

# Degree of Conversion and Temperature Measurement of Composite Polymerised with Halogen and LED-Curing Unit

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## Summary

Today available composite materials are polymerized by blue light, with a wavelength of about 468 nm. Commercially available curing units for composite resin polymerization emit blue light of different intensity. Using curing units of higher light intensity to reach a higher degree of conversion unavoidably leads to higher temperature rise in material during hardening, and also to polymerization shrinkage of material. The aim of this study was to determine if there is any difference between the degree of conversion and temperature rise in three composite materials: Amelogen (Akeda Dental, Denmark), Pertac II (ESPE, Seefeld, Germany) and Z100 (3M Dental Products, St. Paul, Minnessotta, USA) polymerized with exponential program of Elipar Tri-light curing unit (ESPE, Seefeld, Germany) and Lux-o-Max curing unit (Akeda Dental, Denmark) based on LED (light emitting diodes) technology. The results showed only a slightly lower degree of conversion, in the case of polymerization with Lux-o-Max curing unit. The temperature rise was significantly lower in the case of polymerization with Lux-o-Max curing unit for all tested composite materials.

**Key words:** halogen curing units, blue diodes, composite resins, degree of conversion, temperature.

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## Introduction

Visible light curing composite resins possess ( $\alpha$ -1.2 diketone (benzil or camforquinone) as a photoinitiator and amine as a reducing agent, usually dimethylaminoethyl methacrylate. Blue light wavelength from 400 to 500 nm is used for conversion

of  $\alpha$ -diketone in excited state which is a response to free-radicals formation (1).

The degree and depth of conversion of visible light curing composite resins depends on the components of the material (organic matrix, type and volume of anorganic filler and size of filler particle), on optic characteristics (colour, translucency,

refraction index), on intensity and duration of exposure to blue light (2). Intensity of halogen curing units decrease with use, and the maximum polymerization of composite resin recommended by the manufacturer, is possible only when the output light intensity is optimal. Only those wavelengths which enable activation of ( $\alpha$ -diketone enables effective polymerization. Most conventional curing units for photopolymerization have spectrum wavelengths of between 390 and 510 nm and effective wavelengths are only about 468 nm which is the absorption maximum of camphorquinone. Wavelengths above this are not useful for composite resin polymerization and only cause a useless temperature rise (3).

To eliminate the useless wavelengths of the conventional halogen curing units, which are in daily use in clinical practice, a new unit based on LED-technology has been introduced. This unit emits a wavelength spectrum closely to the wavelength spectrum of camphorquinone. Due to the narrow spectrum of wavelengths, higher and useless temperature rise during polymerization is avoided (4-6).

The aim of this study was to compare the degree of conversion and temperature rise of three composite resins, polymerized with a halogen curing unit and a unit based on blue diodes.

## Materials and methods

### *Degree of conversion measurement*

The polymerization effects of the exponential program of the Elipar Trilight halogen curing unit and Lux-o-Max unit based on LED-technology were analysed. The exponential program of Elipar Trilight unit begins with an intensity of 100 mW/cm<sup>2</sup> and exponentially increases in 15 seconds to 800 mW/cm<sup>2</sup> and this intensity remains the same until the end of the 40<sup>th</sup> second. The light intensity for the Lux-o-Max unit was 50 mW/cm<sup>2</sup> for the first 10 seconds and 150 mW/cm<sup>2</sup> for the further 30 seconds. The output intensity is determined by Curing Radiometer Model 100 (Demetron Research, Danbury, CT, USA). Composite resins used in the experiment were: Amelogen (A), Pertac II (PII) and Z100 (Z100) shade A2.

For measuring the degree of conversion five samples for each material were prepared. Composite

resin sample was placed between two Mylar sheets and pressed with 10<sup>7</sup> Pa to 0.1 mm thick and  $\varnothing$ 1.5 cm. The prepared composite resin sample was light cured with a light tip closed to an upper Mylar sheet for 40 seconds. FTIR (Fourier transform infrared spectroscopy) the spectra of polymerized samples were recorded in transmission mode using Perkin Elmer Spectrometer Model 2000 (Perkin Elmer, Beaconsfield, Bucks, England) (4, 5, 7). The ratio of absorption maximum was calculated to the F. A. Rueggeberg (8) baseline. The degree of conversion was calculated by the following formula:

$$\% \text{ conversion} = (1 - (P/N)) \times 100$$

where P - molar ratio is of polymerized and N - molar ratio of unpolymerized sample.

### *Temperature measurement*

For measuring temperature five samples of each material were made in a plastic mould, size 4x4x4 mm. A Metex multimeter was used for recording temperature changes. The multimeter was connected to a personal computer so that the changes in temperature during 40 seconds could be seen. The peak of the temperature probe was stuck into the composite resin sample 1 mm deep and light cured for 40 seconds, with the curing tip close to the surface of the composite sample. Temperature rise was recorded after 10, 20 and 40 seconds of illumination.

Descriptive statistics were used to determine mean value and standard deviation, and ANOVA was used to determine p-values.

## Results

The results of the conversion degree and temperature rise are given in Tables 1 and 2 as medium values and standard deviations. The results of the conversion degree in the case of polymerization with Lux-o-Max curing unit are compared with the results of composite resin polymerization in the case of Elipar Trilight halogen curing unit and are presented in Table 1. It can be seen that the degree of conversion in the case of polymerization with Elipar Trilight curing unit is minimally higher than the degree of conversion in the case of polymerization with Lux-o-Max. The highest values of conversion degree

were recorded for Pertac II composite material in the case of illumination with both curing units ( $66.74 \pm 1.51\%$  by polymerization with the exponential program of Elipar Trilight halogen curing unit and  $62.23 \pm 3.16\%$  by illumination with Lux-o-Max unit). The lowest results of conversion degree was determined for Z100 composite material in the case of polymerization with both curing units ( $61.04 \pm 0.91\%$  by illumination with the exponential program of Elipar Trilight halogen curing unit and  $58.61 \pm 0.48\%$  by illumination with Lux-o-Max curing unit). There is no significant difference ( $p > 0.05$ ) between polymerization of composite materials with Lux-o-Max and Elipar Trilight curing units.

The results of temperature measurements are given in Table 2. The highest temperature values were recorded for Pertac II in the case of illumination with both light sources ( $13.6 \pm 2.88^\circ\text{C}$  by illumination with exponential program of Elipar Trilight unit and  $7.2 \pm 1.92^\circ\text{C}$  by illumination with Lux-o-Max unit after 40 seconds). The lowest results of temperature rise were recorded for A composite material in the case of illumination with Elipar Trilight ( $12.6 \pm 1.14^\circ\text{C}$ ) and for Z100 ( $5.6 \pm 0.89^\circ\text{C}$ ) in the case of polymerization with Lux-o-Max curing unit after 40 seconds. There is significant difference between the temperature rise by polymerization of composite materials with Elipar Trilight and Lux-o-Max curing unit in 20<sup>th</sup> ( $p = 0.049$ ) and 40<sup>th</sup> ( $p = 0.005$ ) second of illumination (Table 3).

## Discussion

The light intensity of adequate wavelength which is emitted during polymerization of composite materials is a very important factor which determines the effectiveness of the curing unit (9). Recent investigations of the conversion degree of composite material polymerization with standard halogen curing units have shown that the degree of conversion lies between 60% and 75% (4, 5, 7, 10-12). A higher degree of conversion leads to greater hardness and stiffness of the material and also to higher color stability. The quality of composite resin polymerization decreased with the distance of the light source. This is very important in deep cavities where application of composite in thin layers is recommended. Incomplete polymerization has as a consequence a

higher quantity of unreacted monomer which can be dissolved in the mouth. Also, the reactive double bonds can be hydrolyzed or oxidized, which leads to degradation of the material and composite filling (13).

The results of the conversion degree of all tested composite materials in this experiment have shown a higher degree of conversion in the case of illumination with the halogen curing unit Elipar Trilight. A little lower degree of conversion was recorded only in the case of polymerization of the composite material with Lux-o-Max unit based on LED-technology. There is no significant difference between the degree of conversion achieved with these two curing units ( $p > 0.05$ ) which can be connected with spectrum distribution.

Earlier investigations of the degree of conversion with blue LED-s which were connected in another way have shown slightly lower results of conversion degree (5, 14-17). This can be caused by unsuitable focusing of blue diodes and as a consequence the loss of emitted blue light.

The best values of the degree of conversion were found for Pertac II ( $66.74 \pm 1.51\%$  in case of illumination with exponential program of Elipar Trilight halogen curing unit and  $62.23 \pm 3.16\%$  in the case of illumination with Lux-o-Max) while the lowest results of conversion degree were determined for Z100 ( $61.04 \pm 0.91\%$  by polymerization with exponential program of Elipar Trilight halogen curing unit and  $58.61 \pm 0.48\%$  by polymerization with Lux-o-Max curing unit).

Polymerization effectiveness depends on the light source, although material composition also has significant influence. Because they all possess camphorquinone as a photoinitiator, the difference in the degree of conversion may be influenced by different amines which make a complex with camphorquinone with different absorption characteristics. This is probably one of the reasons why the results of conversion degree are lower in the case of composite resin polymerization with blue LEDs or plasma curing unit, while they have a narrower spectrum, i.e. they emit a wavelength of about 468 nm, which is the maximum absorption of camphorquinone. The complex which camphorquinone makes with amine or other active components which are added to the composite material, moves the spec-

trum of photoinitiators activation which is no more in wavelengths which emit polymerization curing units. This results in lower polymerization of the composite material (18).

Everyday new polymerization units based on different technology are introduced on the market: standard halogen curing units with different polymerization programs, plazma units, blue superbright light emitting diodes. When choosing curing units usually most attention is paid to output light intensity and illumination time. However, temperature rise during polymerization of composite resins is a very important factor which can have great influence on vital tooth tissue. Protoplasmatic coagulation, expansion and fluid outflow from dentine tubuli, structural changes in blood vessels and tissue necrosis are the mean consequence of high temperature increase (19).

It is known that the higher the degree of conversion the higher the temperature rise. Furthermore the temperature of the material rises not only because of the emitted light influence, but also because of the chemical reaction in the material itself during the polymerization process. This investigation has shown that the polymerization of composite resins with Lux-o-Max unit causes a lower temperature rise than polymerization with exponential program of Elipar Trilight curing unit. The highest temperature rise, which agrees with the highest results of conversion degree, was determined for Pertac II composite material  $13.6 \pm 2.88^\circ\text{C}$  in the case of illumination with exponential program of Elipar Trilight curing unit, and  $7.2 \pm 1.92^\circ\text{C}$  in the case of polymerization with Lux-o-Max curing unit after 40 seconds polymerization). From these results it can be

seen that the temperature rises slowly during 40 seconds of polymerization with Lux-o-Max curing unit, while in case of polymerization with exponential program of Elipar Trilight halogen curing unit the temperature rise in the interval of 10 to 20 seconds is higher than in the interval from 20 to 40 seconds because of the exponential rise of light intensity. There is significant difference between the temperature rise in the 20<sup>th</sup> ( $p=0.049$ ) and 40<sup>th</sup> ( $p=0.005$ ) second by illumination of composite materials with Lux-o-Max and Elipar Trilight curing unit. There is no significant difference in the 10<sup>th</sup> second which can be connected with light intensity. During the first 10 seconds of illumination, Lux-o-Max had intensity of  $50 \text{ mW/cm}^2$ , while the exponential mode of Elipar Trilight unit had  $100 \text{ mW/cm}^2$ . In the 20<sup>th</sup> and 40<sup>th</sup> second the light intensity for Lux-o-Max was  $150 \text{ mW/cm}^2$  and for Elipar Trilight  $800 \text{ mW/cm}^2$ . The greater difference between the light intensity of these two curing units has, as a consequence, greater difference between the achieved temperature values.

## Conclusion

Quite an equal degrees of conversion and markedly lower temperature increase were obtained in the case of polymerization with the blue LED curing unit compared to the conventional halogen unit. It can be assumed that lower heating of the composite material will lead to lower heating of vital pulp tissue. Further development of LED technology and its clinical use will show its advantages and disadvantages in comparison with the halogen curing unit.