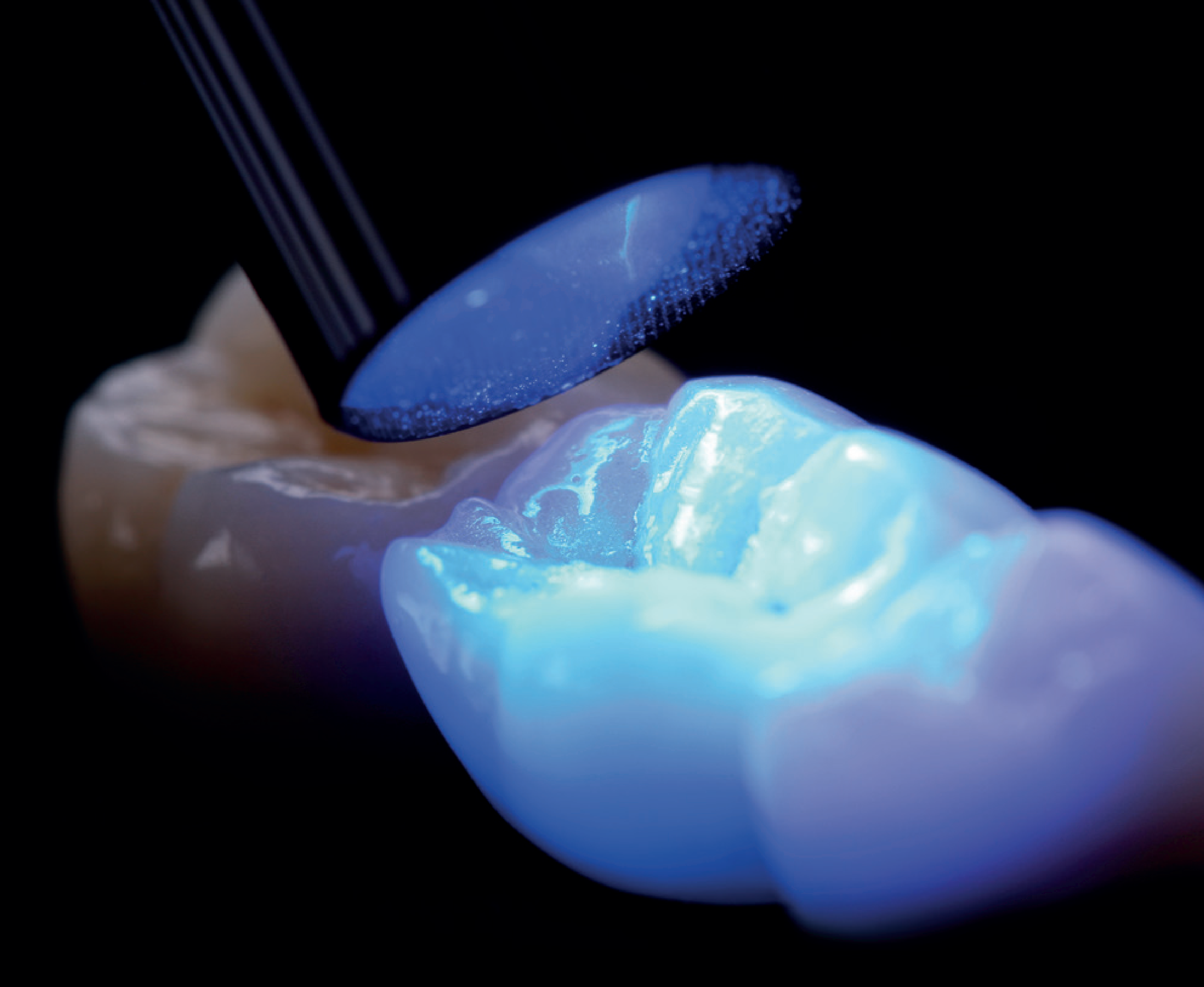


Light-curing

It's good to know the facts

special feature

ivoclar vivadent

passion vision innovation

User's Guide

to the key factors for selecting the right curing device

Table of contents

Clinical relevance
of light-curing

More than just a "necessary evil"

Fig.: Light-curing decisively affects the prospects for a successful long-term treatment outcome.

What is the first thing you think of at the mention of the following questions relating to possible problems in your day-to-day work:

- ➡ How often and for what reasons do postoperative sensitivities occur in your patients?
- ➡ When did you last replace a filling because of premature loss?
- ➡ What are the reasons for retention loss in high-quality ceramic restorations?

Do these questions remind you of your curing light? Curing lights are the number one source of error in the processing of light-cured dental materials [8-13,68-69]. Yet, curing lights are among the most frequently used devices in the dental practice and are therefore directly related to a substantial share of the practice revenue.

It is therefore essential to acknowledge the critical importance of curing lights and to make it a priority to use a high-quality device. Using a high-grade curing device, combined with an appropriate light-curing technique [2], is key to ensuring long-term successful results and the well-being of patients.

Requirements
of clinicians

Questions from the (dental) practice

As the proverb says, 'The chain is only as strong as its weakest link'. Similarly, light-curing materials only perform as intended by their manufacturer if they receive the required amount of light energy and appropriate blue-violet wavelengths for polymerizing them [1]. There are a number of questions that clinicians should answer before they decide on a curing light, for instance:

- "What light intensity is required?"
- "What spectral emission range is required for the materials I use in my practice?"
- "What is the ideal light-curing technique?"
- "How long is the exposure time?"
- "What quality criteria are important to me when buying a new state-of-the-art curing light?"

With decades of experience in the development of innovative curing lights and light-curing materials, we will provide an answer to these questions and many more.

This User's Guide provides an insight into a range of decisive product features and offers well-founded information on clinically relevant criteria that are essential for the daily use of LED curing lights and should be considered when purchasing a new curing device.

Polywave®

Fig.: Innovative strength of Ivoclar Vivadent – Bluephase Style with broadband Polywave LED to generate the required blue-violet spectral range.

Sufficient curing, the main objective of the treatment

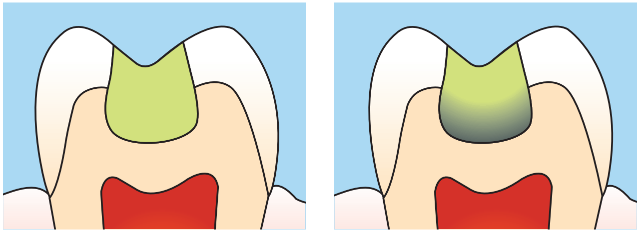


Fig.: The top surface appears to be correctly cured (green) in both the entirely cured (left) and the insufficiently cured restoration. The risk presented by insufficient polymerization (grey) in deep areas of the restorations cannot be identified from the surface.

Sufficient curing is the prime concern of polymerization. A restoration made of light-curing materials will only be a long-term success if it is sufficiently cured. Insufficient polymerization has been shown to have the potential to cause a number of adverse consequences:

- ➡ Reduced hardness and resistance to wear [8-12]
- ➡ Weaker bonding to the tooth [22,23]
- ➡ Increased "washout" of composite resin at the gingival margin [20]
- ➡ Increased bacterial colonization of the composite [20]
- ➡ Reduced colour stability [13,14]
- ➡ Higher release of elutable substances and increased cytotoxicity [21, 24,15-19]
- ➡ Risk for postoperative sensitivities, secondary caries and restoration fracture [8-21]

As the surface of light-cured resin composites appears hard after a short curing time already, it is impossible to determine the polymerization quality in the practice, neither by tactile means using a probe nor other instruments.

The physical characteristics of the entire cured material are of decisive importance. This includes the hardness achieved on the bottom side of the restoration in particular, the flexural strength and elasticity as well as the abrasive values. The specifications of the manufacturers regarding the appropriate curing of their range of materials are important guidelines. At least well-known suppliers base such recommendations on clinical tests with various materials and various layer thicknesses. [26].

Sufficient curing depends on many factors. The most important ones are, however, high light intensity, exposure duration and spectral emission to activate the photoinitiators of the resin. In other words, the curing light must be compatible with the resin materials being used [67].

Compatibility with dental materials

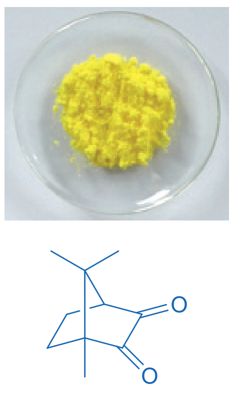
The various photoinitiators

To convert a monomer into a polymer, photoinitiators are required. The photoinitiators decompose into radicals when irradiated with light and cause the monomers to polymerize. Camphorquinone is the most commonly used initiator. Camphorquinone absorbs light in the wavelength range between approx. 390 and 510 nm and displays a yellow colour, which is the complementary colour to blue light. Unfortunately, the yellow colour of champhorquinone affects the shade of the cured restoration [28]. Although the initiator almost completely breaks down in the course of the polymerization process, a slight yellowish tinge always remains.

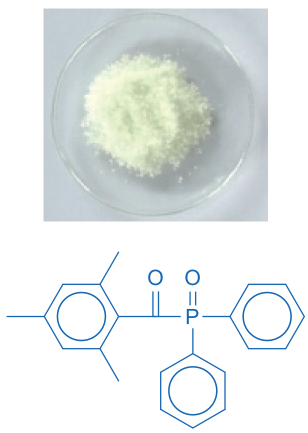
For this reason, composites in bleach shades, which are used for very bright restorations, and other materials such as adhesives contain, among other ingredients, whitish photoinitiators, such as acyl phosphine oxide (e.g. Lucirin TPO) or phenyl-propanedione (PPD). These initiators predominantly absorb light in the wavelength range between 380 and 430 nm [71].

Ivocerin® is another new photo-initiator [70]. Compared with camphor-quinone, Ivocerin offers a high absorption rate in the visible light range, a significantly heightened photoreactivity and excellent colour stability. Given these qualities, Ivocerin has enabled the development of esthetic composites such as Tetric EvoCeram® Bulk Fill and Tetric EvoFlow® Bulk Fill. These composites allow a curing depth of up to four millimetres and can be light-cured with all commercially available curing lights in 10 seconds.

Camphorquinone

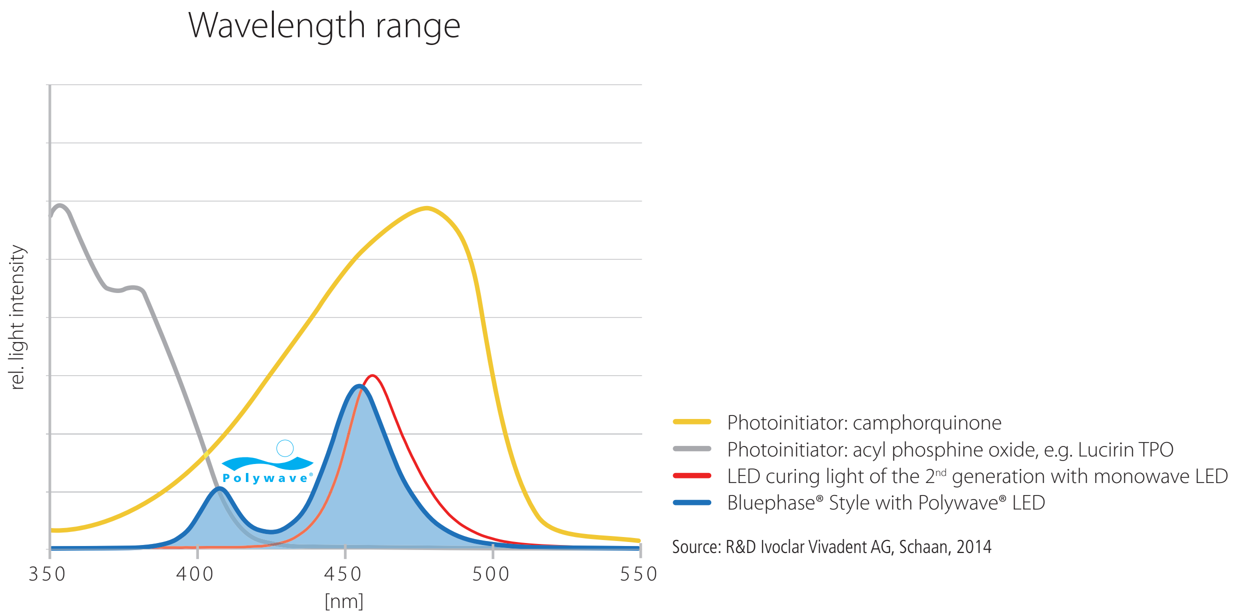


Acyl phosphine oxide



Ivocerin®

Fig.: Report published by Research and Development Ivoclar Vivadent AG, 'Ivocerin® – a milestone in composite technology', Schaan, 2013



The ability of a curing light to cure all dental materials and photoinitiator systems essentially depends on the spectral emission of the curing light. Given their broadband emission spectrum, halogen lights were able to activate the entire range of initiators without any problems. Conventional second-generation LED lights are not automatically suitable to universally cure all materials because of their typically narrow monowave emission spectrum ranging from 430 nm to 490 nm. However, today's third-generation LED curing lights (e. g. Bluephase Style) generate blue light in the range between 385 and 515 nm and are thus suitable for polymerizing all light-curing materials [32,35,36].

Different materials - different requirements

Composite curing

Dental composite curing is the most important indication of curing lights. The quality of the composite cure can be determined by investigating certain properties of the cured material. Composites undergo changes in hardness, flexural strength and elasticity in the course of the polymerization process. The depth of cure is directly related to the irradiance of the curing light. Spectroscopic measurement systems such as infrared spectroscopy, are useful in determining monomer conversion results, i.e. the degree of monomer conversion. Generally, the depth of cure depends on the shade and translucency of the material. The more opaque and dark the composite, the lower the depth of cure [25,26,29-37,38].

Fig.: Tetric EvoCeram® Bulk Fill and Tetric EvoFlow® Bulk Fill

Curing of adhesives

Inappropriate curing of adhesives results in a weakened shear bond strength of the adhesive bond on enamel and dentin. Camphorquinone is often used as a photoinitiator in light-cured adhesive systems. However, camphorquinone is subject to progressive changes over time in highly acidic formulations. This presents a problem in self-etch adhesives in particular. This issue is often circumvented by adding large quantities of camphorquinone or by using an acid-resistant initiator system such as acyl phosphine oxide (e.g. Lucirin TPO). It is therefore advisable to use a broadband LED curing light to polymerize adhesives (see page 7, 'Compatibility with dental materials'). In this way, users can be sure to attain an adequate degree of cure even if the adhesive does not contain camphorquinone.

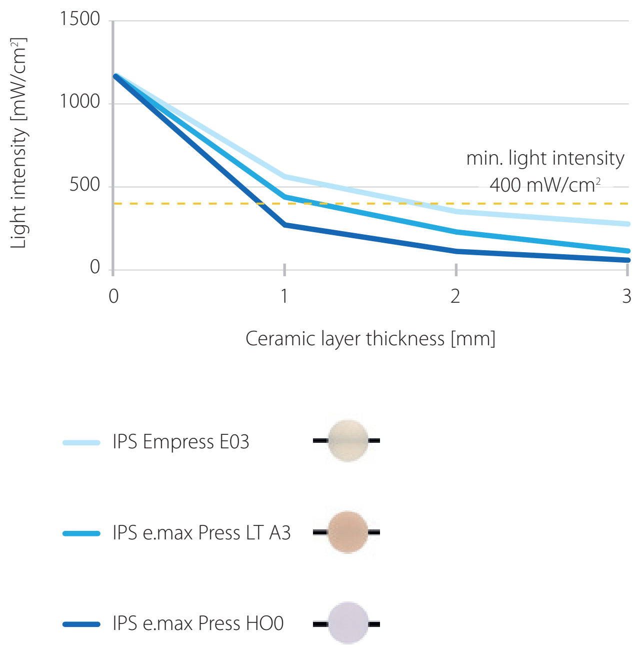
Fig.: Adhese® Universal

Curing through ceramic materials

Light- and dual-curing composites are used for the adhesive bonding of indirect restorative materials. Particularly in the case of high-quality all-ceramic restorations based on glass-ceramic materials, the adhesive bonding technique using composite resin is recommended. Given the opacity of these materials, however, the quantity of light that actually reaches the composite is substantially reduced.

Users should therefore make an effort to ensure that the curing light provides an adequate light intensity when placing indirect restorations. Only if the irradiance is sufficiently high can light reach through the crown or inlay to the luting composite and ensure an adequate depth of cure [2].

Decrease in the intensity of blue polymerization light through ceramic layers of different shades and thicknesses



R&D, Ivoclar Vivadent AG, Schaan, Liechtenstein, 2009

Removal of excess material

Until recently, processing adhesive luting composites was considered difficult because of the inconvenient removal of excess material. Modern luting composites (e.g. Variolink Esthetic) are designed for easy clean-up because they allow the excess material to be pre-cured to an ideal consistency with a short burst of light and then removed with a scaler.

Depending on the type of restoration, the manufacturer's directions on the correct method for the initial light activation of surplus material should be considered. Following the removal of excess material, the luting composite is again irradiated with light to attain the final cure.

Fig.: Variolink® Esthetic LC and
Variolink® Esthetic DC

Curing of fissure sealants

The fissure sealants available on the market are predominantly filled or unfilled one- or two-component systems. [73]. They are mostly based on methacrylate (e.g. Bis-GMA). A distinction is made between self-curing and light-curing sealants, with the majority of current products being light-cured.

Light-curing fissure sealants require an appropriate source of light to polymerize. As with other dental materials, polymerization is triggered with the help of a catalyst (e.g. camphorquinone or other initiator) that absorbs light in a specified wavelength range. This means that care should be taken to ensure that light of a sufficient minimum intensity (≥300 mW/cm^2) in the required blue-violet wavelength range and with an appropriate exposure length is utilized to light-cure fissure sealants.

Fig.: Helioseal® F

Wavelength range

LEDs in general have a more limited light spectrum than halogen lights, which used to be in widespread use. Therefore, the polymerization of materials that do not solely contain camphorquinone as photoinitiator may be problematic, even when modern LED lights are used. Such formulations may include composite materials in bleach shades or special adhesives (see following page). In such situations, curing devices emitting light in a broadband spectrum offer significant advantages. These lights are designed to match not only the absorption peaks of individual photoinitiators such as camphorquinone but they are also universally suited for all dental materials that respond to the blue-to-violet emission spectrum [32,35,36]. Bluephase Style with its Polywave LED is one of these devices.

In order to safely use the dental materials in their practice, operators should be furnished with a "negative" list of all the incompatible materials by the manufacturers of conventional LED lights. However, such lists are often not to hand or they are incomplete. Using a curing device that emits light in a broadband spectrum is therefore the only way to ensure that a reliable cure is achieved.

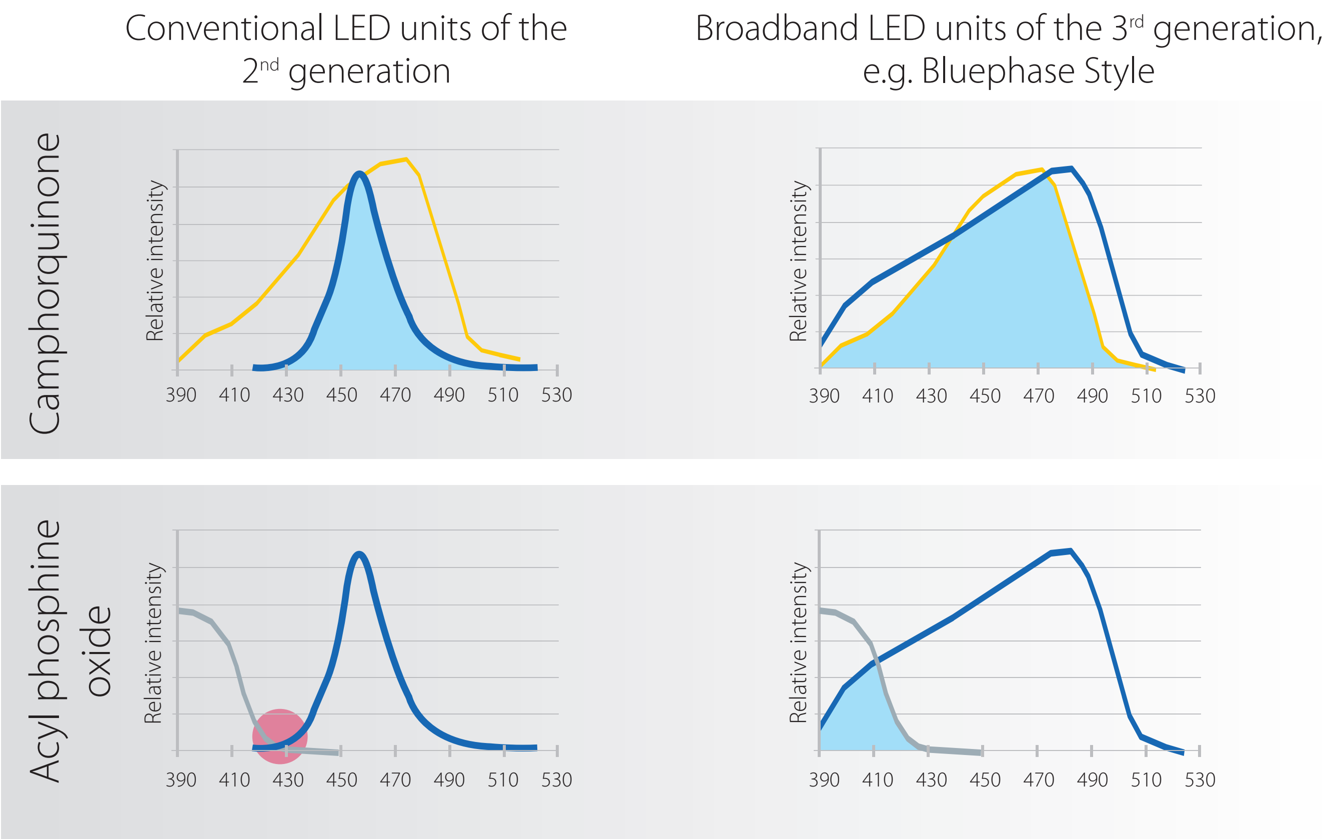


Fig.: A complete cure is only attained in the presence of an adequate overlap (light blue area) between the emission spectrum of the light (dark blue line) and the absorption spectrum of the photoinitiator (yellow/grey line).

Compatibility

The materials listed below, among others, are known to be problematic. Depending on the LED curing light and the light emission spectrum, the material may or may not be compatible:

Filling composite

- ➡ Solitaire 2 from Heraeus Kulzer

Adhesives

- ➡ Touch & Bond from Parkell
  (compatible successor product: Brush & Bond)

Luting composite

- ➡ Panavia F from Kuraray
  (compatible successor product: Panavia F2.0)
- ➡ Calibra opaque from Dentsply

Light-curing protective varnishes

- ➡ BisCover from Bisco
- ➡ Luxaglaze from DMG
- ➡ Palaseal from Heraeus Kulzer
- ➡ Enamic Stains Kit from VITA (manufacturer's recommendation)
- ➡ OPTIGLAZE Color from GC
- ➡ Pro-Seal from SDI Laboratories

?

Does the LED unit emit light in a broadband spectrum including both blue and violet light? Alternatively, does the manufacturer supply a list of all the incompatible materials? Are you using incompatible materials in your practice?

"Another obstacle for LED technology continues to be narrow spectral output that will not cure all current resin formulations."

"No one has a comprehensive list of incompatible products..."

"Clinicians should verify compatibility of their light & resins."
(CRA, Vol. 30, Issue 2, February 2006)

" … most units only work with CQ [camphorquinone] photo-initiator … "
(The Dental Advisor, Vol. 23, No. 5, June 2006)

"… composite sample that appears hard may not be sufficiently converted …"

"Check with the resin manufacturer about compatibility."
(ADA, American Dental Association: Professional Product Review, Vol. 1, Issue 2, Autumn 2006)

"Resin glazes (clear) and bleach shades (white) of composites may not contain CQ… … [and] require a curing light that emits light at a lower wavelength around 420 nm."
(REALITY Now, #184, Nov'/Dec' 2006)

" … is the issue of LEDs not being able to cure all materials."

" … mandate that you still have a halogen around."

" … solution is to buy an LED that is capable of curing all materials."
(REALITY, Vol. 20, 2006)

Light intensity

1,000 mW/cm^2: the ideal value

Normal light is not enough to polymerize materials in the dental practice. For this process, energy-rich blue light is necessary. Even for direct restorations, an irradiance (commonly referred to as "light intensity") of at least 400 mW/cm^2 is generally required [27,39].

However, a minimum value of 1,000 mW/cm^2 is considered to be ideal. This value allows short exposure times of 10 seconds to be consistently applied even if the conditions are not ideal (e.g. light-curing from a distance) and ensures that indirect restorations are sufficiently cured when the irradiation takes place through the ceramic restoration or tooth structure [74].

If the light intensity is lower, the curing time must be extended accordingly. If exposure times are not adjusted, complete curing of the composite or the adhesive in deeper layers cannot be warranted. Against such a background, the light intensity should be checked regularly as the output capacity of the curing light decreases with age. Built-in or separately supplied radiometers or an integrating sphere (Ulbricht sphere) are helpful tools to measure the light output [62- 66].

In the past, several international studies found that the light output claimed by the manufacturers did, in many cases, not comply with the actual light output measured in the dental practice. It is therefore all the more important for clinicians to pay attention to the minimum light intensity guaranteed by the manufacturer and to consistently check this value [3-7,40,41].

Light curing unit	**Manufacturer**	**Light intensity [mW/cm^2]**		Percentage of units with an intensity of **< 70% of the value stated by the manufacturer**
		Value indicated by manufacturer	**Mean value measured**	
Bluephase	Ivoclar Vivadent	1,100 (±10%)	1,066	0%
SmartLite PS	Dentsply	950	927	0%
Mini L.E.D.	Satelec	1,250	872	50%
FlashLite 1401	Discus Dental	1,400	859	88%
Radii	SDI	1,400	825	86%
L.E.Demetron 1	Kerr Hawe	1,000	699	67%
Elipar Freelight 2	3M Espe	1,000	602	58%
Translux Power Blue	Heraeus Kulzer	1,000	513	100%
Elipar Freelight 1	3M Espe	400	231	88%

Table: C.-P. Ernst et al: Field test on the light emission performance of curing devices in dental practices, DZZ 60 (2006) 9, 466 – 471

Does your curing light produce a light intensity of (at least) 1,000 mW/cm^2? Is the minimum light intensity clearly defined, for instance in a statement regarding tolerance values in the manufacturer's operating instructions?

The "Total Energy Concept"...

... or in other words: What curing time is required for successful curing? The Total Energy Concept states that the process of light-curing is energy-dependent and is basically a product of light intensity and time. [74]. The linear relationship to the light intensity applies only within the given initiator or monomer system.

The required dose depends on the type, shade and translucency of the composite [29-34]. As a general rule, a dose of maximally 16,000 mWs/cm² is required to adequately cure a single increment – in some cases, the value may be lower. Based on this maximum value, various curing times can be calculated depending on the light intensity of the polymerization light used.

Total Energy Concept

$$\frac{\textbf{Required energy dose}}{\textbf{Light intensity}} = \textbf{Resulting curing time}$$

Examples

Required Energy dose	16,000 mWs/cm²	16,000 mWs/cm²	16,000 mWs/cm²
÷ Light intensity	÷ 400 mW/cm²	÷ 800 mW/cm²	÷ 1,600 mW/cm²
= Resulting curing time	= 40 s	= 20 s	= 10 s

Modern composites such as Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill can be light cured with an energy dose as low as 10,000 mWs/cm². Depending on the output capacity of the curing light used, these materials can be light-cured in a very short time, even if applied in increments of up to 4 mm.

Tetric EvoCeram® Bulk Fill and Tetric EvoFlow® Bulk Fill

Required energy dose	10,000 mWs/cm²	10,000 mWs/cm²	10,000 mWs/cm²
÷ Light intensity	÷ 500 mW/cm²	÷ 1,000 mW/cm²	÷ 2,000 mW/cm²
= Resulting curing time	= 20 s	= 10 s	= 5 s

Heat build-up - possible side effects

Modern LEDs generate high light intensities and therefore release more energy, which may have an effect not only on the restoration but also on the pulp and/or adjacent soft tissues. Heat is released during the polymerization process due to the exothermic reaction of the resin composite and the irradiation energy of the curing light. As a general rule, it can be stated that the higher the light intensity of the curing light, the higher the release of energy and the higher the perceived heat (and the shorter the required curing time).

To prevent possible damage to the pulp or soft tissue, curing lights should therefore always be used cautiously and with clinical common sense and knowledge. As long as the light emits the light intensity indicated by the manufacturer and the light probe is adequately placed, the recommended curing times should not be exceeded to avoid the risk of an excessive heat accumulation [36,42-45,46-53].

The following measures assist in preventing the risk of a possible heat build-up:

- ➡ Correct and steady positioning of the light probe directly above the restoration
- ➡ Adherence to the curing times indicated by the manufacturer
- ➡ Stream of air to the tooth immediately before, during and after the treatment
- ➡ Longer curing times with lower light intensity

The dominant view is that the temperature of the pulp should not increase by more than 5.5°C (approx. 9°F) [46]. Manufacturers should be able to present the corresponding data regarding their product.

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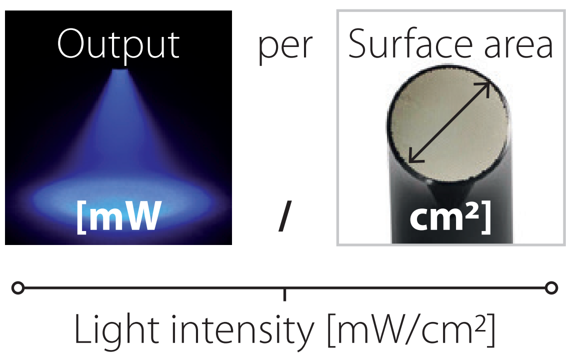
Have you access to data regarding the heat development during polymerization?

Light measurement

Trust is good, control is better

Adequate polymerization of dental materials is key to the clinical long-term success of direct and indirect restorations. In this context, the irradiance (=light intensity) of the curing light in use has a decisive effect on the success of the treatment outcome. The light emitted by the curing device should be checked regularly to be sure that the irradiance is not below the required minimum value. We recommend using an appropriate measuring device such as a radiometer for reliable readings.

The physical measurement unit of light intensity is expressed as the quotient of the emitted light power in milliwatts and the surface area of the active light emission window in square centimetres:



A range of measuring methods are used for determining the light intensity or irradiance of curing lights. The integrating sphere (Ulbricht sphere) is the only recognized measuring device, enabling an accurate measurement of the absolute light intensity. Although this method is very expensive and therefore not suited for use in the dental practice, it represents the gold standard for measuring the light intensity of curing lights. If calibrated on a regular basis, this method provides a measuring accuracy of ± 5%.

By contrast, conventional radiometers fail to provide accurate light intensity measurements. These devices cannot be calibrated and only provide imprecise approximate values. They are therefore only suited for relative, not absolute light intensity readings. Radiometers are generally utilized for checking the consistency of the light output on a regular basis to enable the user to respond to a sudden drop in intensity in good time.

The new Bluephase Meter II is the only radiometer capable of measuring the light intensity of all different types of curing lights currently available on the market (halogen, plasma, laser, LED), providing accurate readings for each of them without limitations. Compared with the integrating sphere, it achieves a measuring accuracy of ± 10%, surpassing the accuracy of all other radiometers currently available. It therefore provides a viable and inexpensive alternative for the dental practice.

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Does the manufacturer of the curing light offer a radiometer for checking the light intensity?

All about light probes

Ways of transmitting light

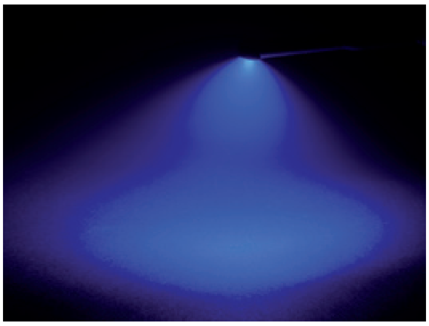
If a polymerization light comes without light probe and contains instead an LED mounted at the front of the light emission window, much of the intensity is lost due to scattering at a certain distance from the material to be cured. However, a larger distance cannot always be prevented in daily working routines, for example, when curing material in deep cavities or on difficult-to-reach proximal surfaces. In such cases, the curing time should be increased accordingly.
Fibreglass rods have proven to be particularly effective in reducing scattering losses. These rods consist of a myriad of individual glass fibres embedded in a protective glass case with precisely defined light transmission rates. Given their exceptional light emission characteristics, parallel-walled (standard) light probes offer an advantage over tapered turbo light guides. Parallel-walled light guides can be placed at a distance of up to 8 to 9 mm before the energy available for the polymerization process is halved and the curing time has to be doubled, in line with the Total Energy Concept.

Besides their optical properties, light probes are characterized by other aspects that also come into play in the day-to-day work of the dental practitioner [9,25,54-58,59,60]. For instance, a light probe that features a shortened tip facilitates access to all parts of the oral cavity without necessitating excessive mouth opening. This is particularly advantageous in paediatric dental care. Light probes that feature a large diameter (approx. 10 mm) also offer an advantage as they ensure that even large cavities and MOD fillings are entirely irradiated and, as a result, eliminate the need for time-consuming multiple exposures. Ideally, it should be possible to remove the light probe from the handpiece and sterilize it in an autoclave to ensure maximum hygiene [61].

Double the curing time at a distance of...

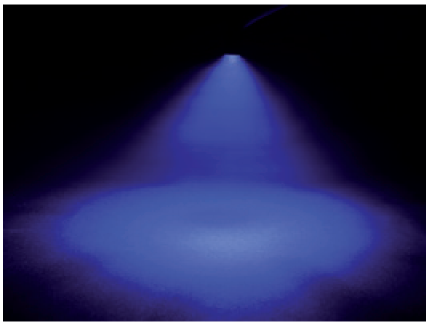
LED mounted at the front

... approx. 2-4 mm



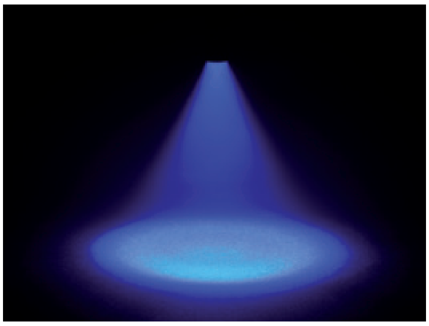
Turbo light probe

... approx. 5-6 mm



Standard light probe

... approx. 8-9 mm



Is the polymerization light designed with a parallel-walled glass-fibre probe? Does the light probe ideally feature a diameter of 10 mm and a shortened tip to ensure that all areas of the oral cavity can be easily and completely irradiated?

Modern batteries
live longer

Nothing is possible without electricity

Given their low power consumption, LED curing lights can be efficiently operated by the power of a battery. Lithium has become the standard in battery technology and is widely used in many applications, including billions of mobile phones. Lithium-ion and lithium-polymer batteries are small and light, they have a long service life while the self-discharge rate is low, and they can be charged in a short time. More than 500 charging cycles are possible – and many more if the battery is only partially discharged. Moreover, special protective circuits provide a high level of security.

The charger technology of these batteries ensures that a memory effect does not occur. The memory effect prematurely and irreversibly reduces the capacity of nickel metal hydride and nickel cadmium batteries to recharge if they are charged before their capacity is exhausted. These types of batteries are considered obsolete by current standards. By contrast, the lithium-ion or lithium-polymer batteries used in high-quality LED lights do not need to be completely discharged before they are recharged. Frequent charging even results in an considerable increase in battery life. It is therefore advisable to place the light back into its charging base after every use.

However, it should generally be possible to use the light-curing device for at least 20 minutes in continuous operation without having to charge it. Consequently, sufficient battery capacity will be available at all times throughout the work day in the practice and the battery will never run out of adequate reserve capacity to place large direct or indirect restorations in a single appointment. Modern devices emit an acoustic and/or visual signal to warn users in time that the light will soon switch off. Nothing is more unpleasant than having to interrupt the treatment of a patient and therefore the entire work routine of the practice team just because the battery is empty.

This raises the need of an emergency mode. If the practice team does not have time to recharge the battery but would like to use the curing light immediately, they can choose between two options: First, an additional battery is supplied. Such an additional battery does not come for free and it should always be charged and kept in a place where it is easy to hand. Second, innovative polymerization lights allow the handpiece to be connected to the power cord of the charging base, offering the possibility of corded operation. This enables the clinician to use the curing light at any time, completely independently of the battery capacity.

Fig.: Click & Cure, corded operation

?

Is the capacity of the battery being used – i.e. the operation time – sufficient when the battery is charged? Is it possible to operate the light without battery in case it has run out (corded operation)?

Proper maintenance of the battery

Rechargeable batteries, being small power plants, require careful handling. The following tips may be helpful to ensure that your battery offers you the smoothest and longest possible service life:

To prevent an irreversible deep discharge, nickel-metal hydride batteries must be recharged after three months at the latest and lithium-polymer or lithium-ion batteries after six months, if they are not used for a long time.

Nickel-metal hydride batteries must be completely discharged before they are completely recharged. Lithium-ion batteries, however, can be discharged and recharged at any time. It is even recommended to place the light back into its charging base after every use to prolong the battery life.

Exposed battery contacts should be kept free of dust and composite debris to ensure adequate conductivity and charging capacity at all times. The electric metal contacts should therefore be cleaned regularly – for example using a cotton bud or wipe dipped in alcohol.

Fig.: Batteries should be easy and quick to remove.

These maintenance measures are not necessary in curing lights that use induction charging. Contactless energy transmission eliminates the need for cleaning exposed or difficult-to-access battery contacts. Standard wipe disinfection is enough to ensure an optimum and reliable power supply at all times.

Any type of battery is subject to ageing. With increasing age, the battery's capacity diminishes. After 3 years of use, lithium-polymer and lithium-ion batteries typically lose approx. 30 per cent of their initial capacity. This means that the operation time of the fully charged battery is significantly shorter than it was when the battery was new. It is therefore advisable to buy a spare battery.

Ergonomics and design

Design should suit your needs

You can dispute about taste, but you cannot dispute about good design. Design includes the external appearance and ergonomics of curing lights. Ideally, the design should be tailored to the needs of the clinician and be optimized in terms of clinical handling and ease of use in day-to-day work routines.

Consequently, the handpiece should be as lightweight as possible, feature a balanced weight distribution and fit comfortably in the user's hand. This minimizes the strain on the arm and hand, which is particularly advantageous when placing large restorations. Furthermore, a cordless design affords maximum freedom of movement to the clinician during the treatment of patients. Both clinician and patient are no longer bothered by the power cord.

Pen- or rod-like shapes have become the standard in the design of housings for curing lights. However, differences can be noted in the workmanship and choice of material. Curing lights that reflect the anatomy of the human hand and do not feel unpleasantly cold or metallic to the touch offer an advantage.

Consistency in ergonomics and design also comes into play in the operation of the curing light. Straightforward intuitive single-handed operation to adjust the exposure time or start the light curing process is key to ensuring a smooth and reliable working procedure. The short angulation of the light probe, combined with the flat design of the handpiece, provides ideal access to the treatment area in the mouth.

Hygiene capability is another clinically important aspect in the design of curing lights. Debris stemming from contamination or disinfectant should be avoided. Housings should have as few joints as possible and the surfaces should allow easy, quick and residue-free cleaning for hygienic efficiency.

In sum, it is recommendable to “test-drive” a new curing light for a while before buying it to ensure that the light meets all your needs in terms of design and ergonomics.

?

Can you operate the light easily, intuitively and without strain? Do the design and ergonomics of the light reflect the anatomy of the human hand and facilitate effective hygienic maintenance? Does the manufacturer allow you to “test-drive” the device for a day or two before buying it?

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Quality
vs. cost

Quality has its price

If we look at the large variety of curing lights on the market, we notice that, besides the well-known and proven brands, a number of suspiciously cheap devices are available. Using such devices in the dental practice poses an incalculable risk to both the user and patient.

This is due to the lack of technical support and the fact that these devices do not fulfil the required minimum quality and safety standards. For this reason, the British Medicines and Healthcare products Regulatory Agency (MHRA) issued, for instance, a warning against using counterfeit or untested devices. The agency sent out a medical safety alert and advised users to immediately dispose of these devices for their own protection and the protection of their patients [75]. Renowned opinion leaders and dental journals have been increasingly drawing attention to this issue, too [76].

However, the buying price alone - even if it is a price commensurate with the prices of the units sold by renowned manufacturers - is no guarantee for high quality. As early as during the development phase, the manufacturers of curing devices are obliged to adhere to all the quality guidelines and national regulations of the countries into which they want to sell the finished product. However, experience has shown that the CE mark alone does not offer a sufficient level of consumer protection. To ensure that you buy a unit that meets the highest quality standards, you should check every new curing light to see if an independent government body, such as TÜV, has tested it and confirmed that it complies with the regulations on product safety and meets the rigorously defined requirements to be classified as a medical device. The well-known TÜV seal of approval and the four characters next to the CE mark tell you that the unit has been appropriately tested.

The light intensity indicated by the manufacturer is probably the quality feature that matters most to clinicians when buying a new curing light. The performance of the curing lights must be meticulously tested and calibrated before delivery to the dental dealers to make sure that the manufacturer's claims on light intensity are met. During the final assembly, the manufacturer should subject each curing light to comprehensive functional checks using high precision test and measuring equipment. These measures are essential to ensure the correct functioning of the unit in day-to-day dental applications.

Additional quality criteria include i) the durability of the individual components when used every day, ii) the availability of spare parts and iii) the service level and warranty offered by the manufacturer.

Does the curing light bear a medical device "CE 0123" mark and other seals of quality? Is the light intensity guaranteed by the manufacturer? What after-sale service and warranty are offered?

Checklist

Decisive criteria when purchasing a new LED curing light

Requirement	Bluephase® Style
Does the LED unit produce light in a broadband blue-violet emission spectrum?	Yes, due to the specially developed Polywave® LED (385–515 nm).
Is a comprehensive list of all incompatible materials supplied?	The Polywave® LED can be used universally for all dental materials.
Is the light intensity (at least) 1,000 mW/cm²?	Yes, guaranteed by the manufacturer.
Does the unit include a radiometer to check the light intensity?	Yes, Bluephase® Meter II.
Is the minimum light intensity clearly defined, for instance in a statement regarding tolerance values in the operating instructions?	Yes, 1,100 mW/cm² ± 10%.
Are data regarding the heat development during polymerization available?	Yes, in the Scientific Documentation, which is available separately.
Is the curing light designed with a parallel-walled light probe which consists of many single glass fibres?	Yes, a 10-mm light probe with a shortened tip.
Is the curing light equipped with a lithium battery?	Yes, it contains a lithium polymer battery.
Is the capacity of the battery used – i.e. the operation time – sufficient for an entire work day at the practice when the battery is charged?	Yes, the full battery capacity is 20 minutes.
Can the battery and charging base be easily cleaned so that no debris remains?	Yes, due to induction charging technology.
Is it possible to operate the light without battery in case it has run out (corded operation)?	Yes, due to Click & Cure.
Is the curing light fast and easy to operate?	Yes, the light is immediately ready for operation when touched and is intuitively operated via a two-button panel.
Is noiseless continuous operation possible?	Yes, due to continuous cooling without fan.
Have aspects of ergonomics and hygiene been considered in the design?	Yes, the design has already received several awards.
Can I borrow the light for a day to test its ergonomic properties?	Yes.
Is the curing light classified as a medical device and has it been checked for safety by an independent body?	Yes.
Does the manufacturer offer a warranty?	Yes, a 3-year warranty on the curing light and a 1-year warranty on the battery.

Bluephase® Style

The curing light

The smallest LED for every use

True innovation proves itself in use. A perfect example of this is the Bluephase Style curing light with the specially developed Polywave® LED, which is suited for all photoinitiators currently being used in dental materials.

Small and ergonomic in shape, Bluephase Style ideally fits the hand of every woman or man. Given the light's low weight and balanced weight distribution, the strain exerted on the hand and arm is reduced, regardless of the size of the hand. Every tooth surface can be accessed without extreme opening of the mouth as the light probe features a shortened tip and can be rotated by 360 degrees.

Every material due to Polywave® LED

The ability to cure all dental materials depends on the light emitted. In contrast to the LED lights of the second generation, the Polywave LED covers the optimal broadband spectrum between 385 to 515 nanometres shown by halogen lamps that served as its model. Therefore, Bluephase Style is suitable for polymerizing all current photoinitiators and dental materials without any restrictions.

Polywave®

Every indication due to continuous cooling

Due to an energy-efficient LED technology, Bluephase Style produces less heat while providing the same light output. As a result, the need for a fan is eliminated. That means you can just get on with your work – even when using the light in continuous operation to place extensive indirect restorations.

Every time due to Click & Cure

The proven Click & Cure function enables you to avoid irritating waiting times in case the battery has run out. With just one click you can connect the handpiece to the power cord of the charging base.

A quick guide

to achieving optimum light-curing results

Consensus statement on light-curing in dentistry, issued in 2014 (Dalhousie University, Halifax, Canada)

Before you light-cure, remember to:

- ➡ Regularly monitor and record the light output of the curing light over time, using the same measurement device and light guide. Repair or replace the curing light if it no longer meets the manufacturer's specifications.
- ➡ Inspect and clean the curing light to ensure that it is on the correct setting, in good working order, and free of defects and debris.
- ➡ Consider that every resin-based material has a specified amount of energy that must be provided at the correct wavelength (minimum) to achieve satisfactory results. Minimum irradiation times are also required.
- ➡ Follow the light exposure times and increment thickness recommended by the resin manufacturer, making allowances if you use another manufacturer's light. Increase your curing times for increased distances (> 5 mm) and darker or opaque shades.
- ➡ Select a curing light 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 the light tip as close as possible (without touching) and perpendicular to the volume of the resin composite to be cured.
- ➡ Stabilize and maintain the tip of the curing device over the resin composite throughout the exposure. Always use appropriate protective goggles and shields to protect your eyes as you watch and control the position of the curing light.

Precautions:

- ➡ Avoid conditions that will reduce light delivery to the resin composite, e.g.
  - – Holding the light tip several millimetres away,
  - – Holding the light tip at an angle to the resin surface,
  - – Dirty or damaged light-guide optics.
- ➡ Supplementary light exposures should be considered under circumstances that may limit ideal light access, such as shadows from matrix bands, intervening tooth structure, or from restorative material.
- ➡ Beware of thermal damage potential to the pulp and soft tissues when delivering high energy exposures or long exposure times.
- ➡ Air-cool the tooth when exposing for longer times, or when using high output curing lights.
- ➡ Never shine the curing light into the eyes, and avoid looking at the reflected light, except through appropriate (orange) eye protection.
- ➡ Testing surface hardness of the resin composite in the tooth using a dental explorer provides no information about adequacy of curing depth.

Short glossary
of terms for light-curing

Absorption Process by which (light) waves or photons are taken up by an absorbing substance, e.g. a photoinitiator.

Battery Rechargeable battery, also known as accumulator.

Capacity A battery's capacity is the amount of charge stored by the battery and is an indicator of how long the curing light can be used before the battery needs to be charged again.

Curing See light-curing.

Curing light generation The first dental LED curing lights (1st generation) showed a comparatively low spectral output of approx. 400 mW/cm². They were followed by lights capable of attaining light intensities of up to 1,000 mW/cm² and more if operated at higher currents (2nd generation). However, the wavelength range of these LED lights was restricted to 430 - 490 nm. In a subsequent development step, the 3rd and latest generation of LED curing lights were released. These curing lights differ from their predecessors by featuring a broad emission spectrum ranging from 385 to 515 nm. As a result, they can be used like halogen lights to cure all known dental composite materials.

Curing time Period of time required to attain a complete cure of the dental material when exposed to the light of a curing device.

Emission Discharge of electromagnetic waves from a light source.

Energy dose Describes the amount of energy absorbed during the entire curing time related to the surface exposed to the light of the curing device. The energy dose is expressed in milliwatt second [mWs] per square centimetre [cm²].

Exothermic reaction A chemical reaction that releases energy, e.g. heat, into the environment. The reaction is started off by a short exposure to a suitable activation energy (e.g. curing light) and, once started, the process sustains itself without the need for additional energy.

Irradiance Radiant power or flux, colloquially also referred to as "light intensity", describes the total amount of electromagnetic energy incident on a surface in relation to the size of the surface area. Irradiance is expressed in milliwatts [mW] per square centimetres [cm²].

LED Light emitting diode, abbreviated LED, is a semiconductor component that radiates light in a predefined wavelength range when a voltage is applied.

Light-curing Light-curing composite materials set via radical polymerization. Incoming photons are absorbed by certain molecules (photoinitiators). The energy absorbed excites the molecules. In their active state, these molecules enable the formation of radicals if one or several activators are present. The free radicals then trigger the polymerization reaction. Initiator molecules, e.g. camphorquinone, are able to absorb only the photons of a specific spectral range.

Light emission window Describes the exit portal at the end of a glass fibre rod or the optical lens mounted directly at the front of an LED.

Light intensity Everyday language for irradiance.

Light transmission Ability of a material to permit the transmission of light.

Optics Everyday language for the sum of all optical parts of a curing light.

Photoinitiator Photoinitiators are light-sensitive substances that decompose into radicals when exposed to the light of a specified spectral range. The radicals then trigger a polymerization reaction.

Radiometer Light checker to measure the light intensity of curing lights.

Scattering losses Scattering, in physics, is a change in the direction of motion of a particle because of an interaction with another local particle, i.e. the scattering of photons when colliding with atoms.

Spatial radiation characteristics Angle-dependent light intensity of a light source to evaluate the spatial distribution of radiation.

Ulbricht sphere The Ulbricht sphere, also known as integrating sphere, is named after the engineer Richard Ulbricht. It is an optical component in technical optics and is utilized to collect light from divergent radiation sources, such as curing lights. The integrating sphere provides the most accurate method for measuring the light intensity of curing lights.

Wavelength The wavelength of light is expressed in nanometres (= 10^{-9} metres). The human eye can see colours in the wavelength range between 380 nm (violet) and 780 nm (red). Only the violet-blue spectral range from 385 to 515 nm is used in light-curing.

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