Scientific Documentation

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Bluephase Style is a small, compact, high intensity (1,100 mW/cm^2) LED light belonging to the Bluephase family. Its ergonomic design fits the hands of both men and women even better than its predecessors. With the light's single operation mode, both composites and adhesives (applied near to the pulp) can be cured reliably and safely. Like the other tried-and-tested members of the Bluephase family, Bluephase Style is equipped with the proprietary Polywave LED.

What does Polywave mean?

To date, only composite materials which contained camphorquinone as the photoinitiator could be cured with conventional LED curing lights (LED devices of the 1st and 2nd generation). All other initiator systems, such as Lucirin TPO, were contraindicated. Compared to halogen lights, this was a drawback. Given the success of LED lights, many manufacturers of dental products had to take this fact into account and modify the composition of their composites, which resulted in compromises in terms of esthetics and the shelf life of certain products.

With Polywave technology (3rd generation of curing lights), users can now cure without restrictions in the wavelength range 380 to 515 nm. The emission spectrum of the Bluephase Style light is therefore similar to the effective range of halogen lights. The Bluephase family featuring Polywave can thus be used to cure composites with all current dental photoinitiator systems without restrictions.

LED lights of the 2nd generation

1. Introduction

1.1 Light-curing of dental materials

Photopolymerization, i.e. light-initiated polymerization, has become an integral part of modern dentistry. Composites, composite-based luting materials and adhesives are all cured with the help of light. The following properties in particular have to be considered in the development of light-curing materials:

- Shade and translucency of the composite
- Shrinkage properties
- Initiator system

These properties in turn set certain standards for light-curing lights or polymerization lamps.

1.2 Optical transparency and a brief historical overview of LED technology

Ideally, a light-curing composite should be optically transparent and consequently feature a high curing depth. The depth of cure is measured according to the ISO 4049 international standard. For this purpose, a 6-mm thick composite specimen is illuminated with light for 40 seconds under defined conditions. Subsequently, the soft uncured portion of the composite sample is scraped off and the remaining sample thickness is measured with a sliding caliper. In addition to the degree of translucency, the depth of cure depends on the exposure time, the shade (i.e. the amount of pigments contained in the composite) and the light intensity of the curing light. The first UV curing lights achieved a limited depth of cure due to poor UV transparency. In addition, they were harmful to the eyes and soft tissues. The power of halogen lights, which emit light almost entirely in the visual spectral range, steadily increased as they were further developed:

Astralis 5	approx. 500 mW/cm^2
Astralis 7	approx. 750 mW/cm^2
Astralis 10	approx. 1,200 mW/cm^2

As the curing depth increased, the exposure times were significantly shortened.

Plasma-arc and laser curing lights, which achieve a high light intensity, have failed to capture the market because they build up too much heat and are very expensive.

Light-emitting diodes (LEDs) represent the most recent light source in dental polymerization. This light source offers a number of advantages:

- Light output at room temperature and therefore higher efficiency
- High mechanical stability
- Long service life
- Narrow emission spectrum

While the irradiation dose of early dental LED curing lights (**1st generation**) tended to be fairly low (approx. 400 mW/cm^2), current lights may attain light intensities of up to 1,000 mW/cm^2 and more if they are operated at higher electrical currents (**2nd generation**).

The first product family of Bluephase curing lights from Ivoclar Vivadent AG was able to meet the exacting demands of LED curing light technology. Launched in 2004, tBluephase (1,100 mW/cm^2) laid the foundation for the Bluephase brand. The high and reliable light intensity by far exceeded that of the 1st generation of LED units (Mainz study 2006, ADA 2006).

In a subsequent development step, **3rd generation** LED curing lights were developed. These lights differ from their predecessors by featuring a broad emission spectrum from 380 to 515 nm, which allows this light to be used like halogen lights to cure all known dental composite materials. Bluephase (G2), Bluephase 20i, Bluephase C8 and Bluephase Style all belong to this generation of products.

1.3 The effect of the initiator system on the light-curing results

Light-curing composite materials set via radical polymerization. Incoming photons are absorbed by certain molecules (photoinitiator). 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. The initiator molecules are able to absorb only the photons of a specific spectral range.

Champhorquinone is typically used as an initiator molecule.

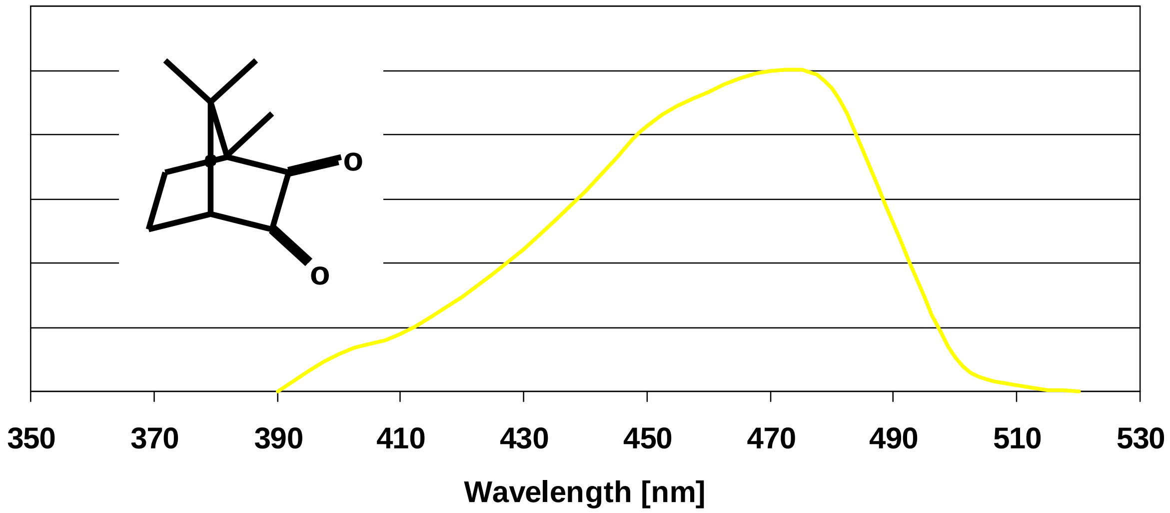


Fig. 1: Absorption spectrum of camphorquinone

The peak sensitivity of camphorquinone is near 470 nm in the blue wavelength range. As camphorquinone has an intense yellow colour due to its absorption properties, other initiators were and are used in dentistry. Alternative initiators are for instance employed in the formulations of composites in bleach shades and colourless protective varnishes.

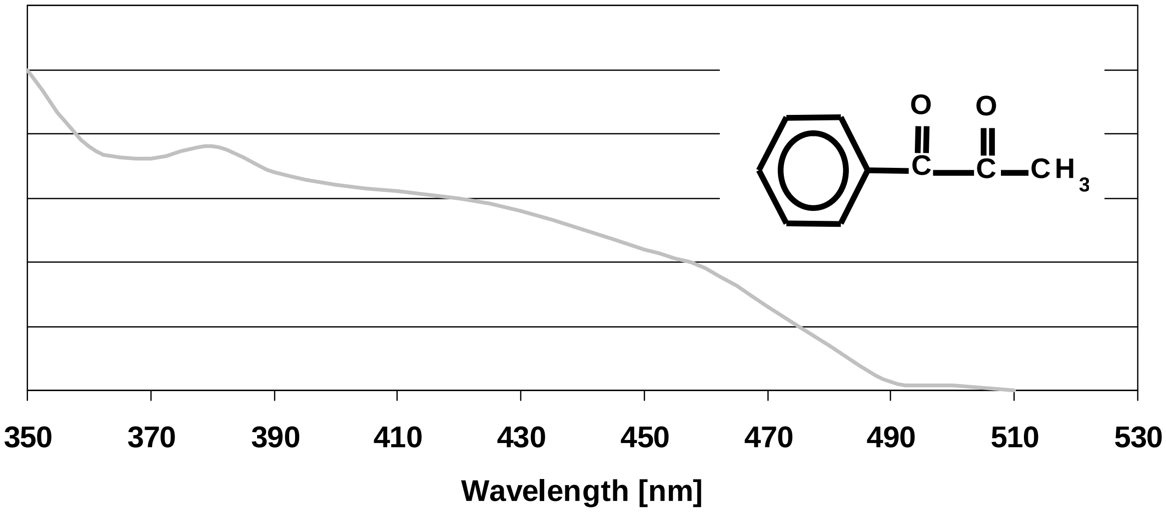


Fig. 2: Absorption spectrum of phenylpropanedione (PPD)

PPD (phenylpropanedione): The absorption spectrum of PPD extends from the UV wavelength range to approx. 490 nm.

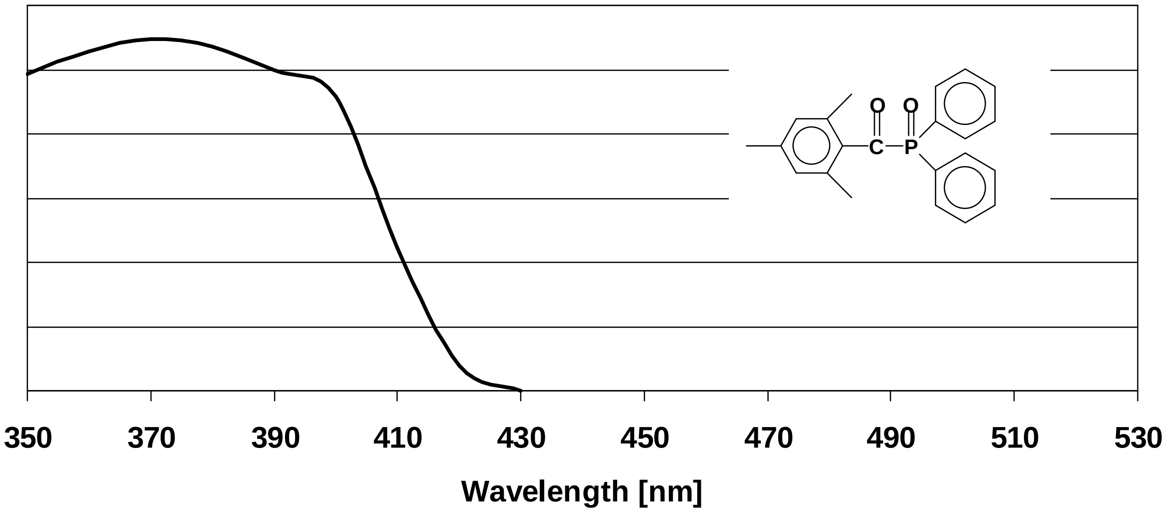
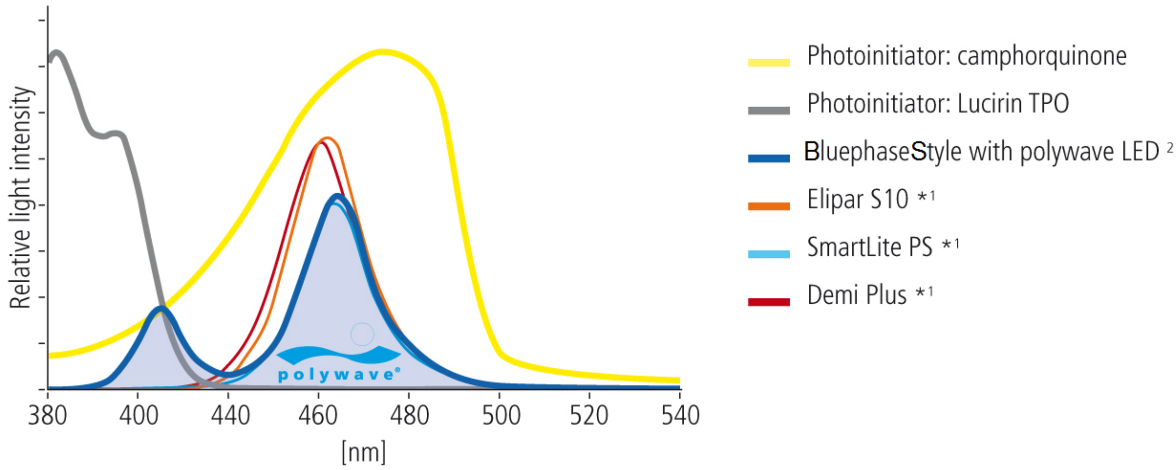


Fig. 3: Absorption spectrum of Lucirin TPO

Lucirin TPO is an acyl phosphine oxide. This photoinitiator has gained in popularity because it completely bleaches out after the light reaction has finished. Its sensitivity peak has been shifted to a considerably lower wavelength range.

Lucirin TPO and PPD can be cured with conventional LED lights of the 1st and 2nd generation only to a limited extent, since their narrow spectral output hardly covers the absorption spectra of these initiators. The objective in the development of the 3rd generation of LED lights was therefore to lower the wavelength ranges of the emitted light in order to excite Lucirin TPO and PPD, similarly to halogen lights. Bluephase Style has a second spectral peak at approx. 410 nm (see Fig. 4), which allows materials with all photoinitiator systems to be cured. An LED developed by Ivoclar Vivadent AG achieves a spectral peak at approx. 410 nm and 470 nm.



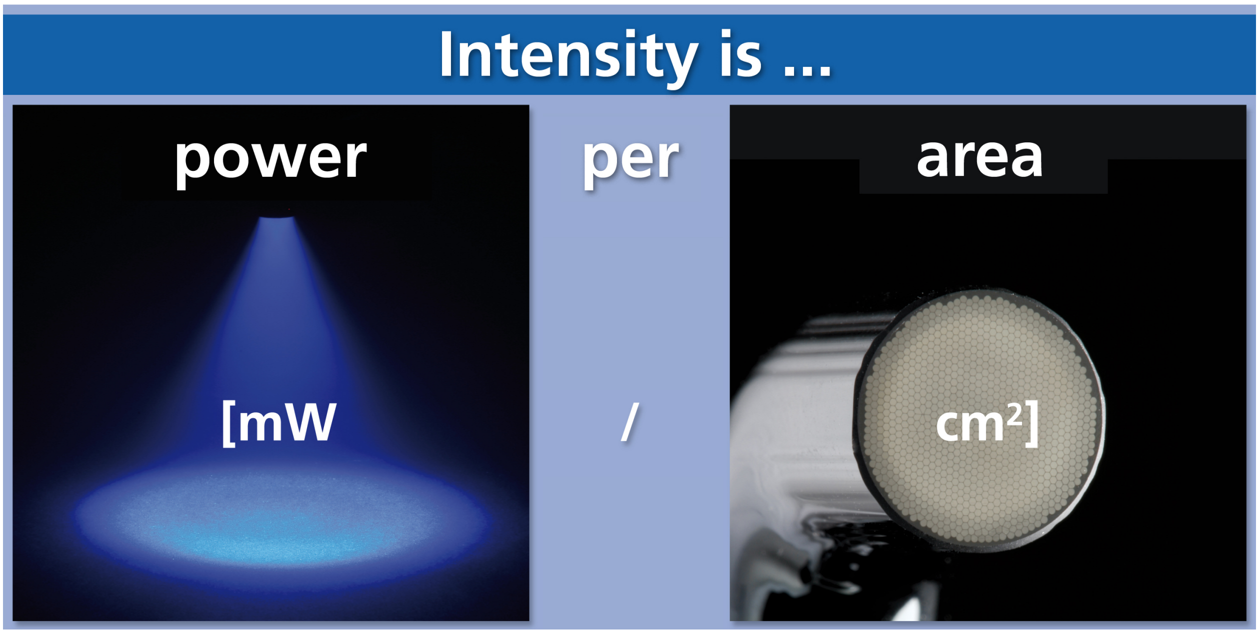
Source: R. Price, Dalhouse University Halifax, 2011

Fig. 4: Wavelength range and light output of Bluephase Style compared with three other LED lights, measured with an integrating sphere (Price, Halifax, 2011)

Due to the halogen-like light spectrum, limitations in the range of 380 to 515 nm are a thing of the past, and it is possible to excite all photoinitiators used in dentistry. This means that in addition to composite filling materials, light-curing adhesives, bonding agents, luting composites and fissure sealants etc. can also be polymerized.

1.4 The Total Energy concept

The light emitted from the light guide is measured by means of an Ulbricht-sphere/integrating sphere which determines the exact emissive power in mW. Appropriate filters ensure that only light in the effective wavelength range is measured. The light intensity in mW/cm^2 is calculated on the basis of the cross-section of the light guide.



The Total Energy concept states that the process of light-induced polymerization is energy-dependent and basically a product of light intensity and time. Therefore, an irradiation interval of 20 seconds with a light intensity of 800 mW/cm^2 results in a dose of 16,000 mWs/cm^2.

As a rule of thumb, a dose of 4,000 to 16,000 mWs/cm^2 is recommended to sufficiently cure a composite increment of 2 mm (depending on the shade and translucency). Higher doses are typically required for darker and less translucent composites. Depending on the intensity of the curing light used, the specific maximum curing times required for curing more "problematic" shades can be calculated e.g. for curing an increment of 2 mm. This is how the various curing recommendations for curing lights with various intensities are indicated. Strong powerful lights enable the curing time to be reduced whilst achieving the same degree of cure – which of course saves time during dental treatment.

Required dose (mWs/cm^2)	16,000	16,000	16,000
Intensity of the light (mW/cm^2)	400	800	1,600
Recommended curing time (s)	40	20	10

Table 1: Maximum curing time recommendations according to the Total Energy concept

According to studies and measurements, LED lights and halogen lights with identical intensities and curing times achieve comparable depths of cure or hardness profiles (see Table 2).

Intensity (mW/cm^2)	Depth of cure (LED) (mm)	Depth of cure (halogen) (mm)
400	2.40	2.43
600	2.54	2.55
700	2.65	2.67
800	2.73	2.69

Table 2: Depth of cure of Tetric Ceram (according to P. Burtscher, V. Rheinberger; R&D, Ivoclar Vivadent AG)

An energy dose of 10,000 mWs/cm^2 is sufficient to cure Tetric, Tetric EvoCeram and IPS Empress Direct. Heliomolar requires a dose of 15,000 mWs/cm^2.

A special, highly optimized system containing the initiator Ivocerin enables an increment of 4 mm of **Tetric EvoCeram Bulk Fill** to be entirely cured with a dose of 10,000 mWs/cm^2 (see Section 3.4).

1.5 Light guides

The light guide also has an influence on the effectiveness of polymerization lights. In order to achieve a high power density, i.e. high light intensity per surface area, many curing lights are equipped with a light guide that features an emission window of small diameter. For example, the diameter of the "Turbo" light guide of the Bluephase 16i decreases from 13 mm to 8 mm. This feature, however, has an adverse effect on the light scattering characteristics. The scattering angle becomes wider and the light intensity decreases more rapidly the larger the distance from the material to be cured. In the dental practice however, curing from a distance is sometimes unavoidable e.g. when curing in deep cavities or difficult-to-reach proximal surfaces.

According to the literature (Price, 2000), light intensity is reduced to 50% at a distance of 6 mm for a parallel light guide and to just 23% for a Turbo light guide.

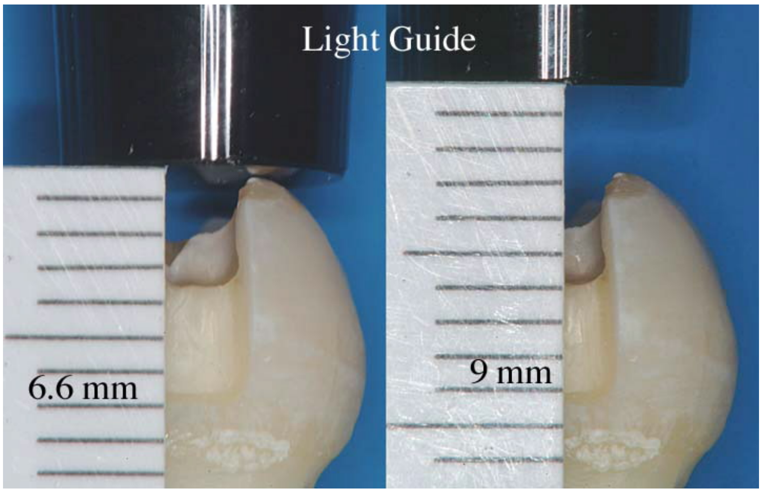


Fig. 5: Distance between the light guide and the composite material in reality

Like the commercially available Bluephase (G2), Bluephase Style is equipped with a parallel light guide, which helps reduce light-intensity-loss when the light guide needs to be held at larger distances from the material to be irradiated. The light guide of Bluephase Style has been slightly shortened, which in combination with the ergonomic pen design ensures that every area in the mouth is easily accessible.

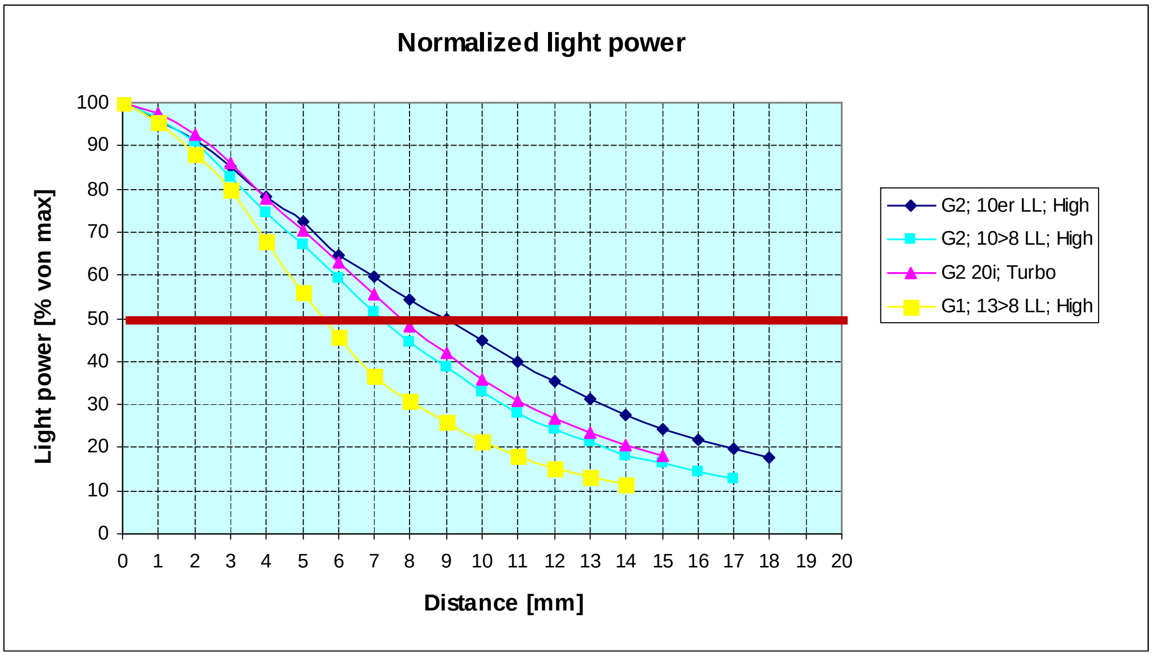


Fig. 6: Decreasing light intensity in per cent with increasing distance from the material to be cured -with different light guides

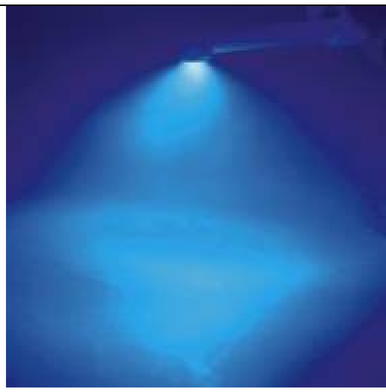
		
Homogeneous light scattering from parallel light guide of Bluephase Style	Light scattering from Turbo light guide (13>8 mm)	Diffuse light scattering if LED is mounted at front

Fig. 7: Light scattering characteristics of different light guides

2. Technical data



Technical data

	Bluephase® C8	Bluephase® Style	Bluephase® 20i	Bluephase® Meter
	800 mW/cm² ±10 %	1.100 mW/cm² ±10 %	2.000 mW/cm² – 2.200 mW/cm² LED-Klasse 2	300 mW/cm² – 2.500 mW/cm² ±20 %
Every hand (ergonomic design)	–	✓	–	✓
Every material (wavelength range)	✓ 385 – 515 nm	✓ 385 – 515 nm	✓ 385 – 515 nm	✓ 385 – 515 nm
Every indication (continuous operation for at least 10 min)	✓	✓	✓	
Every time Click & Cure (optional mains operation)	✓ (mains operation)	✓	✓	
Curing time for selected composite materials 2 mm Tetric EvoCeram/IPS Empress Direct 4 mm Tetric EvoCeram Bulk Fill	15 sec	10 sec	5 sec	
Curing programs				Measuring the light intensity of LED curing lights
TURBO	–	–	2.000 mW/cm²	
HIGH Power	800 mW/cm²	1.100 mW/cm²	1.200 mW/cm²	
LOW Power	650 mW/cm²	–	650 mW/cm²	
SOFT Start	650/800 mW/cm²	–	650/1.200 mW/cm²	
Light probe	10 mm, black	shortened, 10 mm, black	10 > 8 mm, black	
Stromversorgung	Mains operation (upgrade to battery operation possible)	Lithium-polymer battery, capacity: approx. 20 min / charging time: approx. 2 h	Lithium-polymer battery, capacity: approx. 45 min / charging time: approx. 2 h	3 x LR6 AA 1.5 VDC
Garantie	3 years	3 years (battery 1 year)	3 years (battery 1 year)	3 years

3. Results from external and internal studies

3.1 Curing of composites

Composite curing is the main indication of curing lights, and the intensity of the light is a very important parameter (see Section 1.4).

The cure of composites can be measured e.g. by determining their hardness. For this measurement, 2-mm thick test specimens are irradiated according to the manufacturer's operating instructions. After 24 hours, the surface hardness is determined at the bottom of the test specimen. In the process, it is of critical importance that the light guide is not placed directly on the composite specimen. In practical use, the distance between the light guide and the composite may be larger than 5 mm. Depending on the scattering behaviour of the curing light and the light guide, the light intensity may decrease dramatically.

For this reason, a distance of 8 mm was specified for the test set-up at Halifax University. The composites Tetric EvoCeram A3 and Tetric EvoCeram Bleach M were tested. While A3 is a composite with a normal shade, Bleach contains an additional opaquing agent.

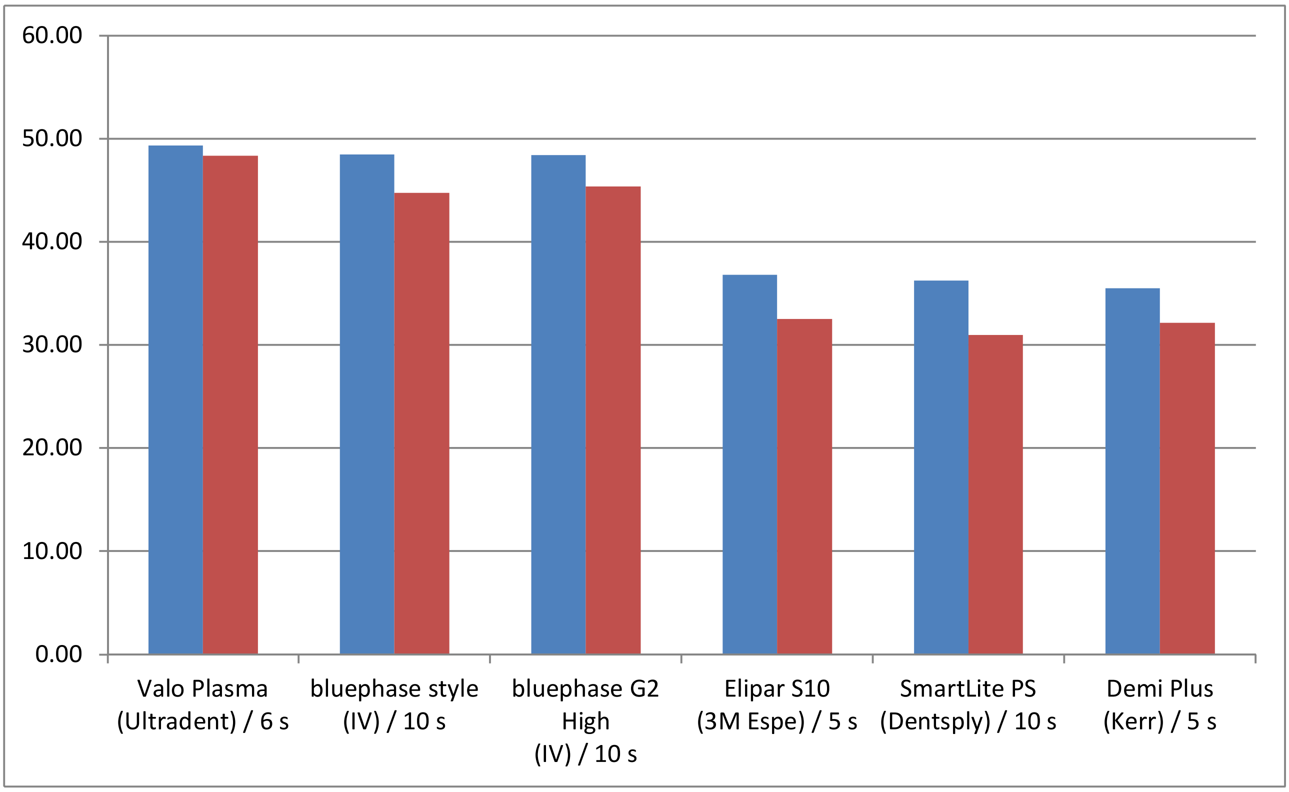


Fig. 8: Knoop hardness after curing of composite test specimens from a distance of 4 mm with different commercially available LED lights. Blue: A3, red: Bleach (Price, Dalhousie University Halifax, 2011)

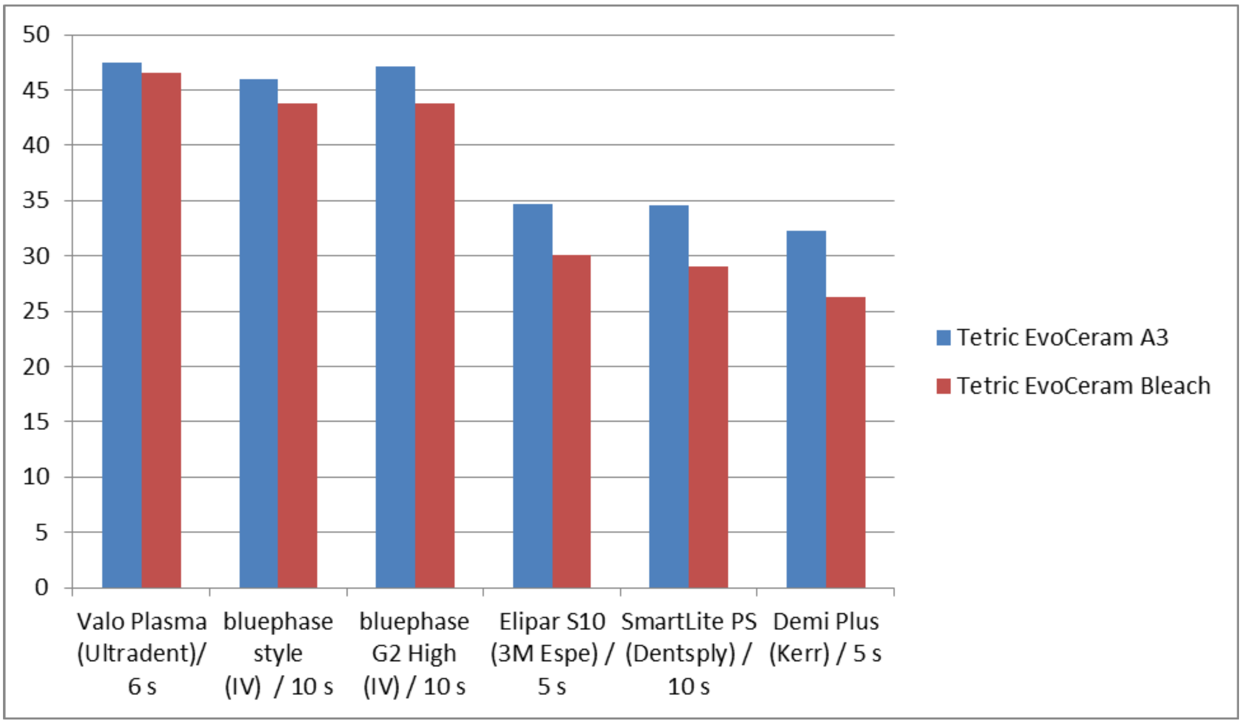


Fig. 9: Knoop hardness after curing of composite test specimens from a distance of 8 mm with different commercially available LED lights. Blue: A3, red: Bleach (Price, Dalhousie University Halifax, 2011)

The curing times indicated by the manufacturers were used. It was shown that under these circumstances Bluephase Style achieved an equivalent or even better degree of cure as compared with commercially available lights. Thus, it is possible to draw the conclusion that Bluephase Style is able to cure composite materials effectively. It is also important that the light intensity and the curing time are selected so as to prevent any temperature-related risk to the pulp and soft tissue (see Section 3.6).

Valo Plasma (Ultradent)	Bluephase Style (Ivoclar Vivadent)	Bluephase G2 High	Elipar S10 (3M ESPE)	SmartLite PS (Dentsply)	Demi Plus (Kerr)
3,200 mW/cm^2	1,100 mW/cm^2	1,200 mW/cm^2	1,200 mW/cm^2	950 mW/cm^2	1,100 – 1,300 mW/cm^2
corded	cordless	cordless	cordless	cordless	cordless

Table 3: Light intensities of the curing lights used in the test; Valo Plasma is the only corded device.

At the University of Jena the Vickers hardness (VH_{5-20}) of Tetric Evo Ceram Bulk Fill was measured after polymerization with a Bluephase and a Bluephase Style curing light. The composite was packed into Teflon moulds that measured 4 mm in height and 8 mm in diameter. The top and bottom sides were covered with foil. The light guide was placed directly onto the foil. The measurements were performed immediately after polymerization, after 24 hours and after 7 days of storage at 23 °C (73 °F). To determine the Vickers hardness VH_{5-20}, the samples were loaded with 5 kg over 20 seconds.

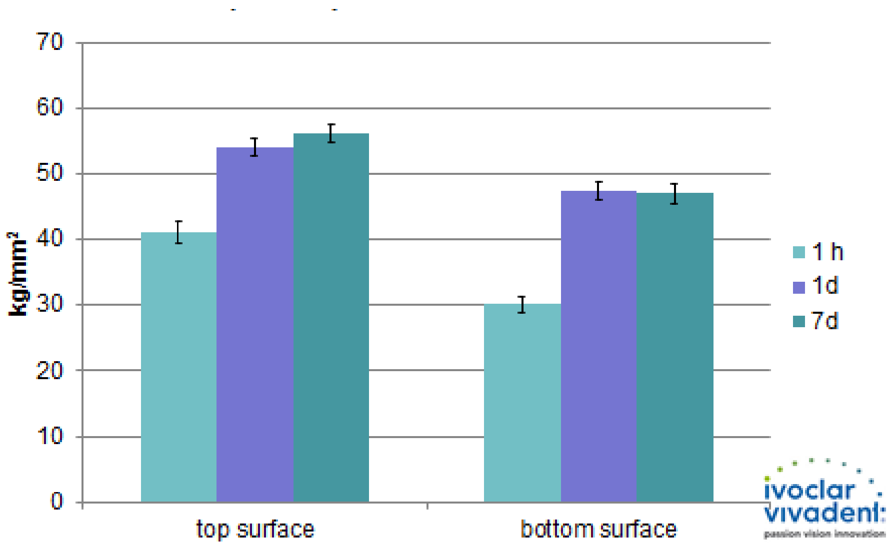


Fig. 10: Vickers hardness values obtained for Tetric EvoCeram Bulk Fill after polymerization with Bluephase Style at the top surface and at a depth of 4 mm (Rzanny, University of Jena 2012)

Even at a depth of 4 mm, Bluephase Style resulted in an effective cure of the bulk fill composite. Post-curing also takes place and at room temperature, this is completed after 24 hours at the latest.

The depth of cure was measured for dental composites according to the international standard ISO 4049, using Tetric EvoCeram A3 as the sample material. Cylindrical test specimens with a length of 6 mm were irradiated with different curing lights according to the manufacturer's instructions. Any non-cured material was scraped away. The values indicated in the graph represent the remaining length of the composite cylinder.

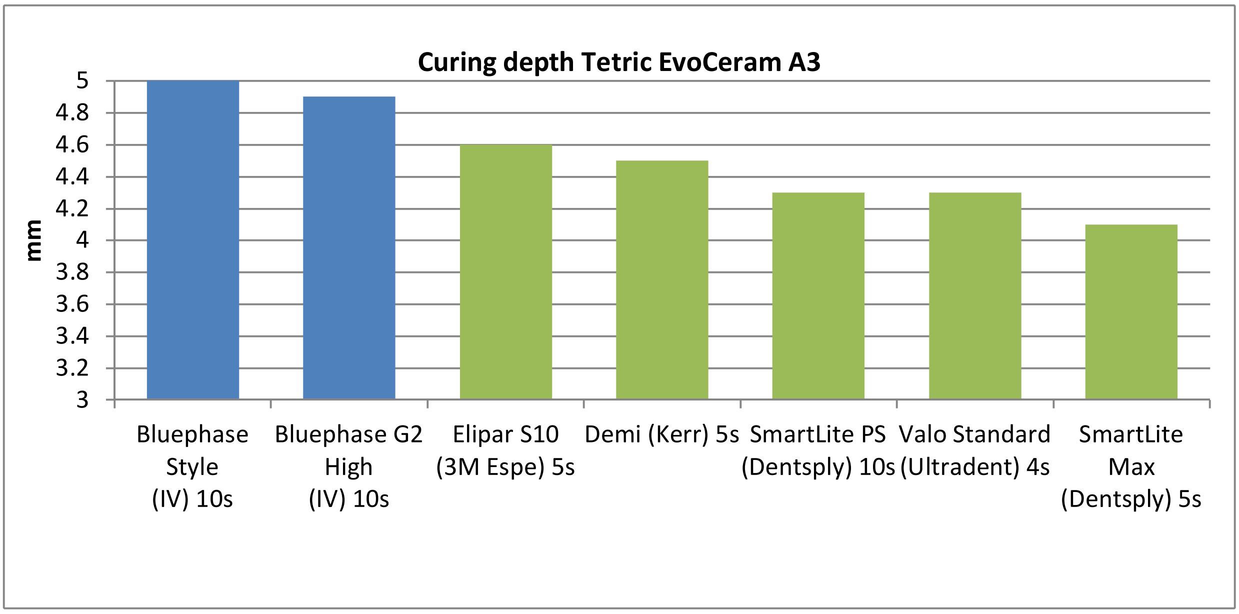


Fig. 11: Curing depths of Tetric EvoCeram after curing with different curing lights

Bluephase Style and Bluephase G2 clearly showed the highest curing depths after the recommended curing time.

The University of Jena also used the Bluephase G2 and Bluephase Style curing devices to measure the curing depth of Tetric EvoCeram, Tetric EvoCeram Bulk Fill and Venus Bulk Fill (Heraeus) with a penetrometer. The measurements were performed immediately after polymerization (curing time: 10 s). In line with the procedure described in ISO 4049, the values were divided by two.

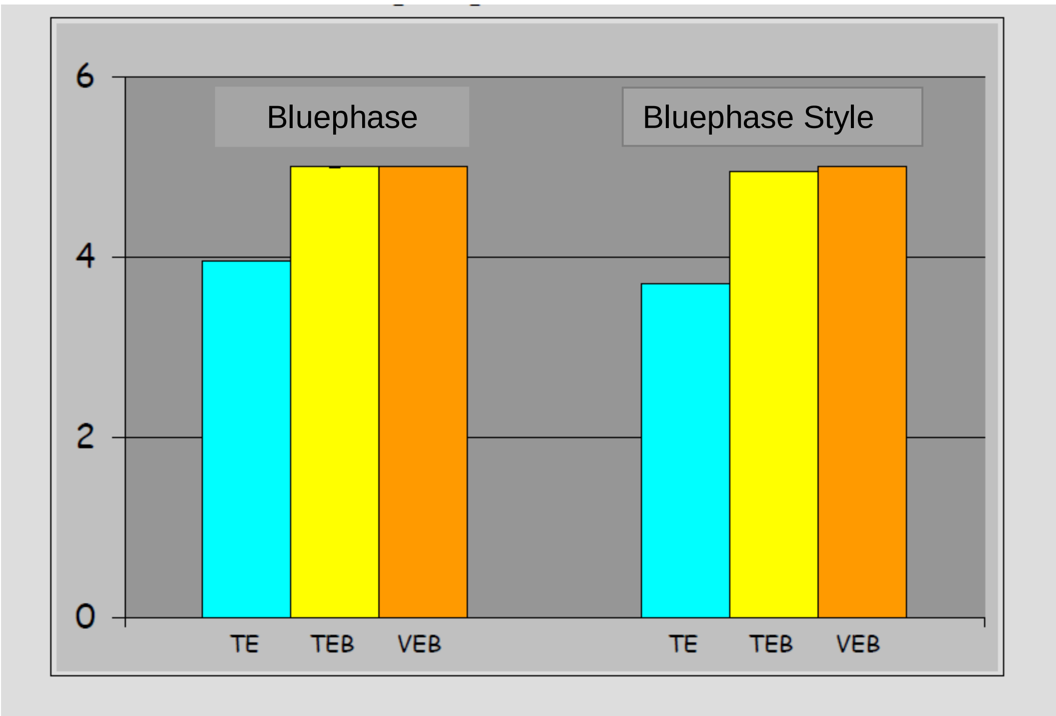


Fig. 12: Curing depths of Tetric EvoCeram (TE), Tetric EvoCeram Bulk Fill (TEB) and Venus Bulk Fill (Heraeus) VEB) after polymerization with Bluephase G2 and Bluephase Style (Rzanny, University of Jena 2012)

Similar to the tried-and-tested Bluephase G2 curing light, Bluephase Style is able to effectively cure bulk fill composites as well as the proven Tetric EvoCeram.

3.2 Curing of adhesives

Inappropriate curing of adhesive cements results in a weakened shear bond strength on enamel and dentin. To investigate this issue, the bonding values of ExciTE F, Syntac and AdheSE One F after curing with Bluephase Style were compared with the values found for Bluephase (G2).

ExciTE F and Syntac are conventional etch-and-rinse adhesives. AdheSE One F is what is known as a self-etch adhesive. Tetric EvoCeram was applied in two increments, and each increment was light-cured for 40 seconds.

In the case of the Bluephase (G2) light, the Low Power mode was used to cure the adhesive. The test samples were stored in water at 37 °C (98.6 °F) for 24 h prior to measuring the bond strengths.

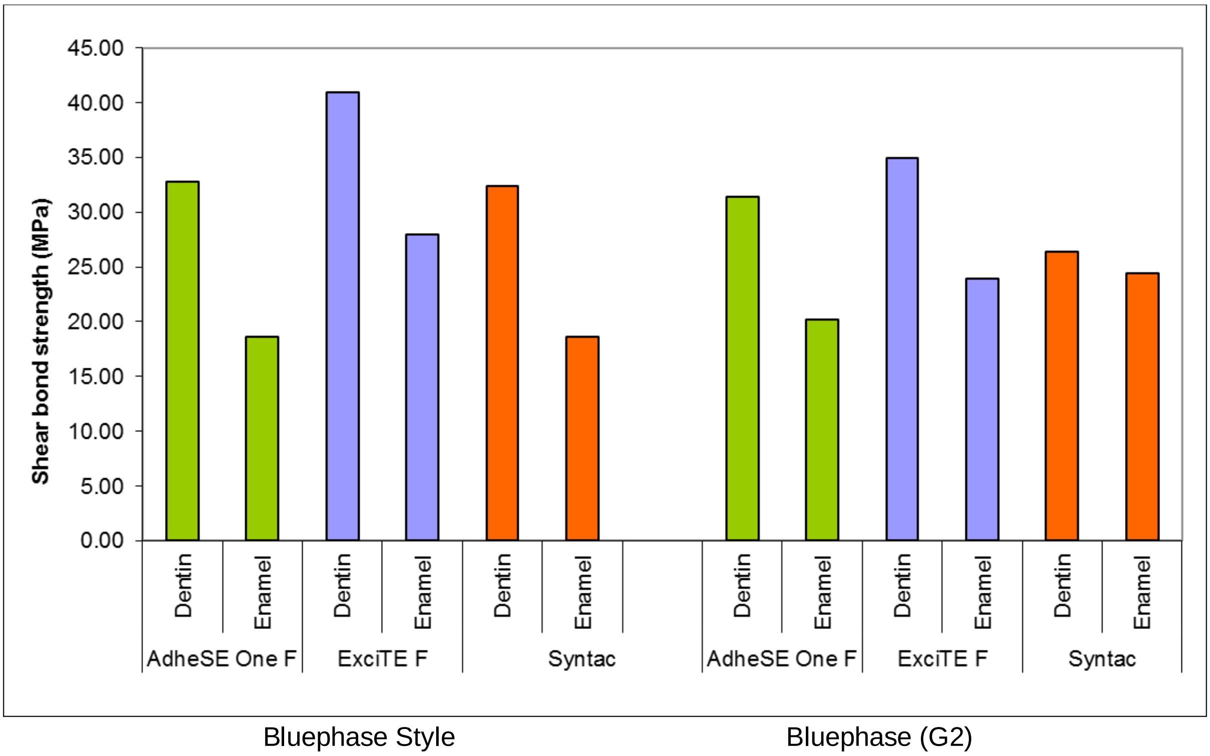


Fig. 13: Comparison of shear bond strength values of AdheSE One F, ExciTE F and Syntac on dentin and enamel after curing with Bluephase Style and Bluephase (G2) (Ivoclar Vivadent AG, R&D, Schaan, 2010)

Result: The bond strength values of adhesives on dentin and enamel achieved with Bluephase Style were all comparable to those achieved with Bluephase (G2) (adhesive mode) after the same curing time (10 seconds). Thus, it can be assumed that Bluephase Style is capable of effectively curing adhesives.

3.3 Homogeneous curing over the entire surface of the light guide

Bluephase Style is equipped with three light-emitting diodes (see Fig. 14). Two generate light with a wavelength of 470 nm, the other generates light at 410 nm. The light intensity of the long-wave LEDs is significantly higher. With this diode configuration, the light intensity at the emission window appears to be inhomogeneous (see Fig. 14).

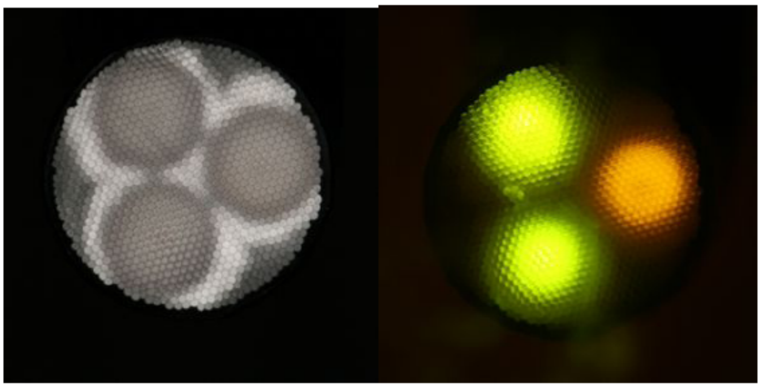


Fig. 14: Diode configuration of Bluephase Style. a) frontal view b) frontal view through yellow filter

3.3.1 Measurements from R&D at Ivoclar Vivadent AG

In order to make sure that the composite material irradiated with this light beam is cured homogeneously, the microhardness was measured along previously determined diagonal lines on the bottom side of a test sample (see Table 4).

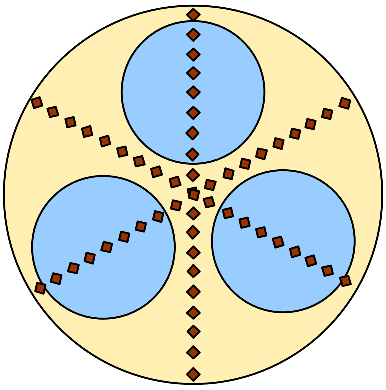


Fig. 15: Arrangement of measuring points to determine the microhardness on the bottom side of a composite test specimen (blue: position of the LEDs)

Tetric EvoCeram A3 b. N07412			
Measuring point	Bluephase Style		
	Measurement series A	Measurement series B	Measurement series C
1	476	463	413
2	521	511	523
3	526	516	518
4	538	519	527
5	536	530	520
6	541	528	523
7	558	548	544
8	561	549	576
9	560	546	576
10	578	565	562
11	564	569	576
12	544	559	558
13	533	544	544
14	531	546	549
15	531	543	553
16	539	530	538
17	536	506	524
18	514	468	491
19	462	405	448

All values are indicated in MPa

Table 4: Microhardness values determined at measurement points according to Fig. 15 (Ivoclar Vivadent AG, R&D, Schaan, 2010)

The values measured confirm that the level of curing is optimal and homogeneous over the entire test specimen surface. A difference between the LEDs with different wavelengths could not be determined. The potential irradiation inhomogeneity does not influence the curing results of composites.

3.3.2 Investigation and corroboration by Prof. Watts (Manchester)

Professor Watts (University of Manchester) carried out an investigation to examine the same issue. He measured the microhardness at predetermined measuring points (see Fig. 15) on the surface of composite test specimens (Tetric EvoCeram). He varied both the distance between the light guide and composite surface and the time span between irradiation and hardness measurement. The samples were irradiated for 20 seconds using Bluephase Style.

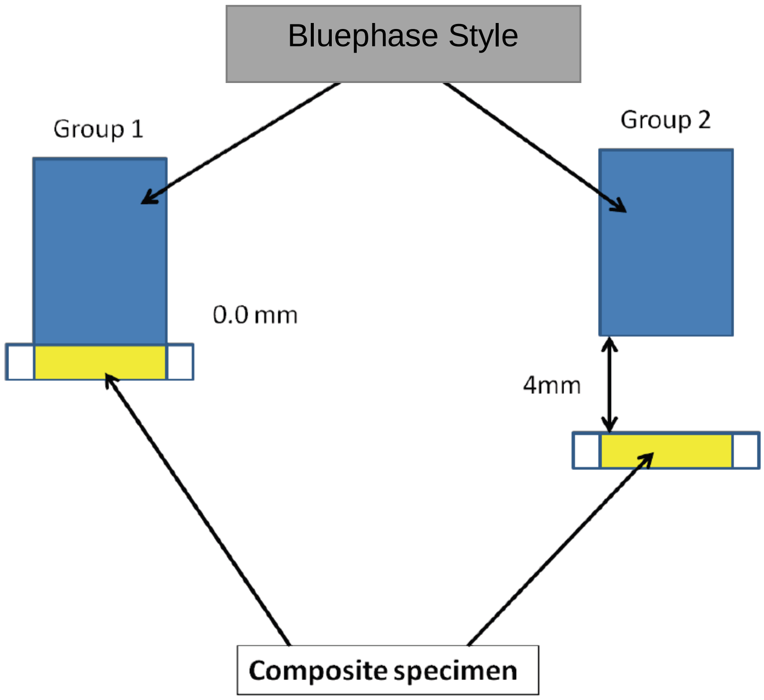


Fig. 16: Schematic representation of the light-curing settings of the composite specimens (Watts, University of Manchester, 2012)

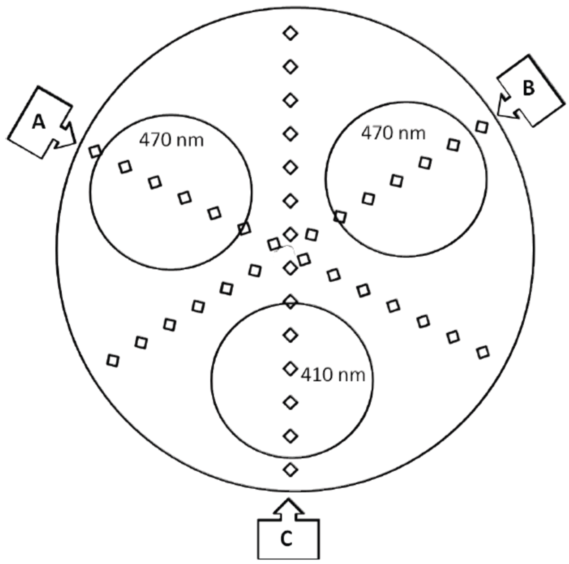


Fig. 17: Arrangement of the measuring points to determine the microhardness at the top surface of the composite specimen. The position of the LEDs is shown. (Watts, University of Manchester, 2012)

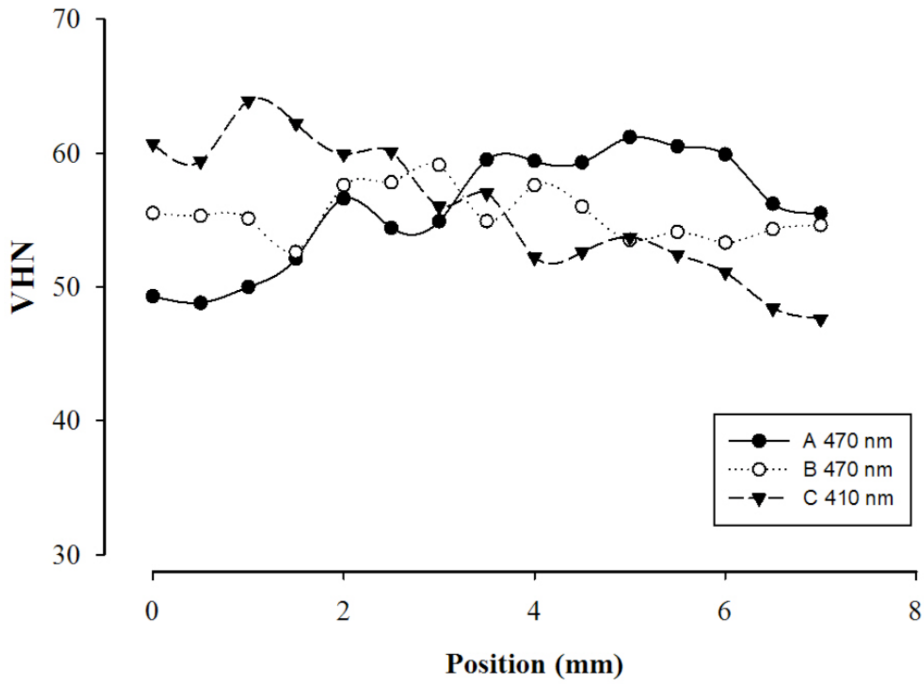


Fig. 18: Microhardness on the surface of the test specimen with direct positioning of the light guide on the material
(d = 0 mm) (24 h storage in water at 37 °C / 98.6 °F). (Watts, University of Manchester, 2012)

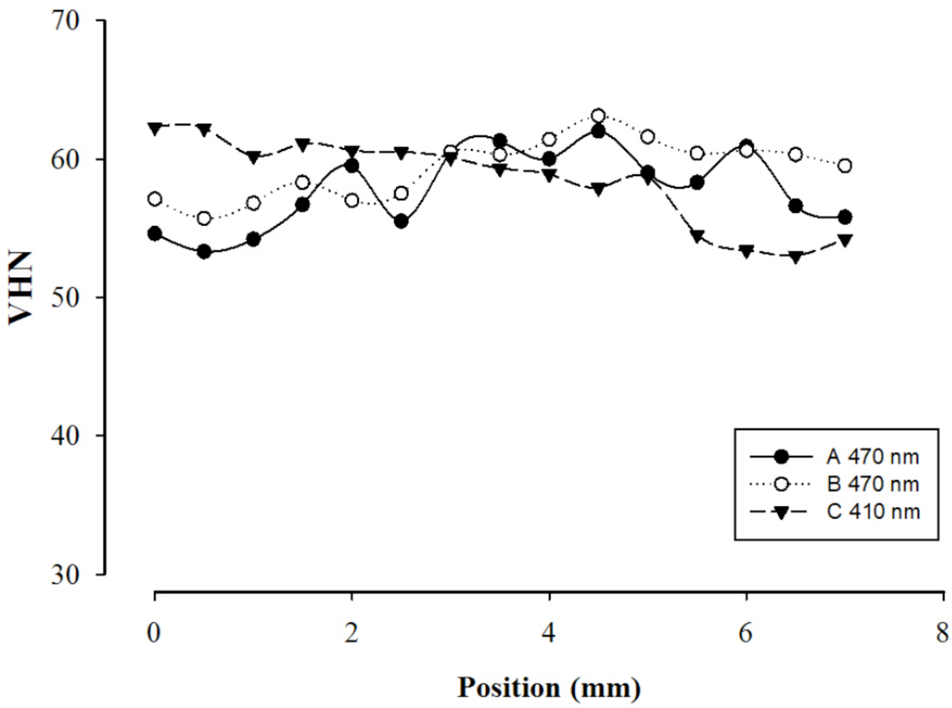


Fig. 19: Microhardness at the surface of the test specimen with positioning of the light guide at a distance of 4 mm (24 h of storage in water at 37 °C / 98.6 °F). (Watts, University of Manchester, 2012)

The results obtained by Prof. Watts can be summarized as follows:

- After storage in water for 24 hours, the composite surface showed a uniform hardness distribution. The measurement performed immediately after irradiation revealed significant differences in the hardness at the surface. However, these differences disappeared relatively quickly in the course of the post-curing phase. Since the curing light is not held motionlessly for 10 seconds over the composite surface to be cured, a homogeneous and clinically acceptable level of cure can be ensured.

3.4 Curing of composites with different initiators

Bluephase Style is an LED light of the 3rd generation. The light emitted by the device covers a wide wavelength range and is thus capable of exciting all photoinitiators used in dentistry. The curing of composites which do not contain camphorquinone has already been tested for the Bluephase (G2) light. This device, like Bluephase Style, features LEDs which emit light at 470 nm and 410 nm. The light intensities of both lights are comparable.

	CC content	Lucirin content	PPD content
Composite 1	0.3 %		
Composite 2	0.15 %	0.4 %	
Composite 3		0.8 %	
Composite 4	0.15 %		0.15 %
Composite 5			0.3 %

Table 5: Experimental composite formulations with different amounts of initiators in the monomer mixture

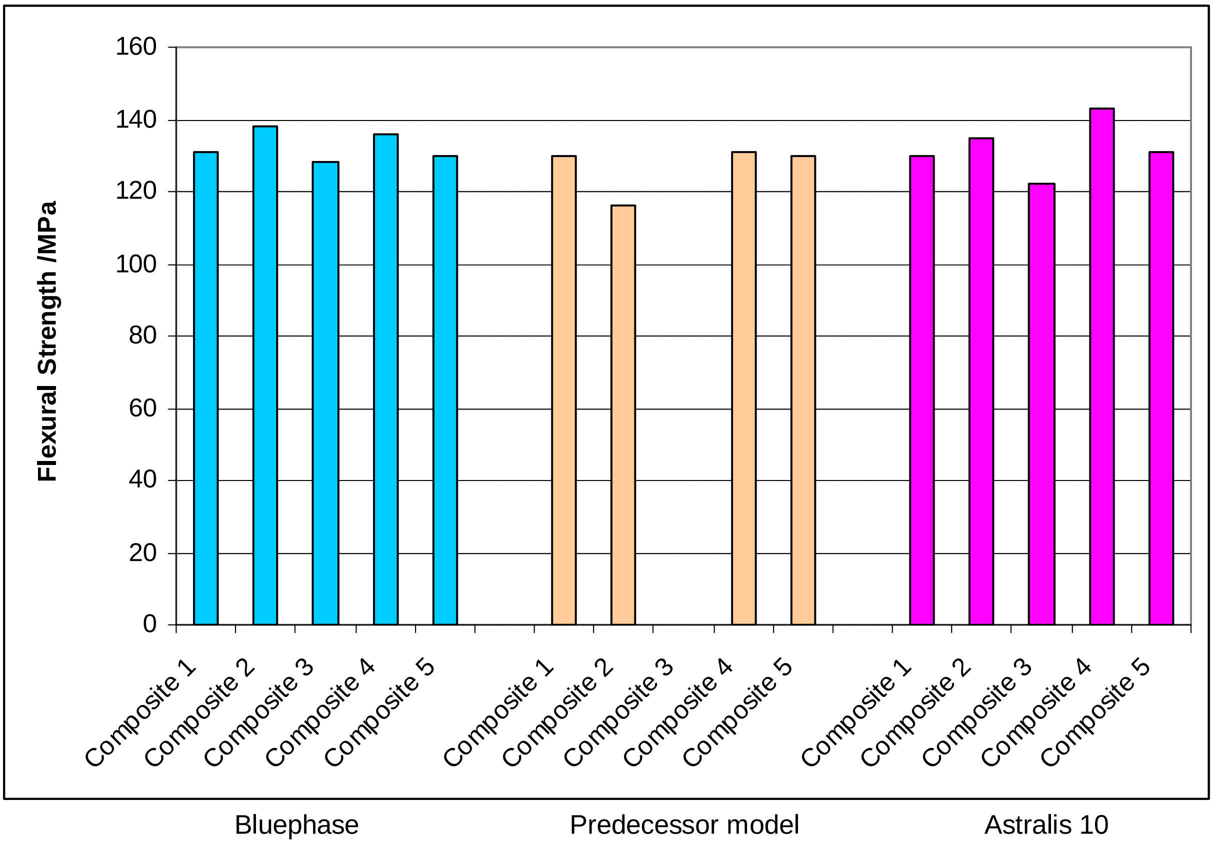


Fig. 20: Flexural strength of different experimental composite formulations with different initiator contents (see Table 2) after having been cured for 20 seconds with the predecessor model and Bluephase in the High Power mode, compared with the Astralis 10 halogen light (Ivoclar Vivadent AG, R&D, Schaan, 2007)

Tetric EvoCeram Bulk Fill is a translucent composite with a specially developed initiator system that enables uniform curing up to depths of 4 mm. Investigations (Table 6) showed that Bluephase Style fully polymerizes Tetric EvoCeram Bulk Fill in 10 s. Even when used with the light guide at a distance of 8 mm from the surface, the Vickers hardness at 4 mm depth reached 80% of the hardness of the top surface.

Tetric EvoCeram Bulk Fill Shade: IVA Curing light: Bluephase Style Curing time: 10 seconds				
	Distance from surface 0 mm	% surface hardness	Distance from surface 8 mm	% surface hardness
0.0 mm	621	100.0	621	100.0
0.5 mm	629	101.3	616	99.2
1.0 mm	624	100.5	618	99.5
1.5 mm	612	98.6	599	96.5
2.0 mm	601	96.8	580	93.4
2.5 mm	594	95.7	562	90.5
3.0 mm	585	94.2	563	90.7
3.5 mm	568	91.5	528	85.0
4.0 mm	528	85.0	499	80.4
4.5 mm	527	84.9	465	74.9
5.0 mm	529	85.2	431	69.4
5.5 mm	506	81.5	372	59.9

Table 6: Vickers hardness at various depths after curing Tetric EvoCeram Bulk Fill with Bluephase Style

3.5 Curing through ceramic material

Light- and dual-curing composites are used for the adhesive cementation of indirect restorative materials. Particularly in the case of all-ceramic restorations based on glass-ceramic materials, the adhesive cementation technique with resin composites is recommended. Due to the opacity of such materials, however, the amount of light which actually reaches the composite is considerably reduced. Therefore, most luting composites also contain initiators for self-curing.

For reasons of esthetics, the self-curing catalyst is often omitted in the case of translucent materials or restorations placed in an exposed and visible area. The catalyst often contains amines which are not light-stable over the years. Therefore, purely light-curing cementation systems, such as Variolink Veneer, are used in the anterior region for e.g. ceramic veneers.

At this point, curious dental professionals might ask whether enough light penetrates through the crown or inlay in order to ensure sufficient curing of the composite.

Doctor Ilie, who works with Prof. Hickel at the LMU Munich, analyzed the effect of various types of ceramics, layer thicknesses and translucencies on the curing depth of a purely light-curing luting composite (Variolink II Base).

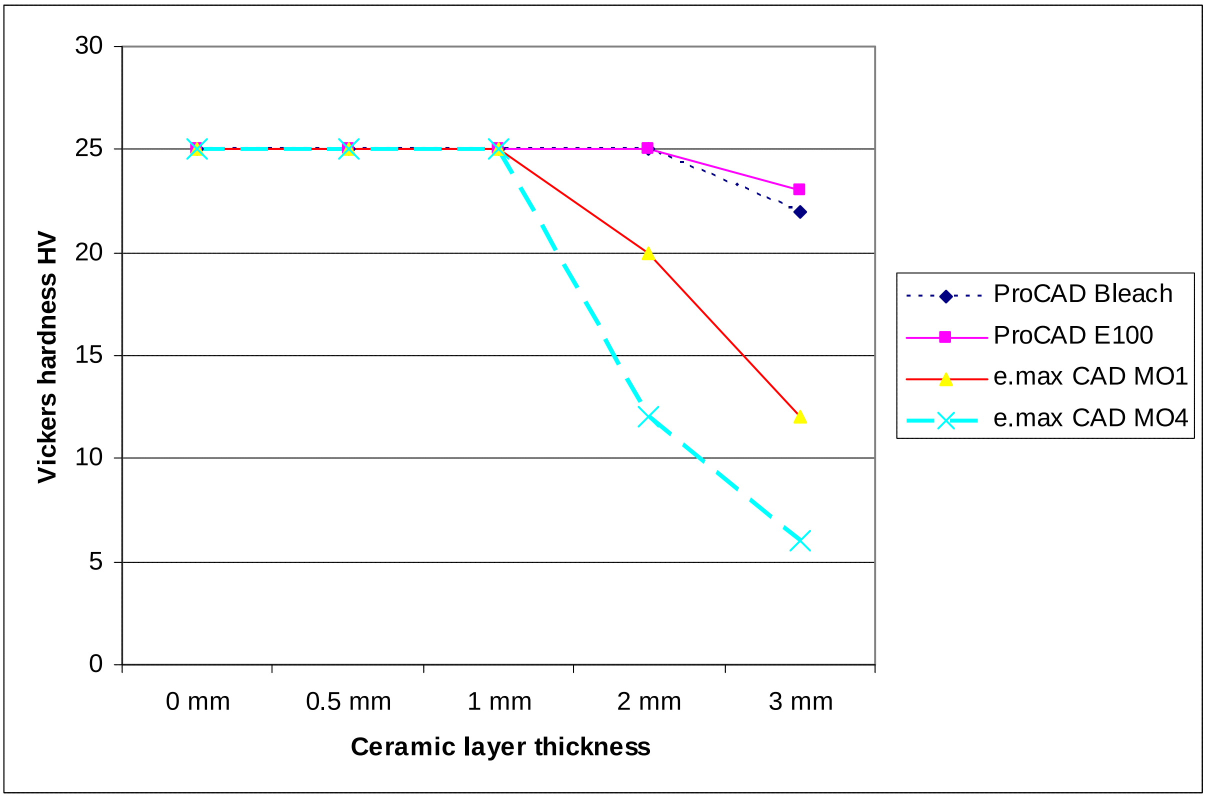


Fig. 21: Vickers hardness of Variolink II Base after curing through ceramic layers of various thicknesses (ProCAD and IPS e.max CAD) with a Bluephase curing light (Ilie, Munich, 2007)

ProCAD was a relatively translucent leucite ceramic (comparable with IPS Empress CAD); IPS e.max CAD MO is a rather opaque lithium disilicate framework ceramic. The composite is thoroughly cured through the translucent ceramic up to a ceramic layer-thickness of 3 mm. However, through the more opaque ceramic, a reduction in hardness is noted “earlier” at a ceramic layer-thickness of 2mm. In such cases, dual-curing luting composites are preferable.

Bluephase (G2) is an LED light with a light intensity of 1,200 mW/cm^2. Similar results can be expected for Bluephase Style.

3.6 Heat release and temperature increase around the pulp

The high light intensity of 1,100 mW/cm^2 ± 10% also generates perceptible heat if the light guide is held close to the skin.

Particularly when areas around the pulp are cured, the use of high-performance lights entails the risk of high temperature build-up in the pulp chamber, which is sufficient to cause irreversible damage to the tissue.

Professor Rueggeberg from the Medical College of Georgia has developed a method to investigate the heating of the pulp. This method has already been adopted by a few researchers.

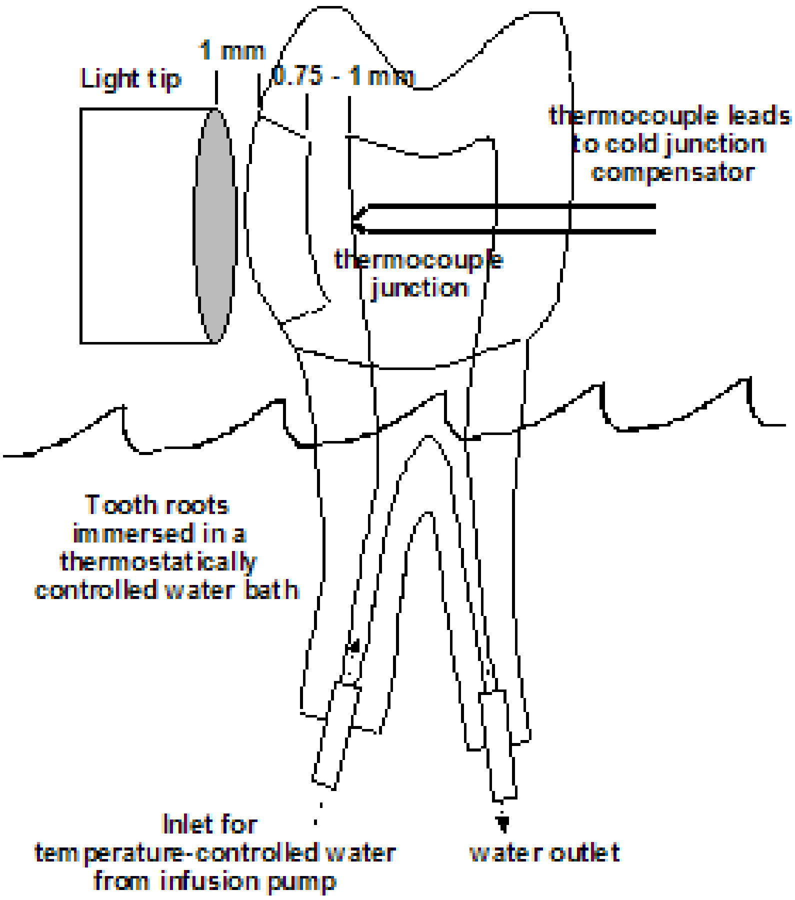


Fig. 22: Diagram of the temperature measurement in the pulp chamber when a buccal cylindrical cavity is irradiated

A buccal cylindrical cavity is prepared in a premolar. The wall of the pulp chamber should display a thickness of 0.75 to 1 mm. The apical ends of the roots are cut to allow a constant flow of water which simulates the heat exchange of the blood flow. An opening to the pulp chamber is prepared opposite the cavity and a temperature sensor is inserted. The tooth roots are immersed in a temperature-controlled water bath of 34 °C (93.2 °F).

The tip of the light guide is positioned at a distance of 1 mm from the surface of the cavity.

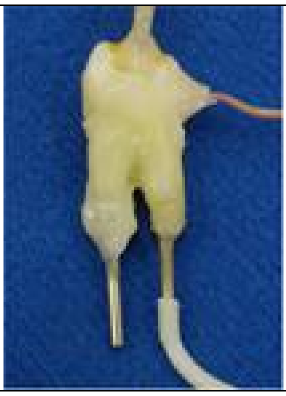


Fig. 23: Photograph of an experimental tooth model	*Fig. 24: Respective X-ray image*

The adhesive layer is applied before the first composite layer. This process takes place the closest to the pulp and is considered the most critical step in terms of tissue-impact.

Contrary to the existing Bluephase (G2) light, Bluephase Style does not provide a specific adhesive program.

Therefore, the worst case scenario is used: The cavity is directly irradiated for 10 seconds. To be able to compare the results, the adhesive (LOW) mode of Bluephase 20i was used as the standard and the HIGH mode of Bluephase 20i as the negative standard.

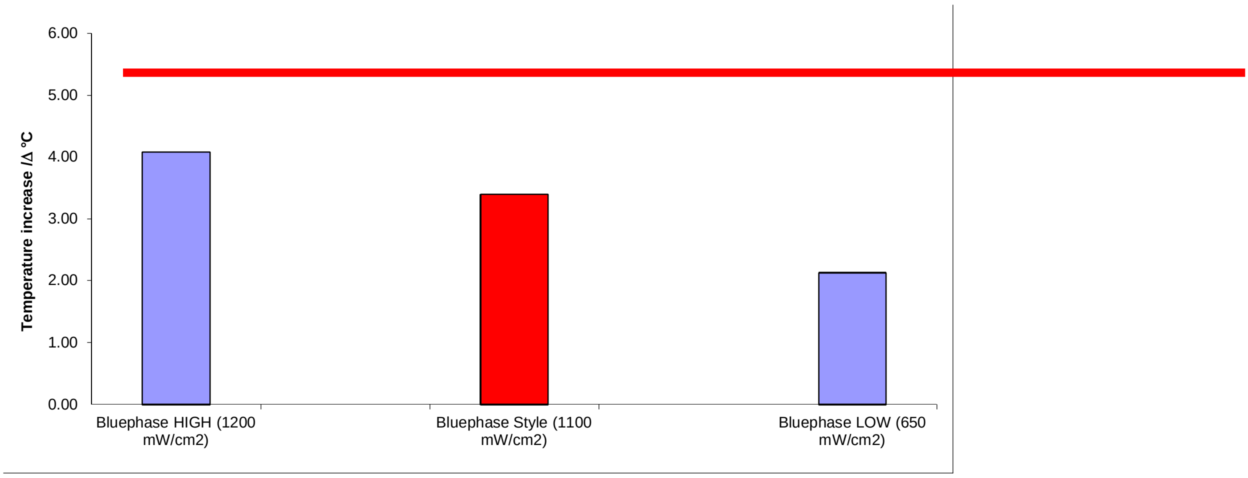


Fig. 25: Temperature increase in the pulp chamber after 10 seconds irradiation of the "adhesive" (Rueggeberg, Augusta, 2010)

The temperature in the pulp chamber was increased by 3.4 °C (6.12 °F) after 10 seconds. This value is lower than the currently valid maximum of 5.5 °C (9.9 °F). This shows that Bluephase Style can be used for this application without any risk. Furthermore, this measurement revealed that the threshold value is not even reached when Bluephase is used (improperly) to irradiate the cavity for 10 seconds in the HIGH mode.

A comparison of commercially available LED curing lights used to irradiate the standard cavity for 10 seconds without composite increment shows that the temperature values of some lights are very close to the critical range. The Valo light was used according to the manufacturer's information for 2 x 3 seconds in the plasma mode. A high light intensity may well represent a risk to the pulp and soft tissue.

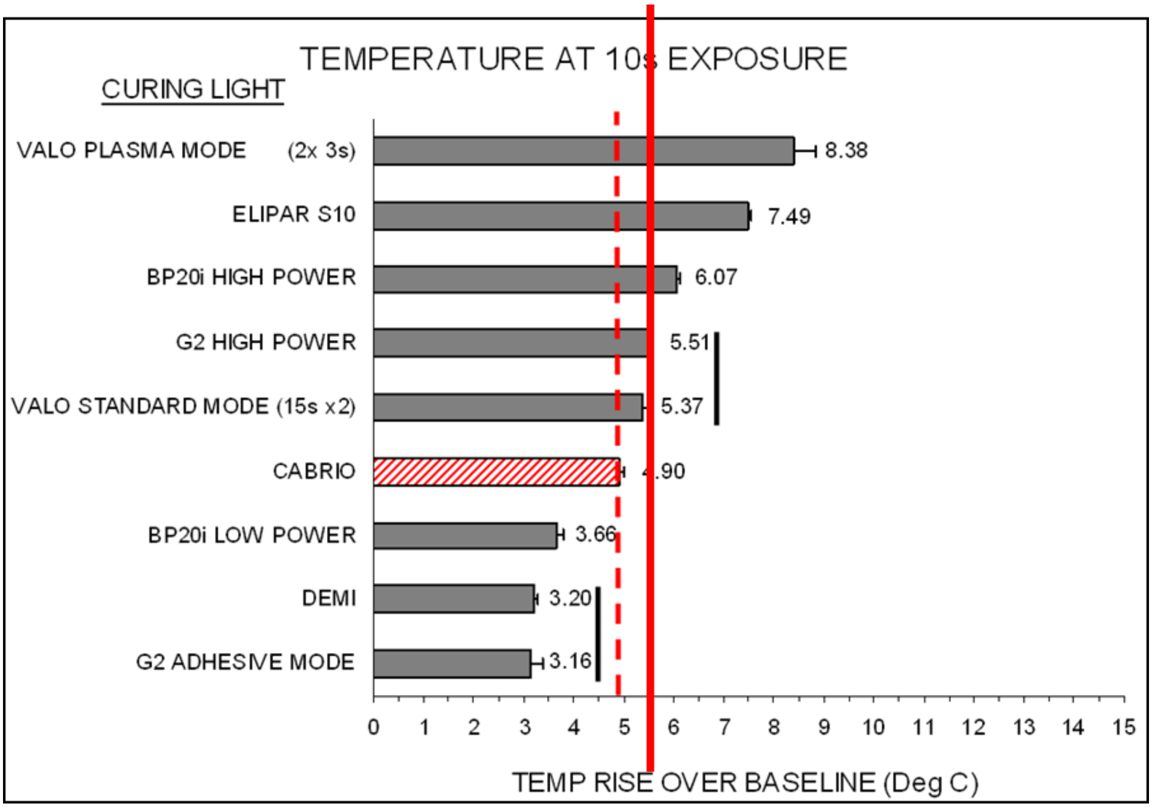


Fig. 26: Comparison of the temperature increase after irradiation with various curing lights and programs. An increase of 5.5 °C (9.9 °F) is the currently accepted maximum value at which the pulp tissue is not irreversibly damaged.

(Rueggeberg, Augusta, 2010)

Cabrio = Bluephase Style

3.7 Influence of heat on soft tissue

The influence of direct exposure of soft tissue to the polymerization light has been tested in living rats at SUNY in Buffalo.

Histological analyses of rats' cheek tissue (Prof. Munoz, SUNY, Buffalo) showed that the tissue regenerated after a maximum period of two weeks after irradiation with different curing lights for the recommended irradiation time. The following curing lights were investigated:

Curing light	Type	Light intensity (mW/cm^2)	Curing time (s)	Energy (mWs/cm^2)
Bluephase	LED	1.200	10	12.000
Bluephase 20i	LED Polywave	2.000	5	10.000
Astralis 10	Halogen	1.000	10	10.000
Swiss Master Light	Halogen	3.000	3	9.000
Sapphire	Plasma	2.700	3	8.100

Table 7: Actual light energy of different curing lights used in the in-vivo testing (Munoz, SUNY, 2006, 2009)

A 10-second curing time with Bluephase Style equals an energy output of 11,000 mWs/cm^2.

Thus, it can be assumed that direct irradiation of the mucous membrane with Bluephase Style for 10 seconds with the light guide placed directly on the tissue does not cause irreversible damage.

More recent investigations on fibroblast cultures did not show any significant impairment of viability after irradiation with a Bluephase (G2) light in the HIGH mode. A cytotoxic risk through irradiation is therefore not present.

3.8 Clinical experience with Bluephase Style

Bluephase Style is used in the internal practice by Dr Peschke. Bluephase Style has shown excellent results both for curing direct restorations and for the seating of indirect restorations. The excellent ergonomic properties of the light is perceived as a particular benefit.

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