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## Editorial

# Let there be More Light!

In 1832, the last words of the German genius, Johann Wolfgang von Goethe, were *Mehr Licht* (more light). This was either a plea for increased enlightenment or – more prosaically – "Do open the shutter of the bedroom so that more light may enter"!

Either way, the thought resonates with preoccupations in the Dental Materials community about achieving more consistent clinical success with resin-composites by efficient and effective photo-polymerization or light curing. Such has been the concern of Professor Richard Price that he has organized two seminal international conferences on this theme at Dalhousie University, Halifax, Nova Scotia. The first, held in October 2012, was supported by the Canadian government. The second in May 2014 was supported by dental industry and attended by scientists and other experts from Universities and industrial companies. Another is forthcoming in June 2015.

Also during 2014, the Nobel Prize in Physics was awarded jointly to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura for their development in the early 1990s of efficient blue light-emitting diodes. Through the foresight and inventiveness of Jandt and Mills, these were then introduced quite rapidly into dentistry for LED light-curing units (LCUs) [1].

As we have noted previously [2], the energy-efficient but relatively narrow band width of LED light sources creates some problems for effective photo-initiation of cure through the challenge of matching output spectra of LCUs to some photo-initiator (PI) absorption spectra. Moreover, the shorter-wavelength violet light from polywave LCUs is somewhat less efficient at penetrating deeply into composite materials than blue wavelengths. Added to this, there is the complexity of uneven light-beam-profiles emerging from a number of LCU optic tips, particularly those mass-produced with poor design, safety features and quality control.

During the 2014 Dalhousie conference the goal was to achieve consensus on a number of issues. Firstly, it was helpful to adopt standard scientific nomenclature for physical quantities and units as expressed in Table 1.

A further major goal was to achieve a consensus statement on light curing intended as advice to practioners. After intense discussion, the following statement (Table 2) was agreed by the 38 delegates.

The scientific discussions in Halifax addressed the factors that are most relevant to the photo-polymerization of dental resins and resin-based composite materials. One of the perennial scientific issues relating to light curing is the question of reciprocity. This concept comes from the world of photography (conventional, and probably also digital) and more broadly from other fields of irradiation, such as X-ray irradiation. In those realms it has been exhaustively examined; but this is less so for photo curing of dental resins. Sometimes this principle is referred to as a Law of Reciprocity, such that energy delivered has the same effect for a given product of irradiance and exposure time. But the equivalence of the effect depends upon what is the outcome (property) under consideration. Clinically, the only aspects of major significance would be properties after 1 month or longer. So the concept of reciprocity gives us a very simple formula to test (it assumes there is no non-linear behavior) – but the understanding of such a concept depends upon a deeper analysis involving light scattering, absorption, photochemistry, polymerization kinetics, and much more. As not all composites and resin-matrices are created equal (because they can each differ in formulation), the conclusions that can be drawn from analysis of a single resin-composite are limited to that single composite (and

**Table 1 – Physical units for light transmission and radiometry.**

| Term | Unit | Symbol |
|---|---|---|
| Radiant energy | Joule | J |
| Radiant exposure | Joule per square centimeter | $J/cm^2$ |
| Radiant energy density | Joule per cubic centimeter | $J/cm^3$ |
| Radiant flux or power | Watt | W or J/s |
| Radiant exitance/emittance | milliWatt per square centimeter | $mW/cm^2$ |
| (Incident) irradiance | milliWatt per square centimeter | $mW/cm^2$ |
| Spectral power | milliWatt per nanometer | mW/nm |
| Spectral irradiance | milliWatt per square centimeter per nanometer | $mW/cm^2/nm$ |

**Table 2 – Light curing – advice to practitioners: a consensus statement from the 2014 Symposium on Light Curing in Dentistry held at Dalhousie University, Halifax, Canada.**

**When selecting a light curing unit (LCU):**

- **All lights are not created equal.** Use a LCU from a manufacturer who provides contact information, a user manual and service. Preferably the LCU should have received a favorable report or certification from a reputable independent 3rd party.
- **Know** the key performance parameters of your LCU, when new: (i) the light output (averaged irradiance in mW/cm$^2$ and spectral emission from the LCU), (ii) whether the beam has a uniform and effective output (profile) across the light tip and (iii) the beam diameter.
- **Be cautious** when using high output LCUs that advocate very short (e.g. 1 to 5 seconds) exposure times. When used for such short times, it is critical that the light tip is stabilized over the resin to be cured. Although some resin composites are matched to specific high output curing lights, high output LCUs may not adequately cure all of today's resin-composites to the anticipated depth when used for short exposure times.

**Before you light cure, remember:**

- **Regularly monitor** and record the light output over time, with the same measurement device. Repair or replace the LCU when it no longer meets the manufacturer's specifications.
- **Inspect** and **clean** the LCU before use to ensure it is on the correct setting, in good working order, and free of defects and debris.
- **Every resin-based material** has a minimum amount of energy that must be provided at the correct wavelengths to achieve satisfactory results. [Energy (Joules/cm$^2$) = output (W/cm$^2$) x exposure time (seconds)]. However, minimum irradiation times are also required.
- **Follow the recommended light exposure times** from the resin-composite manufacturer and increase your curing times for increased distances and darker or opaque shades.
- **Select a LCU tip that** delivers a uniform light output across the light tip and that covers as much of the restoration as possible. Cure each surface independently using overlapping exposures if the light tip is smaller than the restoration.
- **Position** your light tip as close as possible and with the tip surface parallel to the surface of the resin composite being cured.
- **Stabilize, watch and maintain** the tip of the LCU over the resin composite while curing. Always use the correct "blue blocking" glasses or shields to protect your eyes.

**Precautions:**

- **Avoid** conditions that will reduce light delivery to the resin-composite, e.g.:
  - ○ Holding the light tip several millimeters away.
  - ○ Holding the light tip at an angle to the resin surface.
  - ○ Dirty or damaged light-guide optics.
- **Supplementary light curing** should be considered under circumstances that may limit exposures, such as, shadows from matrix bands, or intervening tooth structure, or restorative material.
- **Beware of thermal damage** to the pulp or soft tissues when delivering high energy exposures.

**Air-cool** the tooth when curing for longer times, or when using high output LCUs.

- **Never shine** the LCU into the eyes. Also, avoid looking at the reflected light except through an appropriate 'blue-blocking' filter.
- **Testing surface hardness** of the resin-composite in the tooth using a dental explorer provides NO information about adequacy of curing depth.

perhaps to other composites that closely resemble it in all key respects). The assumption of reciprocity may well prove valid with some materials and not others. Wydra et al. [3] investigated experimentally and theoretically the question of a reciprocity law applied to BisGMA/TEGDMA photopolymers. The outcomes measured were conversion and shrinkage stress. As far as these properties are concerned, they concluded that this system does not and should not be expected to follow reciprocity behavior. Rather the properties studied depend upon irradiance and the corresponding rate of cure.

Strategic matters debated in Halifax were concerned with how to improve oral health by disseminating the research and consensus statements to other interested parties including: manufacturers, regulatory authorities, researchers, and clinicians in an understandable format for each group, and by means most appropriate for each group. Agreement is sought on the measurement parameters and evaluations that should be included when describing a dental curing light. This could lead to establishing the minimum amount of information that should be provided to clinicians to help them purchase and use a curing light.

## REFERENCES

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