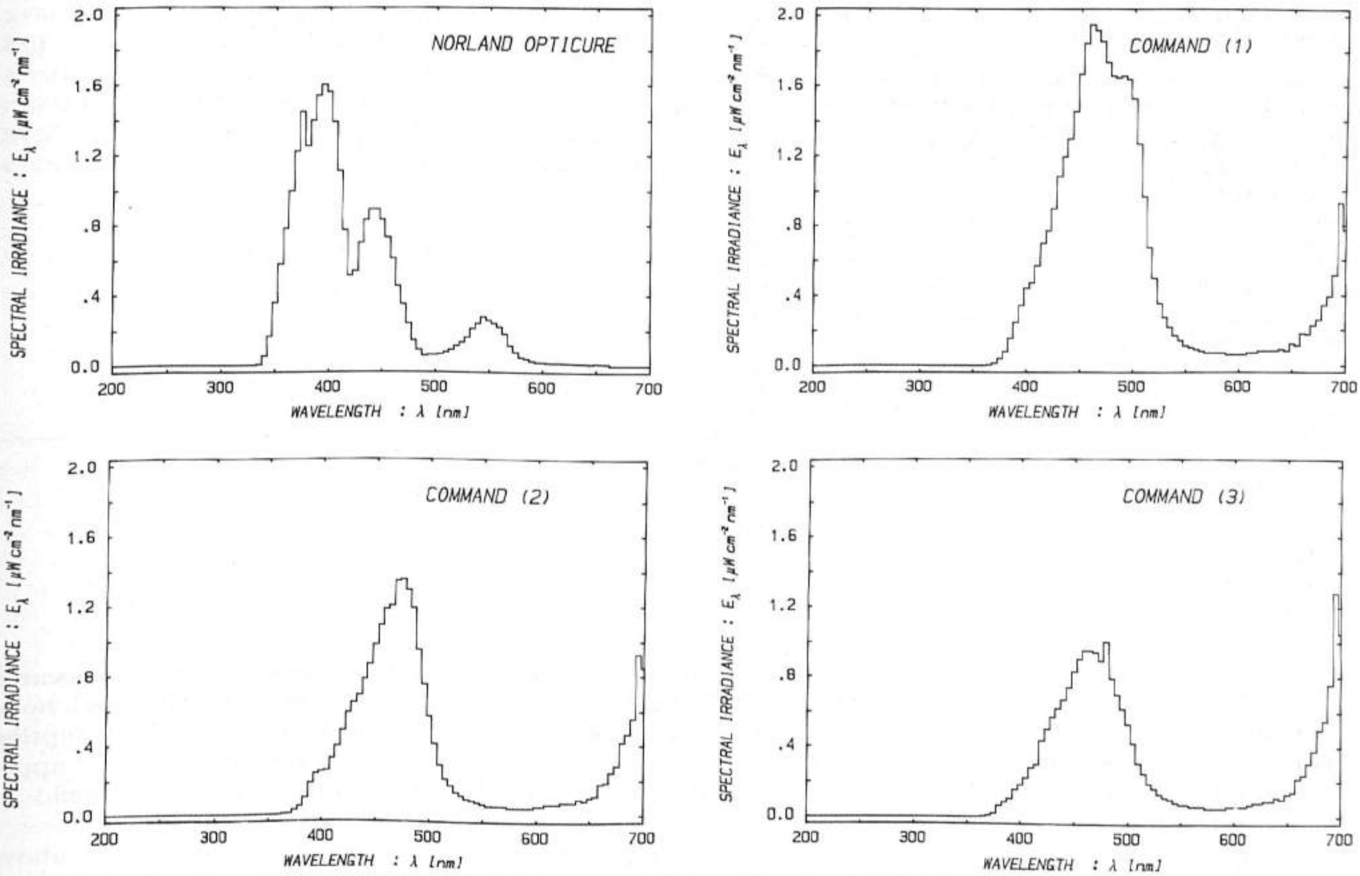

Fig. 3. Spectral irradiance of four dental curing lights. Measurement distance: 0.3 m, bandwidth: 2.5 nm.

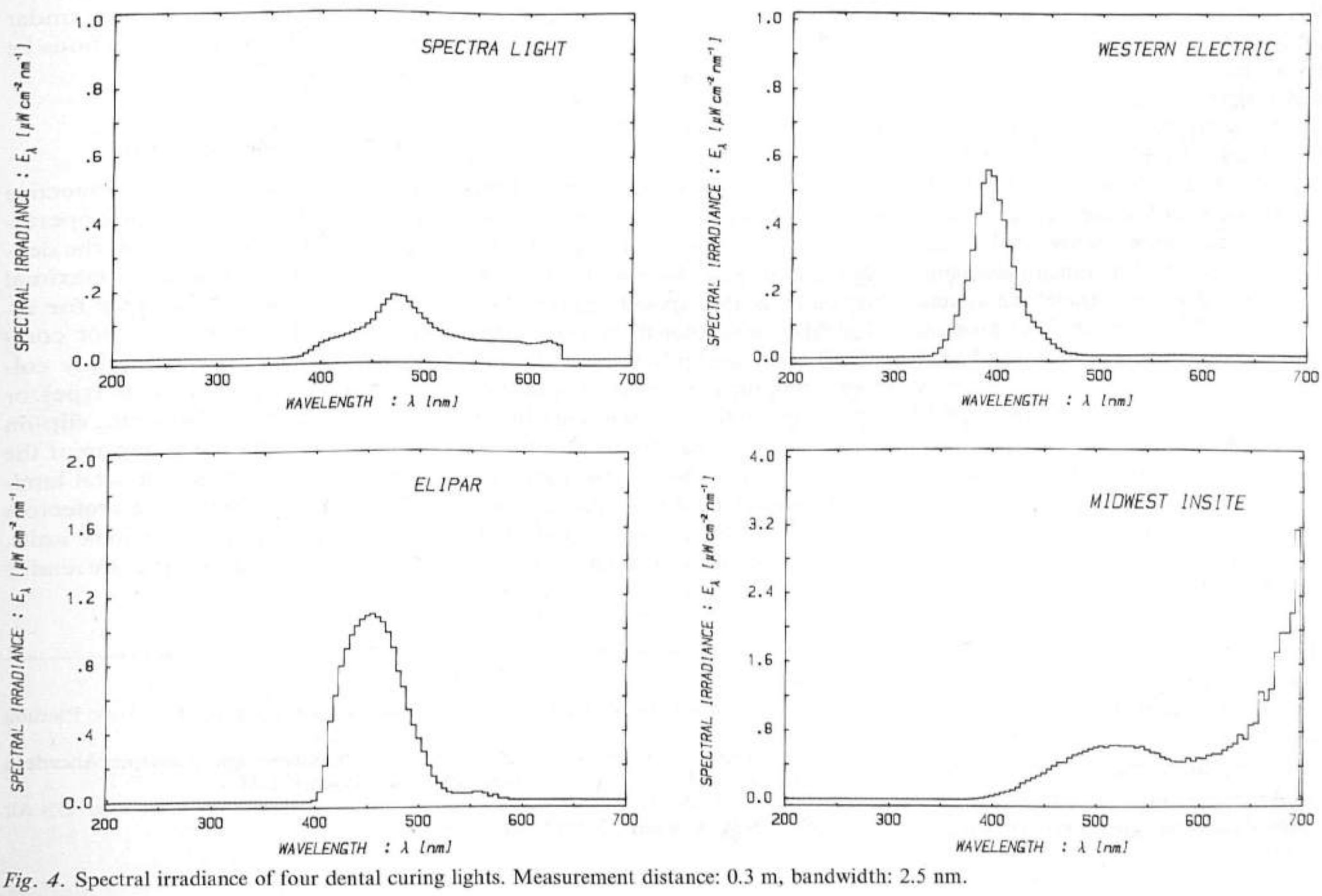

Fig. 4. Spectral irradiance of four dental curing lights. Measurement distance: 0.3 m, bandwidth: 2.5 nm.

Table 2. Measured and calculated radiometric and photometric quantities used to describe the output of dental curing lights*

Source	D mm	E $uWcm^{-2}$ (0.3 m)	E_{eff} $uWcm^{-2}$ (0.3 m)	E_{UVA} $uWcm^{-2}$ (0.3 m)	E_B $uWcm^{-2}$ (0.3 m)	E_V lx (0.3 m)	L_V cdm^{-2}	L_B $Wcm^{-2}sr^{-1}$	L_R $Wcm^{-2}sr^{-1}$	T_{max} (L_B) min
Caulk Prisma-Lite (1)+	5	40	ND	0.07	12	41	1.9×10^5	0.060	0.61	28
Caulk Prisma-Lite (2)	5	88	ND	0.24	46	95	4.4×10^5	0.21	2.1	8
Caulk-Prisma-Lite (3)	5	71	ND	0.05	37	73	3.3×10^5	0.17	1.7	10
Command (1)	5	190	ND	5.5	95	220	1.0×10^6	0.43	4.5	4
Command (2)	5	120	ND	3.6	58	110	5.1×10^5	0.27	2.8	6
Command (3)	5	110	ND	2.2	46	110	5.0×10^5	0.22	2.3	8
SPECTRA-Lite§	5	34	ND	0.90	12	37	1.7×10^5	0.030	0.31	56
Norland Opticure//	7	130	ND	61	43	92	2.1×10^5	0.10	1.1	17
Western Electric**	7	26	ND	16	6.4	0.57	1.3×10^3	0.015	0.16	110
Caulk NUVA-Lite	10	9.4	ND	8.1	0.4	0.55	6.3×10^2	0.0043	0.044	–
Midwest Insite**	5	202	ND	0.45	21	414	1.9×10^6	0.096	1.7	17
Elipar**	7	81	ND	0.00	56	63	1.5×10^5	0.13	1.3	13

* The permissible exposure time is given in min. D is source-tip diameter.
\+ Bulb close to burnout.
§ Evaluated at Fort Sam Houston, Texas.
// New unit.
** Old unit.
ND, Not detectable.

Potential hazards

Three potential hazards could exist which require evaluation: The UV hazard to the cornea and lens, the blue-light retinal hazard, and the thermal burn retinal hazard. The measurements revealed that the UV hazard was nonexistent; i.e. no actinic UV radiation was detected and the UV-A emission from all units was sufficiently below the occupational exposure limits to cause no harmful effects under normal operation conditions. In effect, the only hazards requiring careful study were the blue-light and thermal hazards. Both of these hazards have their most pronounced adverse effect at short (blue-violet) visible wavelengths. The blue-light hazard is dominant for lengthy exposure times (> 10 s) and the thermal hazards is dominant for short exposure durations (< 10 s). The blue-light hazard TLV is L_B (max) = 100 J $cm^{-2}sr^{-1}$ for exposure times less than 10^4 s. The thermal-hazard TLV is L_R (max) = $1/(\alpha\sqrt{t})$ where α is the angular subtense of the source in radians and t is the viewing duration in seconds (limited to 10 s).

Only one of the evaluated units (Command No. 1) exceeded the TLV for a theoretical thermal hazard, and then only if one deliberately stared directly into the light at a very close distance (less than 15 cm) for more than 15 s. However, because the luminance (brightness) was also very high, the eye's aversion response would limit the exposure time to about 0.25 s and, since a viewing distance of 15 cm is less than the near accommodation point of 25 cm for the normal individual, this is not a realistic viewing situation.

It is more likely that an operator would be exposed to light levels approaching the blue-light hazard TLV during normal treatment procedures. Thus, only the blue-light hazard was considered to be of any practical concern. Therefore, only the maximum stare time, T_{max} [calculated from the blue-light radiance (L_B) and the TLV for this quantity (1, 2)] is shown in Table 2. It is seen that T_{max} ranges from 4 min to more than 100 min. Assuming total additivity of blue-light retinal exposures over an 8 h workday, a total of eight 30-s cures with the light-source (positioned so that the dentist could see the exposed tip) would exceed the occupational exposure limit (TLV). Since the tip is normally directed away from the eye, this is an unrealistic operating condition. Again, since the luminance is high, and since normal treatment times are short, these lights can be considered nonharzardous for both operator and patient when used as intended. Since these measurements were performed another study has appeared (5) which suggests eyewear be used; however, this was based upon an assumption of a heavier workload, i.e. 17 to 81 applications a day where the tip would be seen.

For reasons described in the above paragraph, reflections, either specular or diffuse, can be considered nonhazardous under normal use conditions. Only under excessively heavy use could reflections be of possible concern.

Eyewear, luminance and comfort

It is not necessary to use protective eyewear during normal use when operating dental lights. However, since the dental lights luminance exceeds the maximal comfort luminance of 10^4 cd/m^2 for indoor work, the operator may, for comfort, choose to wear either slightly colored plastic eyewear (sunglass type) or to attach special, small-diameter, clip-on plastic lenses to the protruding tip of the "gun". Under heavy use (e.g. total laminations of front teeth), eye protectors may be advisable when using some units. Both tip shields and spectacles are readily

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available from various dental supply houses (6). The cost per spectacle varies greatly, but need not be excessive. For example, Younger Optics sells spectacles at a wholesale cost of approximately $ 15 each.

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