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SmartLite® FOCUS

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1 Introduction

Modern adhesive restorative dentistry is mainly depending on light curing materials such as adhesives and composites. The shift away from QTH to LED driven curing devices allowed the design of smaller, quieter, lighter weight, and cordless curing lights.

Light curing of composites and adhesives were traditionally considered to be an “easy” and “reliable” procedure which quite often is performed by the assistant. However, recent research using patient simulating devices showed that there is a huge variety of how much light (energy) is received by a filling when different operators use the same light (Price et al., 2010).

In addition to any variance caused by handling, the design of a curing light could significantly influence the energy delivered to the restoration, too.

In the following chapters the main features of the new SmartLite Focus are described and the performance is compared to a selection of current curing devices.

2 Description

SmartLite Focus (SL Focus) is a pen-style (see Figure 1) curing light for CQ-initiated light curing dental materials designed to provide robust curing in a simple way for direct and indirect restorations.

Key Features are:

- The unique design of SmartLite Focus optics reduces divergency and ensures a homogeneous beam profile
- Reliable Curing even over larger distances (up to 8mm) through collimated light beam
- Easy intra-oral access through ergonomic, slim pen-style design, low-profile head, and 330° rotatable tip
- One-button-interface (ON / OFF) for simple & easy operation
- Only one curing mode of 20 seconds curing cycle (beep after 10 seconds) to provide consistent & reliable curing
- Smart Charging Technology provides both Standard & Quick charging modes
- LSD (Low-Self-Discharge) battery technology for prolonged usage time between charges

Figure 1 Pen-style SmartLite Focus

3 Technical Data

Following graphs and tables (except Figure 5 and Figure 14) are based on data derived from reports by an independent research company (Bluelight Analytics 2012).

3.1 Emission spectrum

Figure 2 shows how the emission spectrum of the LED used in SmartLite Focus overlaps the absorption spectrum of CQ.

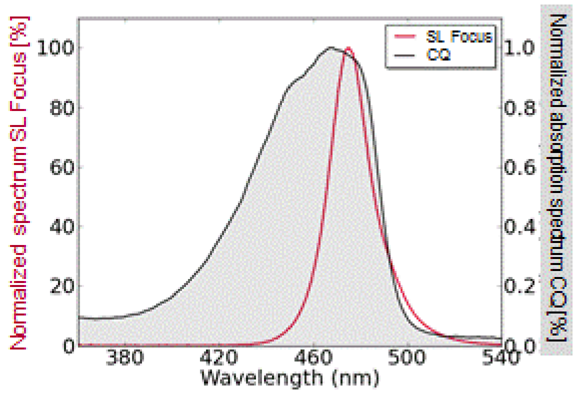


Figure 2 Normalized absorption spectrum CQ (grey) and emission spectrum SL Focus (red).

However, the graph does not allow deriving the efficiency of an emission spectrum to initiate CQ. This may be expressed by the CQ-Efficiency. Values calculated using respective formulas (Neumann et al., 2005, Schepke et al., 2009) are shown in Table 1 for various curing lights.

	[%]
SL Focus	79.7
bluephase Style	75.5
bluephase G2	70.4-77.8
Demi Plus	85.7
Elipar S10	82.3
radii plus	86.1
Valo cordless	68.5-70

Table 1 CQ Efficiency

To fully describe the performance of a curing light and possible implications for its clinical use more parameters are needed.

Though Output Power (mW) describes the actual power of the emitted light within certain range of wavelength, only irradiance (mW/cm² - the power of light emission per unit area on a surface) allows comparing lights in regard to curing a given surface. Furthermore, the distribution of irradiance and wave lengths across the beam is of high importance to understand the clinical performance as inhomogeneous distribution of either one may lead to localized differences within the cured composite.

3.2 Irradiance – but where to measure?

Typically, irradiance is measured while the device is hold as close to the photometer sensor as possible – "near-to-tip" irradiance. Respective values of all curing modes provided by a device are shown in Figure 3.

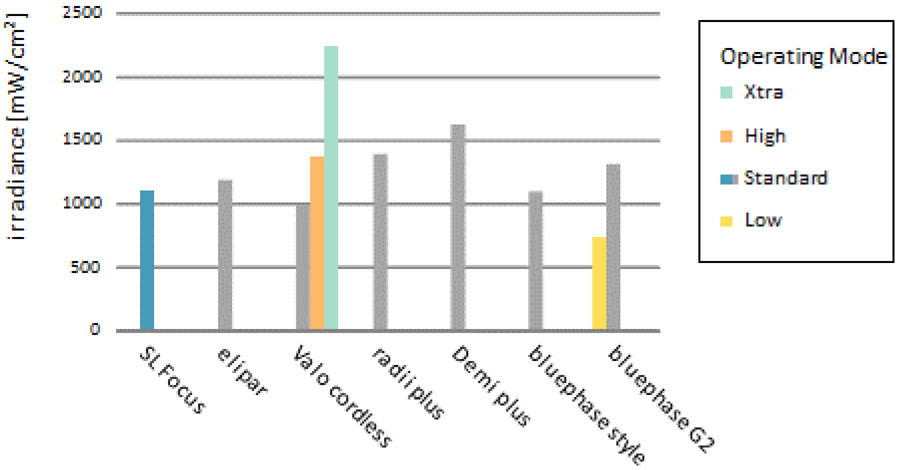


Figure 3 "Near-to-tip" irradiance at 0 mm distance to the tip for different operating modes

Due to different designs of the components influencing the overall optic performance (LED dome, reflector, lens, light guide) devices show completely different pattern when irradiance is measured over distance.

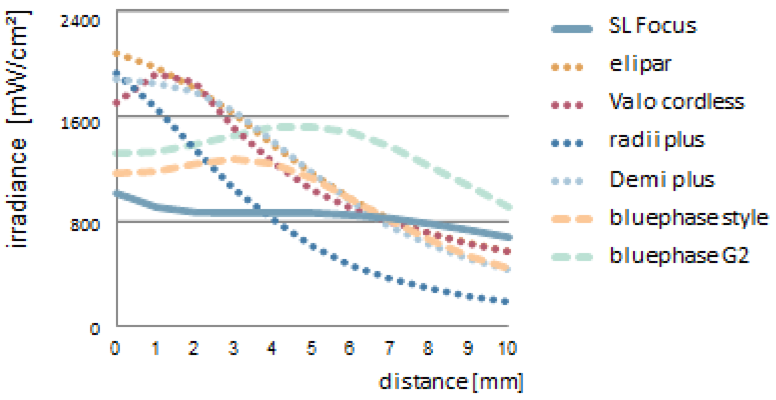


Figure 4 Irradiance over distance

From Figure 4 it is obvious that the optics of SmartLite Focus was optimized to allow a lower "near-to-tip" irradiance (measured at 0 mm distance) but to maintain high irradiance over distance – which is opposite to the behaviour of a number of competitive lights.

This is quite important to note as it stands in contrast to the current approach promoting curing devices via the "near-to-tip" irradiance.

Why lower irradiance near the tip provides clinical advantages will be explained under *Pulp chamber temperature increase*.

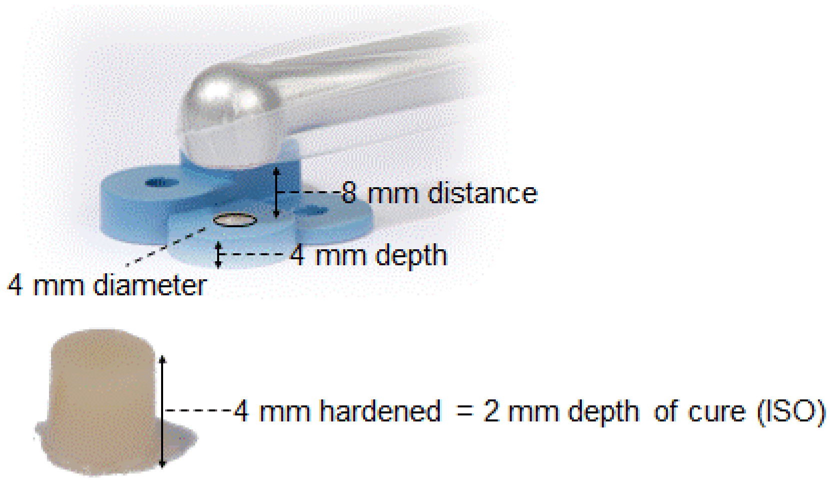


Figure 5 Depth of cure at 8 mm distance

Measurements using SmartLite Focus at a distance of 8 mm (test set-up schematically illustrated in Figure 5) confirmed a given exposure time / depth of cure combination as determined with the tip in direct contact to the specimen (according to ISO 4049). Thus, SmartLite Focus is more robust regarding vertical distance to the cavity.

3.3 Beam Profiling

When irradiance distribution is analysed using latest technology, huge differences can be visualized. In order to standardize beam profiling, wave length range and measurement areas need to be defined (Figure 6). To date, CQ is used in the majority of current resin based composites as the sole initiator. Therefore, wavelength range is set to 420-540 nm. The active area represents the surface in which irradiance can be measured. The reference area is set to 10 mm diameter representing a posterior molar. Circles of 4 mm diameter – which are similar to a medium sized class I, an approximal slot preparation, or the specimen diameter specified in ISO 4049 for depth of cure measurements – are defined as cold spots (with lowest irradiance) and hot spots (with highest irradiance) in relation to either active or reference area and the defined wave length.

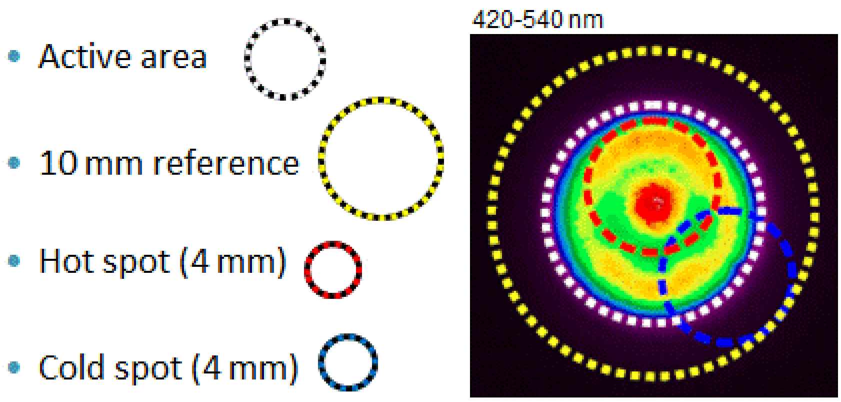


Figure 6 Areas defined for beam profiling within reference area

One way of evaluating the variability of a given curing light regarding position is to express the ratio of irradiance between hot and cold spots as shown in Figure 7. In other words this expresses the difference in irradiance received by a medium sized cavity in the worst versus the best case of positioning the light tip.

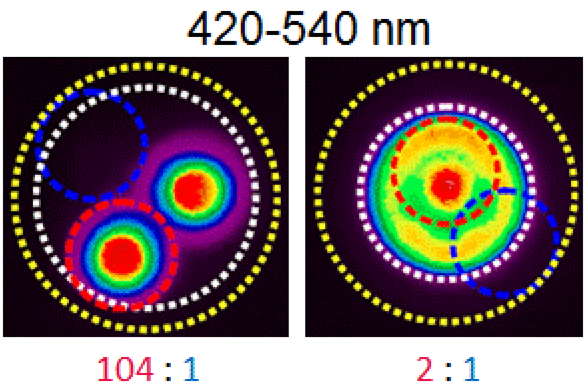


Figure 7 Ratio of hot : cold spot irradiance within reference area and wave length range 420-540 nm

Besides the simple ratio of hot to cold spots, it is of high importance how much irradiance is actually delivered within these areas. Both extremes should be avoided as very low irradiance may have an adverse effect on the degree of conversion of the curing material (under-curing) whereas very high irradiance could provoke adverse temperature changes in the pulp chamber.

Figure 8 defines areas used to describe center, hot, and cold spot irradiance within the active area.

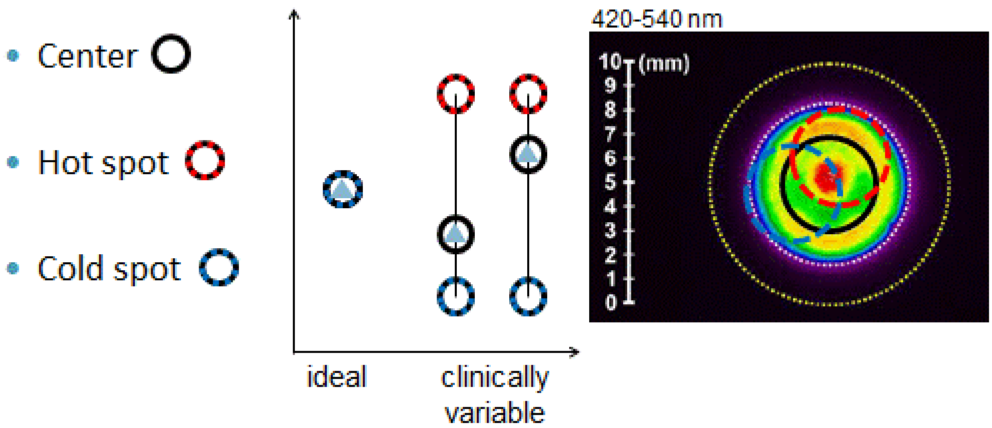


Figure 8 Areas used for beam profiling within the active area

Hot, center, and cold spot irradiance of a selection of curing devices are shown below either at 0 mm (Figure 9) or 10 mm distance (Figure 10) to the tip. Note that SmartLite Focus comes close to the ideal situation where no differences occur within the active area at 0 mm distance and is the only light in the comparison providing at 10 mm distance more than 500 mW/cm² in the cold spot of the active area.

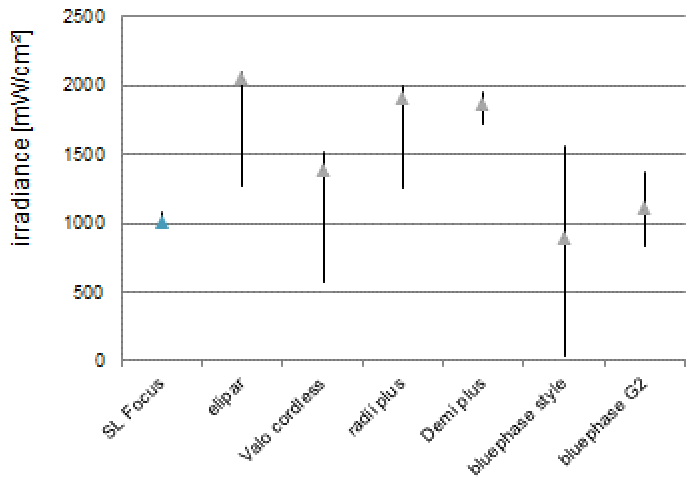


Figure 9 Irradiance in center (triangle), hot (upper end), and cold (lower end) spot of the active area **at 0 mm distance**

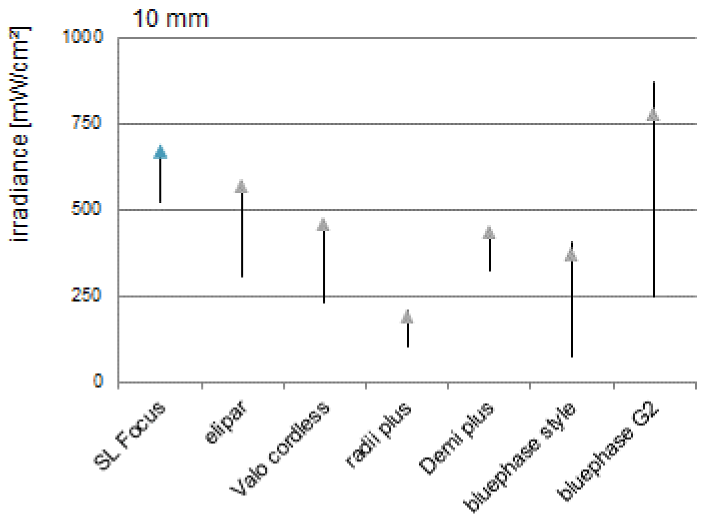


Figure 10 Irradiance in center (triangle), hot (upper end), and cold (lower end) spot of the active area **at 10 mm distance**

Figure 11 shows the highest irradiance per pixel measured via beam profiling of several curing lights run in different modes.

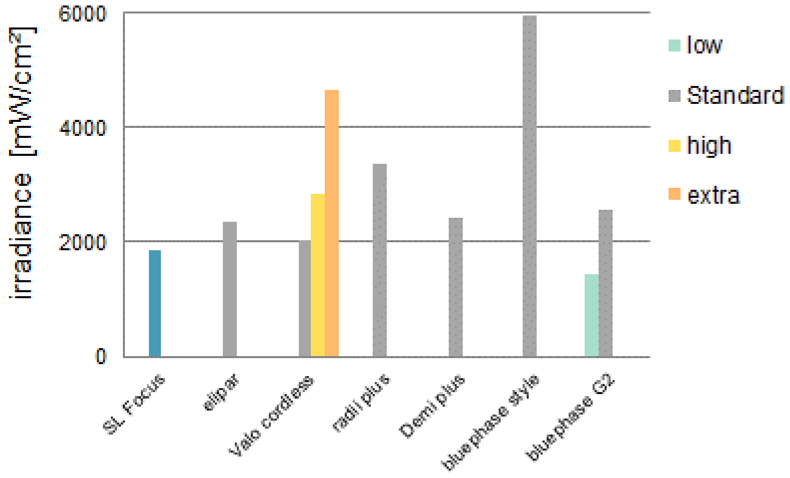
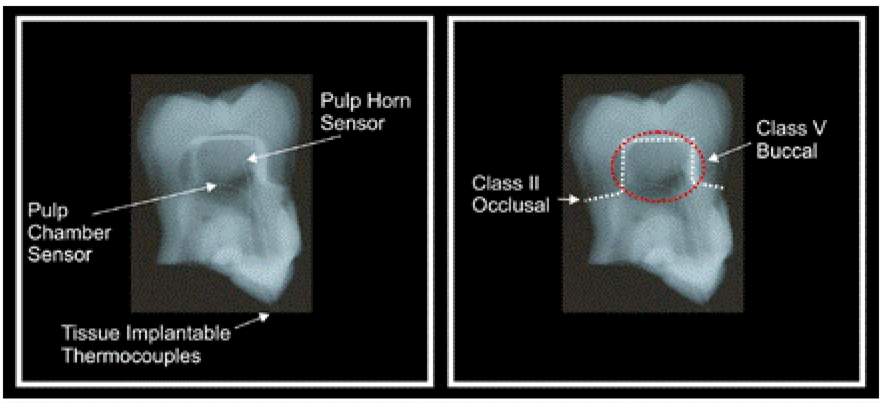


Figure 11 Maximum irradiance of a pixel from beam profiling in different curing modes

As mentioned above and further explained in detail below, too high irradiance should be avoided.

3.4 Pulp chamber temperature increase

Temperature increase was measured in two different constellations (class II and V) with two differently positioned sensors (pulp horn and pulp chamber). Radiographs illustrating the position and distance to the light tip are shown in Figure 12.



distance to tip [mm]	Pulp Horn	Pulp Chamber
Occlusal class II	4	5
Buccal class V	2	5

Figure 12 Placement of sensors and distance to surface

It is described in the literature that a temperature increase of 5.5°C may induce permanent damage to pulp cells (Zach et al., 1965). Time until this critical value was reached at the pulp horn sensor in class V is shown in Figure 13.

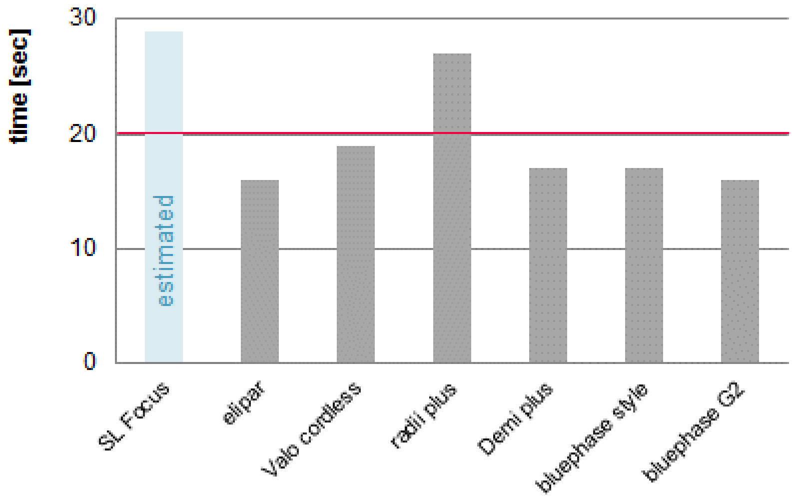


Figure 13 Time to reach 5.5°C temperature increase at the pulp horn sensor in class V cavities in standard mode

Note: SmartLite Focus switches off after 20 seconds and did not reach 5.5°C temperature increase. Therefore, the above given value is an estimate from projected temperature increase rate within the first 20 seconds.

All other curing lights allow operating the light until this critical value is reached in at least one of the described constellations such as pre-set curing time up to 60 seconds (radii plus) or different curing modes as shown in Figure 3.

As a consequence, when curing adhesives in class V cavities other lights need to be either shut-off manually or the settings for curing time and/or curing mode need to be changed, in order to avoid potential hazard to the pulp.

3.5 Multi-wave versus mono-wave – a discussion of in-vitro data

One of the main challenges when developing a dental curing light is to balance the needed power for efficient curing with its adverse effects (i.e. heat development). Additionally, provided wave lengths and power should be evenly distributed over the entire surface of the light tip or light guide.

The broad wave length emission spectrum of QTH curing devices predominantly used in the past can't be covered by one LED. Trends like bleaching teeth or the attempt to increase depth of cure by more effective initiator systems have led to initiators with absorption spectra different to CQ. Therefore, so called "multi-wave" curing devices were introduced in the market.

However, as a consequence the wavelengths needed to initiate CQ (which is still the most frequently used initiator system in dental materials used for direct restorative treatments) may be unevenly distributed over the beam (Figure 14 and Figure 15) with cold spots low as15 mW/cm² as shown in Figure 9.

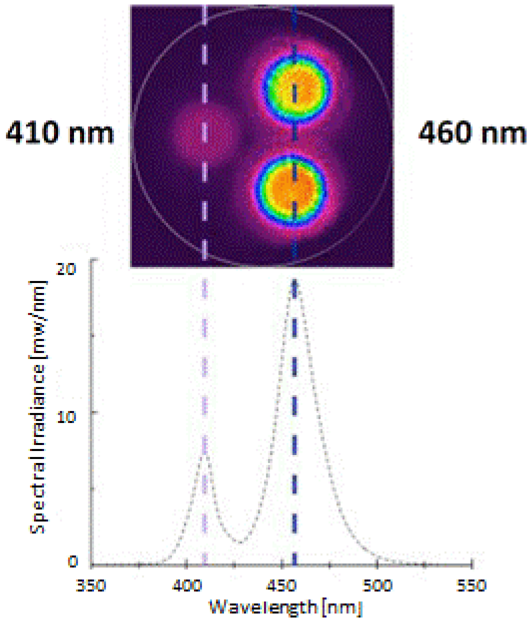


Figure 14 Distinct wave length distribution in a "multi-wave" curing light
Price et al., 2013

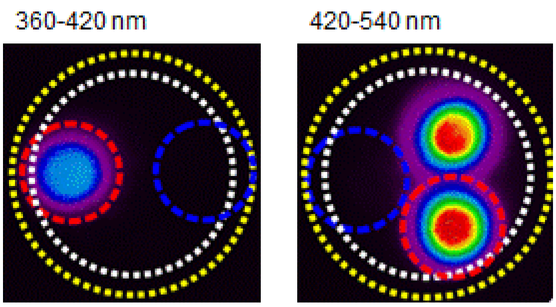


Figure 15 Hot and cold spot areas depending on the wave length spectrum

On the other hand, those materials using other initiators than CQ should clearly state which wavelengths need to be emitted by a curing device to be properly cured.

Using very high irradiance in the respective curing mode (see Figure 3) is often combined with very short exposure time as the irradiance multiplied by exposure time defines what is needed essentially: energy density (J/cm²). Though the short curing time may help to avoid adverse temperature increases (see Figure 16), positioning of the light tip may get very sensitive & critical. 1 second misplacement out of 3 seconds operating time is equal to 33 % loss of energy intended to deliver; whereas 1 second misplacement out of 10 seconds operating time only accounts for 10 % of loss of energy intended to deliver .

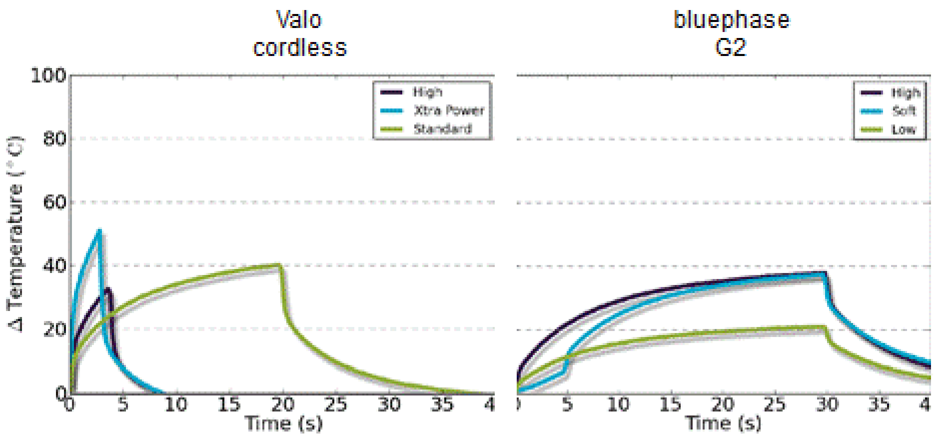


Figure 16 Surface temperature increase of different curing modes

3.6 Conclusion

The main objective for developing the SmartLite Focus curing device was to allow easy and reliable curing of CQ initiated dental materials.

Based on the technical data described above, SmartLite Focus provides

- a wavelength range suitable for CQ evenly distributed over the active area
- the most homogenous distribution of irradiance[1]
- the lowest loss of irradiance over distance[1]
- the least temperature increase induced in the pulp chamber within 20 seconds curing time[1]

[1] within the shown comparison

4 Instructions for Use

The up-to-date version can be found in all European languages on www.dentsply.eu.

5 References

Bluelight Analytics (2012). BlueLight® LCU Reports on Bluephase G2, Bluephase Style, Demi Plus, Elipar S10, radii plus, Valo cordless.

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6 Glossary and Abbreviations

CQ	Champhorquinone
IFU	Instructions for Use
LED	Light Emitting Diode
SL Focus	SmartLite Focus
QTH	Quartz Tungsten Halogen

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Brand: abbreviation(s) (Manufacturer):
Elipar s10: elipar (3M ESPE)
bluephase style: (Ivoclar Vivadent)
bluephase G2: (Ivoclar Vivadent)
demi plus: (Kerr)
radii plus: (SDI)
Valo cordless: (Ultradent)