SCIENTIFIC REPORT

Light curing of dental materials – information for users

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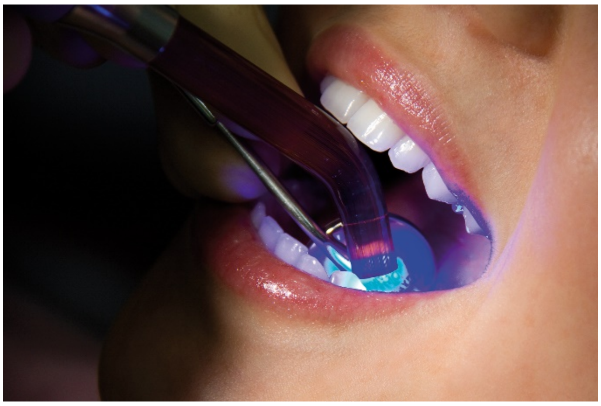

Light curing is an essential aspect of adhesive restorative treatment. Complete curing of dental materials is dependent upon sufficient energy exposure. Postoperative sensitivity, poor marginal integrity and, ultimately, adhesion failure are all possible consequences of insufficient light curing and should not be written off as material defects. This Scientific Report summarises the points raised at the "Light curing in dentistry" symposium in Halifax, Canada, in 2014 and takes further literature sources into account.[1-6]

When it comes to purchasing a light curing unit, dentists are spoilt for choice. Prices range from €20 for cheap, imported devices right up to €1,000 for equipment from leading manufacturers. This poses the justified question of why the price differences are so great and whether there is really any need to spend so much money.
In order to answer this question, this Scientific Report takes a closer look at the fundamentals of light curing and the essential parameters of light curing units.

Background

Irradiance

The curing reaction of dental materials requires a certain amount of energy to fully complete. This required energy dose is supplied to the material via the light energy from the light curing unit. Modern composites require between 8 and 20 J/cm^2 of energy, with these values being dependent on the opacity of the materials. However, composite manufacturers specify the curing time in combination with a minimum irradiance (in mW/cm^2) as opposed to a requisite amount of energy. It has been determined that irradiances of 1,000 to 1,500 mW/cm^2 are sufficient for the reliable light curing of composites, for which reason lights offering these outputs are explicitly recommended by the DGZMK (German Society for Dental, Oral and Maxillofacial Surgery).[1,2] Higher irradiances are regarded critically, as they can cause irreversible damage to soft tissue after exposure lasting just 10 s or less.[3] Part of the light energy is absorbed by the dental hard tissue and converted into heat, which increases the temperature of the tooth overall. However, this effect is even more intense in pulp tissue, where a greater proportion of the light energy is absorbed.

Light tip

A light's irradiance depends on the surface area of the light tip, which is why its diameter is another important factor that must be taken into consideration.[4] One advantage of large light tips is that they cover the majority of restorations completely, even large MOD cavities, meaning they can be fully cured in just one cycle. The use of smaller light guides renders a number of overlapping curing cycles necessary. Smaller light guides offer advantages in the case of class V cavities when working close to the gingiva, for example.

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The DGZMK recommends lights with light tips with an external diameter of at least 8 mm. However, it is important to note that the external diameter does not correspond to the active diameter. In fibreoptic light guides (Figure 1 a), the active diameter is 1 mm smaller than the external diameter on average; in collimator light guides (Figure 1 b), the active diameter is often a few millimetres smaller than the external one. In addition, the LEDs in collimator light guides are located directly adjacent to the light tip. This has proven to be a disadvantage, as lights with this type of light guides generate more heat in the pulp than lights with fibreoptic light guides.[3]

Photoinitiators / emission spectrum

All dental composites use camphorquinone as a photoinitiator, which absorbs light in the wavelength range from 420 to 480 nm. Therefore, it is important to ensure that the light curing unit is designed for this range. However, some composite manufacturers add alternative photoinitiators (for example Lucirin®), which need to be stimulated with UV light (wavelength < 400 nm). For this reason, in addition to standard light curing units, polywave lights including UV LEDs alongside LEDs emitting blue light (420-480 nm) are also available. However, UV light also has the serious disadvantage that its light intensity decreases considerably faster than that of blue light as it passes through the composite. For this reason, even when 2 mm increments are used, not enough energy is transmitted with UV light to activate the photoinitiator.[5] The arrangement of the LEDs is another problem with polywave lights. They often feature four LEDs arranged in a square: three emitting blue light and the fourth LED emitting UV light, see Figure 1 d. As such, the light distribution of these lights is very non-homogeneous and in one quadrant of the light guide no light at all capable of activating camphorquinone for curing of the composite is emitted.

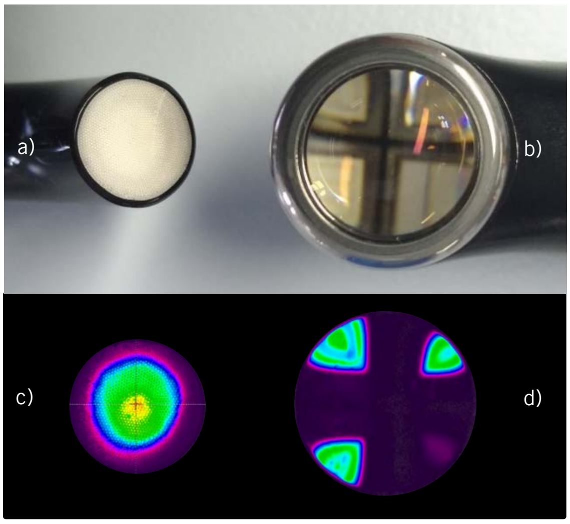

Figure 1 a) Fibreoptic light guide (Celalux 3)
b) Collimator light guide (VALO Cordless)
c) Beam profile (Celalux 3)
d) Beam profile (VALO Cordless)

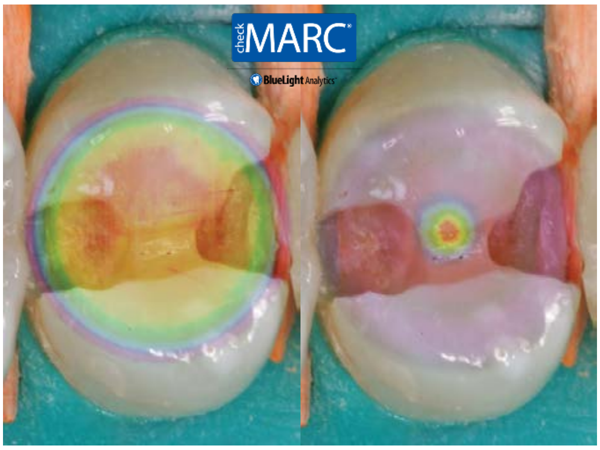

Figure 2 Projection of beam profiles into an MOD cavity: (left) homogeneous beam profile, (right) very non-homogeneous beam profile with a hotspot

Light distribution

The light distribution at the light tip and in the depths of the cavity can be qualitatively visualised using *beam profiles* (Figures 1 c and d). The goal is that the total energy is distributed homogeneously over the entire surface (Figure 1 c) without so-called hotspots (Figure 1 d), which result in insufficient energy being available around the edges or even in the centre of the light guide. The optimisation of the light distribution in the light curing units depends heavily on the optics. Manufacturers of cheaper lights cut costs here and cheap devices always come with the risk of only a small portion of the restoration being irradiated and cured. Figure 2 illustrates precisely this limitation by projecting two different beam profiles onto the same MOD cavity. It becomes immediately clear that the light curing unit with the homogeneous irradiation profile on the left covers the whole restoration, whereas the hotspot on the right only touches part of the restoration and the remainder of the filling is not exposed to sufficient light energy.

Service life

Additional important aspects include the service life of the lights and the associated necessary regular performance checks. The parts of the lights which are particularly subject to wear are the LEDs and batteries. The LEDs have a service life of around five years. It is more difficult to specify a service life for the batteries in years as the batteries last for a certain number of charging cycles (500 - 1,000 for lithium polymer batteries). Two to three years can be taken as a rough guide. It makes sense to use the lights during the day without intermediate charging and then charge them fully overnight.

Performance check in the dental office (relevant for QA)

In order to detect declines in performance, the lights should be regularly checked and the findings documented, for example once a month. Inexpensive hand-held radiometers are well suited to these regular performance checks. It is important that the measurements are always performed at the same place, under the same conditions and ideally by the same person. These values then signal when the light's performance deteriorates significantly. The exact performance value is not important and can also not be determined with hand-held radiometers, as their measurements can deviate considerably from the light's actual power due to the unprecise measuring method they use.

Precise performance checks

Precise performance values can only be achieved using a spectrometer, which can detect both the performance and the wavelength range. The gold standard for this is an integrating sphere, but these are very expensive and only found in photometry laboratories. However, a hand-held spectrometer for the measurement of light curing units has now been available for some time. The checkMARC from BlueLight Analytics is the size of a hand-held radiometer, but is in fact a spectrometer and its accuracy corresponds to the gold standard. This device is also very expensive to purchase. However, it is possible to have measurements performed on the behalf of the dental office.

Table 1 contains a comparison of the most popular portable measuring devices.[6]

Table 1: Comparison of portable measuring devices

Product	Company	Measuring method	Display	Diameter of light input (mm)	Wavelength measuring range (nm)	Performance measuring range (mW/cm²)	Precision compared with gold standard
Bluephase Meter II	Ivoclar Vivadent	Radiometer	Digital	12	380-550	300-12,000	++++
checkMARC	Blue Light Analytics	Spectrometer	Web-based software	16	300-700	< 10,000	+++++
Cure Rite	Dentsply	Radiometer	Digital	6.5	400-525	< 2,000	++
Demetron LED	Kerr	Radiometer	Analogue	7	400-500	< 2,000	++
SDI LED	SDI	Radiometer	Digital	12	380-515	< 2,000	+++

The most important information and hints concerning everyday use are summarised on the next page.

Conclusion: Light curing is a complex process and the light curing unit needs to do a lot more than "just" emit blue light. Developing and manufacturing a light requires careful research and development, which is reflected in the price of a high-quality light. As such, the recommendation is not to save on the light curing unit and purchase cheap models. It is worth investing in a light, as it ensures the success of the dentists day-to-day work.

[1] Roulet J-F, Price R, *J Adhes Dent* 2014, *16(4)*, 303.

[2] DGZMK, *S1-Handlungsempfehlung: Kompositrestaurationen im Seitenzahnbereich* 2016.

[3] Rueggeberg FA *et. al.*, *Braz. Oral. Res.* 2017, *31*, e61.

[4] Price R, *Illuminating the Resin: What You Need to Know – Oral Health Group, Features* 2018.

[5] Harlow *et al.*, *J. Dent.* 2016, *53*, 44.

[6] Lien W et al. Announcement: An Evaluation of a New Portable Spectrometer System (checkMARC); USAF Dental Evaluation & Consultation Service 2017.

Suggestions for decision making when purchasing a light curing unit:

Manufacturer, documentation, customer service and guarantee

- Use light curing units from manufacturers who provide contact information, include instructions for use and have a Customer Service department. If possible, base your decision on independent positive reviews.

Knowing the light's performance parameters

- How high is the light output? Light guide (fibre bundles or collimator), diameter of light tip (>8 mm), irradiance in mW/cm^2 and wavelength range – or overall performance of light?
- Beam profile: Homogeneous and effective distribution of light at light tip?

Take care when using high-intensity lights (above 1,500 mW/cm^2); as very short curing times (for example 1-5 s) are specified for these lights. Curing times below 10 s are viewed as very critical and should thus be avoided![1,2]

Considerations before the light curing:

Check and document the **performance of the light curing unit** regularly. Use the same measuring device and the same light guide. Repair the light, exchange the light guide or replace the light if the set values are not reached.

Checking and cleaning: parameters set correctly? Light condition? Defects and debris?

Compliance with minimum curing times and maximum layer thicknesses! Prolong the curing time when working from a greater distance and when using dark and opaque shades.

Selection of light guide: ensure the restoration is covered completely. If the light tip is smaller than the restoration, cure with individual and overlapping segments.

Position the light tip: as close as possible and parallel to the surface of the restorative material to be cured.

Maintain the light tip steady for the duration of the curing time. Wear suitable safety goggles (orange) and watch closely.

Precautionary measures

Avoid the following conditions:

- Holding the light tip several millimetres away – lowers the performance
- Holding the light tip at an angle to the restoration surface – throws shadow
- Using a contaminated or damaged light guide – reduces the surface of the light tip

Perform **additional light-curing cycles** if the clinical situation limits the light supply, e.g. due to shadows resulting from matrix bands, neighbouring dental hard tissue or restorations.

Pay attention to the **risk of thermal damage** to pulp/soft tissue; avoid high intensity lights in combination with long curing times. In the case of longer curing times and high intensities, plan in **pauses** of 2 s or **cool** with air at the same time.

Never shine light curing units directly into eyes and avoid looking directly at reflected light.

Testing the surface hardness of the cured restoration in the tooth using a periodontal probe does not give any information about the sufficient depth of cure.