Temperature Rise During Photo-polymerization Under Ceramic Restorations

Dimitrios Dionysopoulos, Constantinos Papadopoulos, Pantelis Kouros, Effrosyni Tsitrou, Eugenia Koliniotou-Koumpia

Department of Operative Dentistry, School of Dentistry, Aristotle University of Thessaloniki, Greece.

Abstract

Aim: The aim of this study was to measure the temperature increase induced by various light-curing units during photo-polymerization beneath ceramic restorations.

Methods: Three light-curing units were used; a high intensity QTH unit Elipar 2500 and two LED units: Translux Power Blue and Excelled 1400. The 15 ceramic specimens (CEREC Blocks) used in this study were of 2.5 mm thickness, 5 mm wide and 6 mm long and made using a slow speed saw. Using the same slow speed saw the occlusal enamel portion of 15 mandibular third molars was removed and 15 dentin discs of 1 mm height were prepared. The thickness of the luting cement was delimited to 0.5 mm, using a Teflon mold and then brought into contact with the dentin disc. Light-curing time for all the groups was 20 sec. The temperature rise was measured placing underneath the dentin disc a K-type thermocouple wire connected to a data logger. Five measurements were carried out for each group. Statistical analysis was performed using ANOVA (a=0.05).

Results: The results indicated that there was a lower temperature rise induced from Translux Power Blue than from the other two light-curing units, which did not present statistically significant difference ($p<0.05$). However, temperature rise from the light-curing units used in this study is lower than 5.5^{o}C, which is the limit of pulpal damage.

Conclusions: Within the limitations of this study, although the type and characteristics of light-curing units may affect temperature rise under ceramic restorations, this influence is possibly not of clinical significance.

Key Words: Light-curing Units, Ceramic Restorations, Temperature Rise

Introduction

Dental pulp is a specialized tissue, which performs its vital functional mission within a specific temperature range. An intrapulpal temperature increase of 5.5˚C, resulting in a critical temperature of 42.5˚C, could cause irreversible damage to the pulpal tissue [1]. However, this threshold remains controversial in the light of most recent studies [2].

Polymerization of light-curing resin cements used in ceramic restorations results in a temperature increase caused by both the exothermic reaction process and light delivered from the light-curing unit [3]. Although, dentin has a low thermal conductivity, in deeper preparations, the potential for pulp damage is greater as the tubular surface area increases [4]. Thus, the remaining dentin thickness of the cavity preparation is of great importance for the vitality of the pulp. Observations have indicated temperature rise of between 10 and 18°C within composites and adjacent tooth structures [5].

The amount of light energy received in the resin cement is affected by many variables, such as light intensity of the curing unit, duration of photo-polymerization, mode of the irradiation, diameter of the tip of the guide, distance from the tip of the guide, as well as composition, thickness, shade, and opacity of the resin cement and the ceramic material used [6-8].

Quartz-Tungsten-Halogen (QTH) Light-Curing Units (LCUs) are the most often used light sources for composite photo-polymerization, yet their major disadvantage is heat generation [9]. These types of light sources usually operate at light intensities between 400 and 800 mW/cm^2 and polymerize the resin-based material within 40 sec to a depth of 2 mm. Newer high intensity QTH LCUs have been introduced which can operate in excess of 1500 mW/cm^2 in order to reduce the polymerization time [10]. The wavelengths of their light emission range from 400 to 500 nm [11].

Light Emitting Diode (LED) curing units are highly efficient light sources because they emit very narrow spectral ranges. In particular, the wavelength of their light emission is around 470 nm and this coincides with absorption peak of the most common photoinitiator of resin-based materials, the camphorquinone [12]. The curing efficiency of LEDs is explained by the better match of their emission spectra with camphorquinone, than the broad spectra of QTH lamps [13]. LED technology promises comparable curing abilities to QTH units at lower polymerization temperatures [14]. LEDs have a lifetime of over 10,000 hours and undergo little degradation of output over this time. Furthermore, they require no filters to produce blue light, are resistant to shock and vibration, and take little power to operate [15].

Aim

The aim of this *in vitro* study was to evaluate temperature increase induced by one high intensity quartz-tungten-halogen (QTH) and two light emitting diode (LED) light-curing units during photo-polymerization beneath ceramic restorations.

The null hypothesis of the study was that the temperature rise under the ceramic restorations was similar for all the light-curing units investigated.

Methods

Three LCUs were used in this study; a high intensity quartz-tungsten-halogen unit Elipar 2500 (3M ESPE) and two LED units: Translux Power Blue (Hereaus) and Excelled 1400 (Jovident) (*Table 1*). The 15 ceramic specimens (CEREC Blocs, Sirona) (*Table 2*) used in this study were of 2.5 mm

Corresponding author: Dr. Dimitrios Dionysopoulos, Department of Operative Dentistry, School of Dentistry, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece, Tel: +302310999579; Fax: +302310999599; e-mail: ddiondent@gmail.com

thickness, 5 mm wide and 6 mm long and made using a slow speed saw (Isomet 1000; Buehler Ltd, Lake Bluff, IL, USA) under water cooling.

Fifteen intact mandibular third molars, which were extracted for orthodontic reasons, were used in the present study. The teeth were stored in 0.2% thymol for not more than 4 months, and randomly assigned to 3 groups of 5 teeth each. Prior to the experimental part of the study the teeth were cleaned of all superficial debris using an ultrasonic scaler. Using the same slow speed saw under water cooling the occlusal enamel portion of the teeth was removed by sectioning it perpendicular to the long axis of each tooth and 15 dentin discs of 1 mm height were prepared.

The thickness of the commercially available self-etch luting cement used (Rely X Unicem - 3M ESPE, St. Paul, MN, USA) was delimited to 0.5 mm, using a Teflon mold and then brought into contact with the dentin disc. A silicone mold was prepared as a supporting structure for the dentin/resin cement/ceramic complex (*Figure 1*). Light-curing time for all the groups was 20 sec (fast-start curing mode) and the tip of each light device was in contact with the ceramic specimens and was centered on the ceramic surface.

The temperature rise was measured by placing underneath the dentin disc a K-type thermocouple wire connected to a data logger (Pico Log, Pico Technology Ltd, Cambridgeshire, UK). The sampling rate of the data logger was set to one sample every second for a recording period starting 5 sec before light-curing for 60 sec. Five measurements were carried out for each group in room temperature (23 ± 0.5°C). The difference between the initial and highest temperature readings was recorded and the 5 calculated temperature changes were averaged to determine the mean value in temperature rise. The curing radiometer Hilux Curing Light Meter (Benlioglu Dental Inc, Turkey) was used to measure the intensity output of each light unit.

Statistical analysis was performed using analysis of variance (ANOVA) and Tukey HSD test (SPSS 19.0) at a level of significance of a=0.05.

Results

The mean values of the lowest and highest temperature readings and the average temperature changes during photo-polymerization of each experimental group are shown in *Table 3*. The graphic form of a representative measurement of temperature change for each light-curing unit is presented in *Figures 2-4*.

The results indicated that there was a significant lower temperature rise induces from the Translux Power Blue LCU than from the other two LCUs ($p<0.05$) (*Figure 5*). But no statistical difference was seen between the Elipar 2500 and the Excelled 1400 LCUs ($p>0.05$). However, temperature rise from the LCUs used in this study is lower than 5.5°C, which is the limit of pulpal damage.

Table 1. *The light-curing units used in the present study.*

Light-curing unit	Type	Manufacturer	Light intensity mW/cm^2	Diameter of the tip (mm)
Elipar 2500	QTH	3M ESPE, St. Paul, MN, USA	1300	8
Translux Power Blue	LED	Heraeus Kuzler GmbH, Hanua, Germany	1000	8
Excelled 1400	LED	Jovident GmbH, Duisberg, Germany	1400	8

Table 2. *The chemical composition of Cerec Blocs.*

Oxide	% of total weight
SiO_2	56-64
Al_2O_3	20-23
Na_2O	6-9
K_2O	6-8
CaO	0.3-0.6
TiO_2	0-0.1

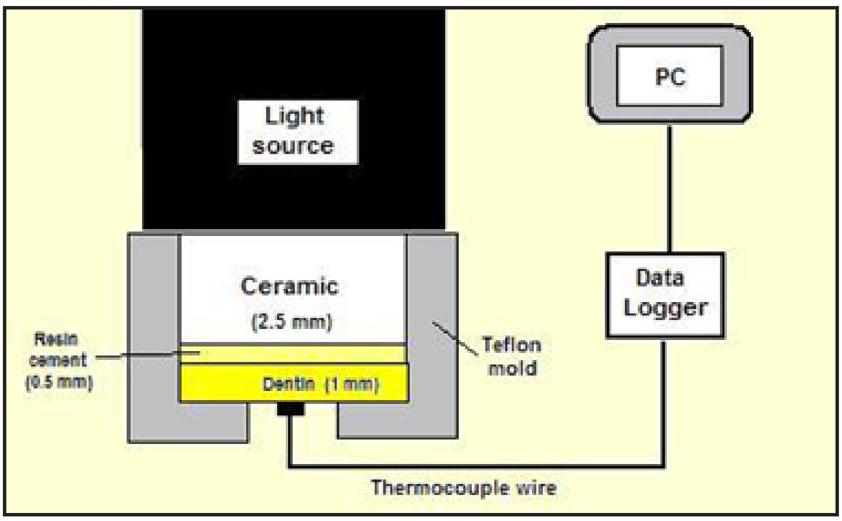

Figure 1. *ments during photo-polymerization of resin cement through ceramic bloc.*

Table 3. *Mean and standard deviations of temperature change, as well as the highest and the lowest temperature recorded for each light-curing unit.*a,b- Same letter as superscript in "Average change of temperature " indicates no statistically significant difference (p>0.05).*

Light-curing unit	Lowest temperature (°C)	Highest temperature (°C)	Average change of temperature (°C)
Elipar 2500	23.50	28.18	4.65 ± 0.15^{a}
Excelled 1400	27.28	27.64	4.30 ± 0.16^{a}
Translux Power Blue	23.42	26.66	3.19 ± 0.16^{b}

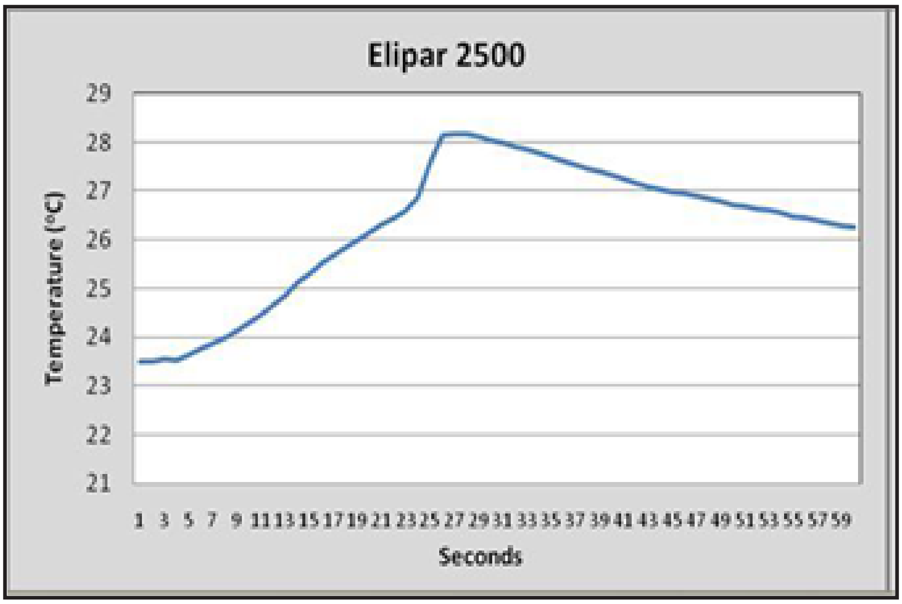

Figure 2. *Temperature change during photo-polymerization with Elipar 2500.*

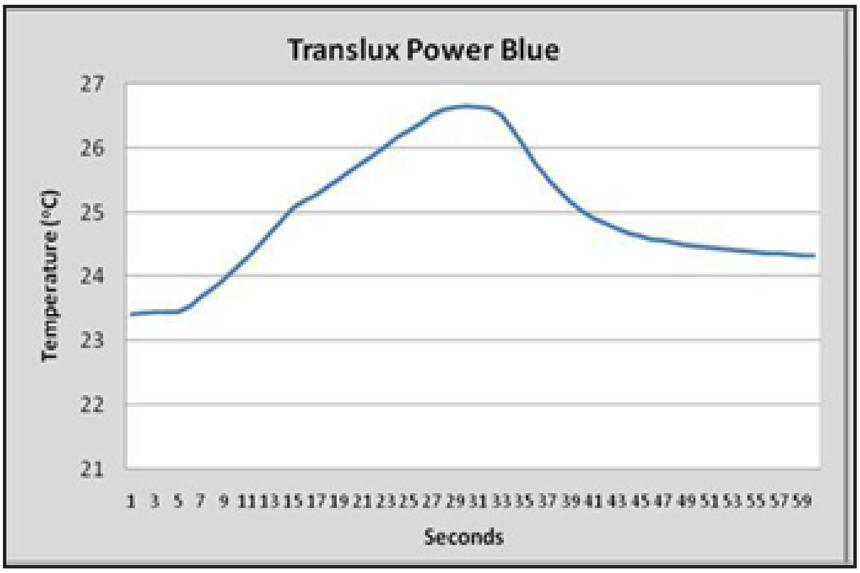

Figure 3. *Temperature change during photo-polymerization with Translux Power Blue.*

Discussion

The results obtained from this *in vitro* study demand rejection of the first null hypothesis that there were no significant differences in temperature rise under the ceramic restorations among the light-curing units investigated. This is in agreement with previous studies, which investigated the temperature rise under ceramic restorations using various light-curing units [16,17].

In the current study, the averaged temperature rise under the dentin discs was between 3.1°C and 4.6°C from a starting temperature of 23°C. Even the highest temperature increase was less than 5.5°C which is the estimated critical temperature for damaging the pulp. The temperature of 23°C was used as a baseline in this *in vitro* study. Perhaps the temperature of 37°C (the normal intrapulpal temperature) might have been more appropriate [3] In this study the highest rise in temperature was induced by the QTH light-curing system Elipar 2500. This is in agreement with previous studies which reported that LEDs induce lower temperature rise than QTH lamps [18,19]. However, there was no significant difference in comparison with temperature increase induced by LED Excelled 1400. Nevertheless, the LED Translux Power Blue exhibited significant lower temperature rise than the other two LCUs. This may be due to the lower light intensity of the device (1000 mW/cm^2) compared to Elipar 2500 (1300 mW/cm^2) and Excelled 1400 (1400 mW/cm^2). This finding supports the work of Hannig and Bott [3], who found that light intensity rather than the type of light source was important.

In agreement with the findings of previous studies, the results of this study demonstrated an almost instantaneous temperature rise, occurring as soon as the light source was

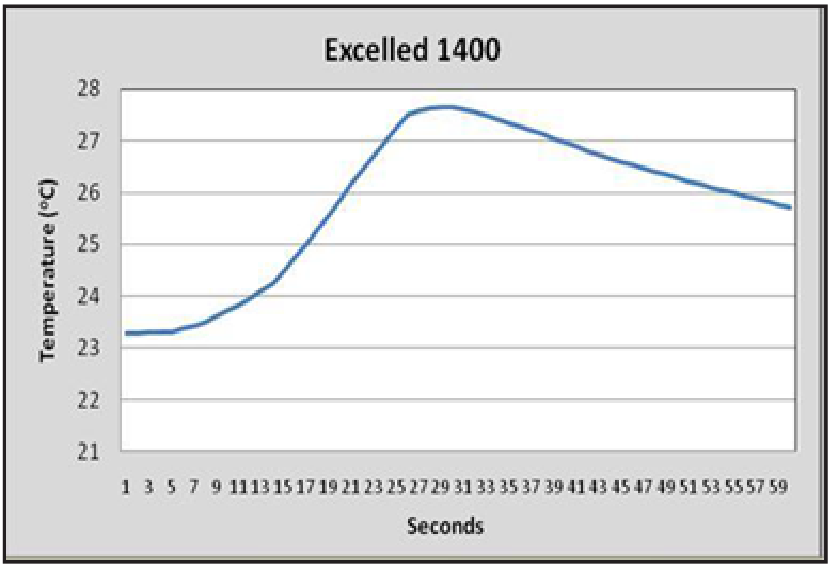

Figure 4. *Temperature change during photo-polymerization with Excelled 1400.*

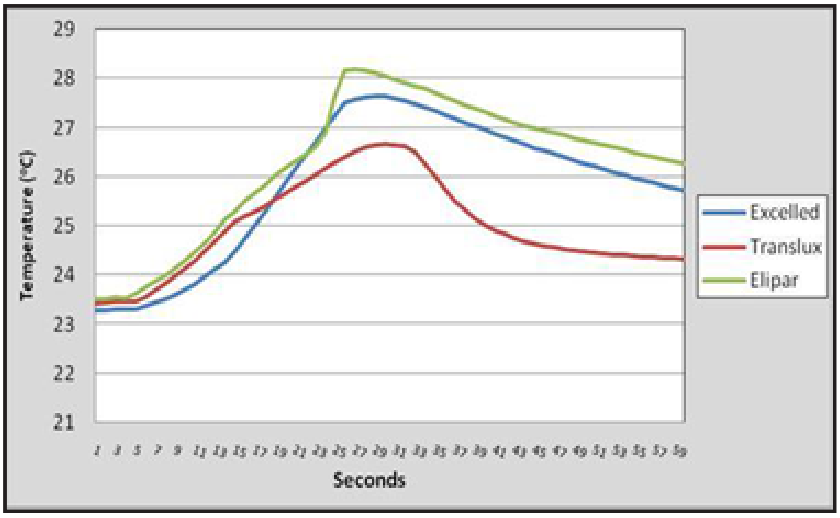

Figure 5. *Temperature change during photo-polymerization with all light-curing units used in this study.*

activated, regardless the LCU used. The highest temperature was achieved, just after finishing the exposure time, as well as the temperature continues to rise almost linearly while the light is on [5,7].

As mentioned before, the thickness of ceramic restoration and resin cement affects the temperature rise in the pulp chamber [20]. In particular, temperature increases correspond with decreased material thickness [12]. In the present study the thickness of the ceramic specimens was 2.5 mm, which is in respect with deep cavity preparation for ceramic inlays or onlays. Moreover, the thickness of the resin cement was 0.5 mm as manufacturer recommends.

It has been found that the type of ceramic system shows a significant effect on temperature increase [17]. This may be due to the different composition and density of the ceramic systems which influence thermal conductivity of the material [21]. In this study only one type of ceramic system (CEREC Blocs, Sirona) was investigated.

Furthermore, the temperature values measured in this study cannot be directly compared to temperature changes *in vivo*, because the experimental design of this study did not consider heat conduction within the tooth due to the effect of blood circulation in the pulp chamber [22]. Additionally, the surrounding periodontal tissues may limit the increase pulp temperature during photo-polymerization [3].

The soft-start mode LCUs were introduced to reduce polymerization shrinkage of resin-based materials [23]. In addition, the soft-start mode light sources slow the temperature rise within the resin-based material resulting in a lower temperature maximum. As a consequence, the tissue has more time to adapt itself and recover from the trauma [24]. Although, in the present study the temperature rise induced by fast-start mode LCUs was higher than that recorded with soft-start mode in previous studies [5] this temperature rise was lower than 5.5°C, which is the critical temperature rise that causes irreversible pulp damage [1].

Many studies investigating the increase of temperature within the pulp cite Zach and Cohen [1] as evidence that heat can seriously affect the pulp. However, some other studies have failed to demonstrate the loss of vitality experienced in that study [1]. More specifically, Nyborg and Brannstrom [25] reported that pathologic changes with aspiration and loss of odontoblasts occurred in all teeth subjected to heat [25]. Baldissara et al. [2] reported no necrotic or reparative changes in teeth following intrapulpal temperature rise averaging 11.2°C [2]. Moreover, Eberhard et al. [26] who focused on the detection of inflammatory mediators produced in response to heat as a noxious stimulus, found a significant increase in the synthesis of leukotriene B4 within the pulp cell cultures exposed to temperature increases of up to 7°C, similar to those deemed relevant to clinical practice [3,26].

Although the results of this study show that the temperature rise induced by the tested LCUs is low, the right choice of the LCU for the photo-polymerization of resin-based materials may play important role in pulp health when deep prepared cavities are restored. Dentists have to be informed about the technical characteristics of the LCUs in order to use the appropriate device for each clinical case.

Conclusions

Within the limitations of this *in vitro* study the following statements can be concluded:

1. Translux Power Blue induced lower temperature rise under ceramic restorations than the other two LCUs, which did not present statistically significant difference. This lower temperature change may be attributed to the lower light intensity of the device.

2. Although the type and characteristics of LCUs may affect temperature rise under ceramic restorations, this influence is possibly not of clinical significance (<5.5°C).

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