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Original

Influence of the light curing unit and thickness of residual dentin on generation of heat during composite photoactivation

Ricardo D. Guiraldo, Simonides Consani, Thais Lympius, Luis F. J. Schneider,
Mario A. C. Sinhoreti and Lourenço Correr-Sobrinho

Department of Restorative Dentistry, Dental Materials Division, Piracicaba Dental School,
State University of Campinas, Piracicaba, SP, Brazil

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Abstract: **The aim of this study was to determine the effect of different types of composites (Filtek Z250, Esthet X and Filtek Supreme) and dentin thicknesses (0.5 or 1.0 mm) on the generation of heat during photoactivation by QTH (conventional halogen light), LED (light emitting diode), and PAC (xenon plasma light) light-curing units. Temperature changes were recorded with a thermocouple type K connected to a digital thermometer. Twenty chemically polymerized acrylic resin bases were prepared in order to guide the thermocouple and to support the dentin disks. On the acrylic resin base, elastomer molds of 2.0-mm thickness were adapted. The temperature increase was measured after composite photoactivation and the matrix was stored at 37°C. After 24 hours, photoactivation was performed again and the temperature increase was measured. Obtained data were analyzed by ANOVA and Tukey's test ($\alpha = 0.05$). The mean temperature increase produced by QTH was significantly lower than that of the other photoactivating units ($P < 0.05$), due to its low radiant exposure. There were no significant differences among the samples with regard to dentin thickness and type of composites ($P > 0.05$). The immediate temperature rise was statistically higher when compared to the increase after additional polymerization (24 h), in all groups ($P < 0.05$). Light intensity and exposure time appeared to be the most important factors causing temperature change. (J. Oral Sci. 50, 137-142, 2008)**

Keywords: composite types; dentin thickness; photoactivation; light-curing units; generation of heat.

Introduction

A dental composite can be defined as a three-dimensional combination of at least two chemically different materials, with a different interface separating the components (1). Basically, they are composed of an organic matrix, load particles (glass, quartz and/or melted silica) and a bonding agent, usually an organic silane, with a dual characteristic enabling chemical bonding with the load particle and co-polymerization with the monomers of the organic matrix (1).

Photoactivation is performed with visible light belonging to the blue area of the electromagnetic spectrum to excite camphorquinone (the most commonly used photo initiator in composite resins) that possesses an absorption spectrum in the interval between 400 and 500 nm. The most efficient wavelength for polymerization would be 468 - 470nm (2), which induces rupture of benzoate peroxide molecules together with a tertiary amine (3), followed by polymerization by addition. Among the photoactivation units available in the market, the most traditional ones are those that use halogen lamps as a light source.

Light emitting diode (LED) was developed to minimize the heat produced by the halogen lamp during photoactivation (4). LED, emitting a wavelength between 455 and 486 nm, is related to the camphorquinone absorption

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Correspondence to Dr. Simonides Consani, Faculdade de Odontologia de Piracicaba, UNICAMP, 901 Av. Limeira, 13414-903 - Piracicaba, SP, Brazil
Tel: +55-19-21065345
Fax:+55-19-21065218
E-mail: consani@fop.unicamp.br

spectrum (5). The plasma arc was developed with the aim of increasing the speed of photoactivation. Due to the elevated light intensity produced, the plasma arc can promote temperature increase, which is harmful to the pulp tissue (6-8).

In an *in vivo* experiment performed by Zach and Cohen (9), it was demonstrated that teeth from *Rhesus* monkeys subjected to different temperature increases suffered irreversible pulp changes due to the elevation of temperature within the pulp chamber. Thermal trauma can be induced during preparation of cavities or application of lining or restorative materials (10). Several authors (11-13) have suggested that photoactivation by visible light can also contribute to temperature increase inside the pulp chamber, damaging the pulp.

High light irradiance increases the temperature during polymerization due to a greater amount of radiation energy supplied by the photoactivation unit (6). When the residual dentin thickness is minimal in cavities without lining and the activation intensity is high, the irradiation time required to photoactivate the adhesive must be minimal (14).

Hannig and Bott (7) investigated the effect of different photoactivation units on the temperature that reached the pulp chamber during composite curing and reported temperatures exceeding 42.5°C. It would be interesting to compare the effect of different photoactivation sources and residual dentin thickness on heat generation during composite polymerization.

The objective of this study was to verify the effect of different photoactivation methods on the thermal variations occurring during the photoactivation of composite resins (Filtek Z250, Esthet X, and Filtek Supreme) with different dentin thickness (0.5 or 1.0 mm). We hypothesized that the thermal variations that occurred during the polymerization were dependent on the photoactivation/thickness of the residual dentin.

Materials and Methods

Three restorative resin composites of shade A3 were used in this study (Table 1): Filtek Z250 (3M-ESPE, St. Paul, MN, USA), Esthet X (Dentsply-Caulk, Milford, DE, USA) and Filtek Supreme (3M-ESPE). The A3 shade is an intermediary shade that was used to standardize the light absorbed during the photoactivation procedure. The three light curing units used included a conventional halogen light-curing (Degulux Soft-Start, Degussa Dental, Hanau, Germany); a light-emitting diode curing (Ultra-Lume 5, Ultradent, South Jordan, UT, USA); and a plasma arc curing unit (Apollo 95E, DMD, Westlake Village, CA, USA). The characteristics of the light curing units (LCU) are shown in Table 2. The light intensity was measured by a radiometer Model 100 Curing Radiometer (Demetron Research Corporation, Danbury, CT, USA).

Temperature change was recorded by a thermocouple K connected to a digital thermometer (Iopetherm 46, IOPE, São Paulo, Brazil), with 0.1°C of accuracy. Twenty bases of chemically polymerized acrylic resin (JET, Artigos Odontológicos Clássico, São Paulo, Brazil) were prepared to serve as guide for the thermocouple and as support for the dentin discs. Ten bases were used with 0.5-mm-dentin discs and ten with 1.0-mm-dentin discs. All discs were derived from bovine teeth. The dentin discs were used to simulate two different thicknesses remaining after cavity preparation. The dentin discs were not treated with adhesive

Table 1 Information about the composites employed according to the manufacturers

Composite	Manufacturer	Organic Matrix	Filler	Shade	Batch number
Filtek Z250	3M-ESPE, St Paul, USA	BIS-GMA, UDMA and BIS-EMA	60% in volume (average of 0.19 to 3.3µ) – Zr and Si	A3	4KG (1370A3)
Esthet X	Dentsply-Caulk, Milford, USA	BIS-GMA and TEGDMA	60% in volume (0.6 to 0.8µ and 0.02 to 2.5µ - glass powder (BAFG) 10 to 20nm - silica dioxide)	A3	0510281
Filtek Supreme	3M-ESPE, St Paul, USA	BIS-GMA, BISEMA,UDMA and TEGDMA	59,5% in volume (clusters of 0.6 to 1.4µ - particules of 5 to 20nm) – Zr and Si	A3B	4EJ (3910A3B)

BAFG = Barium aluminoflurosilicate glass.

since it is difficult to standardize the adhesive thickness in clinical situation, and this would be an undesired variable of the *in vitro* study.

Circular molds made of elastomer (2 mm height and 3 mm diameter) were adapted on the acrylic resin bases to standardize the composite thickness (Fig. 1).

The composite was inserted into the circular elastomer mold, covered with a polyester strip and photoactivated by LCU. For photoactivation, the curing tips were positioned close to the elastomer mold/restorative composite set. With the conventional halogen light (QTH) and light emitting diode (LED), photoactivation was performed for 20 seconds, according to the manufacturer's recommendation. For light emitted by the xenon plasma light (PAC), photoactivation was performed for 10 seconds, based on previous literature (15). Eighteen experimental groups (n = 10) were established.

All the measurements were performed in a temperature/humidity-controlled room, with a constant temperature of 21°C and 30% relative humidity. For temperature measurements, the initial temperature was recorded following temperature stabilization (21°C); the composite was then light cured and temperature peak (t_1) registered. The initial temperature was deducted from the final temperature, and the immediate temperature change (vt_1) obtained.

The photoactivation procedures were repeated after specimen storage in conditions of relative humidity, at 37°C for 24 h. The temperature (t_2) was considered as temperature peak, and (vt_2) as the temperature change that occurred in the photoactivation procedure, after 24 h.

Table 2 Characteristics of light curing units

LCU	Intensity of light	Equipment	Exposure
QTH	600 mW/cm^2	XL 2500	20 s
LED	700 mW/cm^2	Ultra-Lume 5	20 s
PAC	1400 mW/cm^2	Apollo 95E	10 s

The temperature change data were analyzed with ANOVA and the means compared by Tukey's test, at 5% of significance level (α= 0.05).

Results

As shown in Table 3, for the LCU factor independent of other factors, the temperature increase with QTH was significantly lower than that with the other two methods. There was also no statistically significant difference among the composites when the composite factor, independent of other factors, was considered (Table 4).

Table 5 indicates that in the factor dentin thickness, independent of other factors, there was no statistically significant difference in the temperature increase between the two dentin thicknesses, while the immediate temperature rise in all groups was statistically higher than the values obtained after 24 h, as shown in Table 6.

Discussion

External heat applied to the tooth can increase the temperature within the pulp chamber, resulting in irreversible damage to the pulp (9). Thermal trauma can

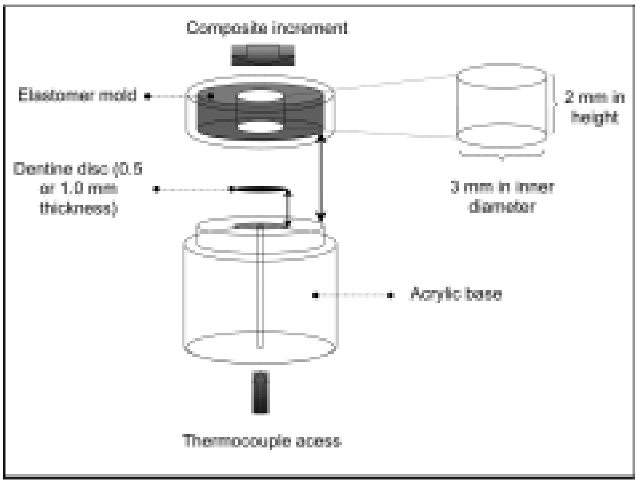

Fig. 1 Apparatus for measuring temperature changes.

Table 3 Mean temperature increase (Celsius degrees) for the light curing unit factor, independently of other factors

LCU	Temperature increase (°C)
LED	2.66 (0.82) a
PAC	2.66 (0.73) a
QTH	2.36 (0.68) b

Mean values followed by different lowercase letters differ statistically by the Tukey's test at 5% level. ( ) Standard Deviation.

Table 4 Mean temperature increase (Celsius degrees) for restorative resin composites factor, independently of other factors

Restorative resin composites	Temperature increase (°C)
Filtek Z250	2.48 (0.70) a
Esthet X	2.59 (0.84) a
Filtek Supreme	2.61 (0.72) a

Mean values followed by different lowercase letters differ statistically by the Tukey's test at 5% level. ( ) Standard Deviation.

Table 5 Mean temperature increase (Celsius degrees) for dentin thicknesses factor, independently of other factors

Dentin thicknesses	Temperature increase (°C)
0.5 mm	2.54 (0.79) a
1.0 mm	2.58 (0.73) a

Mean values followed by different lowercase letters differ statistically by the Tukey's test at 5% level. ( ) Standard Deviation.

Table 6 Mean temperature increase (Celsius degrees) for the immediate/after 24 hours temperature increase factor, independently of other factors

Groups (light curing unit/restorative resin composites/dentin thicknesses)	Immediate temperature increase	After 24 hours temperature increase
QTH/Filtek Z250/0.5 mm	2.76 (0.59) a	1.95 (0.43) b
QTH/Filtek Z250/1.0 mm	2.55 (0.48) a	2.02 (0.36) b
QTH/Esthet X /0.5 mm	2.82 (0.85) a	1.67 (0.44) b
QTH/Esthet X /1.0 mm	2.83 (0.41) a	1.98 (0.64) b
QTH/Filtek Supreme /0.5 mm	2.93 (0.32) a	2.54 (0.42) b
QTH/Filtek Supreme /1.0 mm	2.47 (0.82) a	1.84 (0.64) b
LED/Filtek Z250/0.5 mm	2.96 (0.70) a	2.32 (0.79) b
LED/Filtek Z250/1.0 mm	2.96 (1.00) a	2.17 (0.73) b
LED/Esthet X /0.5 mm	3.03 (0.97) a	2.08 (0.59) b
LEd/Esthet X /1.0 mm	3.28 (0.90) a	2.69 (0.98) b
LED/Filtek Supreme /0.5 mm	2.99 (0.48) a	2.40 (0.38) b
LED/Filtek Supreme /1.0 mm	2.84 (0.76) a	2.29 (0.65) b
PAC/Filtek Z250/0.5 mm	2.89 (0.59) a	2.12 (0.28) b
PAC/Filtek Z250/1.0 mm	2.90 (0.57) a	2.22 (0.62) b
PAC/Esthet X /0.5 mm	3.05 (0.58) a	2.35 (0.67) b
PAC/Esthet X /1.0 mm	3.11 (0.72) a	2.21 (0.53) b
PAC/Filtek Supreme /0.5 mm	3.17 (0.76) a	2.42 (0.81) b
PAC/Filtek Supreme /1.0 mm	3.03 (0.81) a	2.45 (0.74) b

Mean values followed by different small letters in line differ statistically among increment-type for the Tukey's Test at the 5% level. ( ) Standard Deviation.

be induced by cavity preparation, exothermic reaction of cements and restorative materials or heat generated by photoactivating units (4). Thus, the activation of composites by means of visible light can also contribute to temperature increase inside the pulp chamber causing damage to the pulp integrity (11). The hypothesis of the present *in vitro* study that the thermal variations occurring during light curing could be dependent on the photoactivating methods/dentin thickness was partially accepted.

The temperature increase caused by photoactivation occurs due to the energy density produced by the photoactivating unit (3). The conventional photoactivating unit with halogen light (Degulux Soft-Start Degussa) used in this study emitted a radiant exposure of 12 J/cm^2, considering that the light intensity was 600 mW/cm^2 during 20 seconds (J = light intensity × exposure time / 1,000). Under similar conditions, LED (Ultra-Lume, Ultradent) emitted a radiant exposure of 14 J/cm^2 (700 mW/cm^2 for 20 s), and PAC (Apollo 95E, DMD) emitted a radiant exposure of 14 J/cm^2 (1400 mW/cm^2 for 10 s). Figure 2 shows the wavelength distributions of the light curing units. The temperature increase produced by QTH was significantly lower than that of the other photoactivating units, which was probably due to the low radiant exposure.

According to Lloyd and Brown (16), the exothermic reaction occurring during light curing is directly related to the quantity of inorganic content in the composite. Thus, the smaller the inorganic content, the larger the organic amount and, consequently, larger the exothermic reaction. The findings observed in this study were due to the similarity of inorganic content among the composites, where Filtek Z250, presented 60% of the portion expressed in volume, Esthet X with 60%, and Filtek Supreme with 59.5% did not differ statistically in the temperature increase (Table 4).

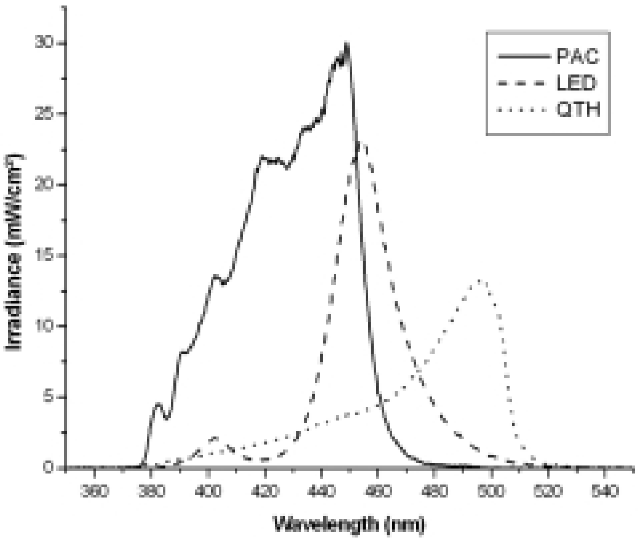

Fig. 2 Wavelength distributions of the light curing units.

The heat that reaches the pulp is influenced by both dentin thickness (17) and thermal conductivity of the resins (18), which is considered to be within the range of 25-30 × 10^{-4} to 12-15 × 10^{-4} (cal/sec/cm^2[°C/cm]).

According to Loney and Price (8), thicker dentin can reduce the temperature because of the low thermal conductibility of this substrate. The present study did not confirm this assertion. There was no statistically significant difference in the temperature increase for different dentin thicknesses. Considering that the composite volume was similar in all groups, this result could have occurred because the difference in thickness of dentin discs was not enough to determine different temperature increase recorded by the thermometer. Although this study was performed in matrix, the result can be considered clinically relevant. Composite resin restorations of 2-mm thickness made in cavities with 0.5 or 1.0 mm of residual dentin would not cause a temperature increase harmful to the pulp tissue, as only values over 5.5°C would be harmful to the pulp (9).

According to Lloyd et al. (12), the most important factor causing a temperature increase during composite photoactivation would be the heat developed by the light curing units. Thus, the exothermic reaction resulting from composite photoactivation would be a secondary factor. This was also observed in this study, when the irradiation was made on the composite already cured (after 24 h), proving that, in this case, a temperature increase was promoted by the irradiation emitted by the light curing units (Table 6). There was a statistically significant difference between immediate photoactivation and after 24 h, when theoretically there is no photoactivation reaction that causes temperature increase.

Our results seem to indicate that the correlation between the intensity of light emitted by light curing units and the exposure time would have a higher influence on the temperature increase than the residual dentin thickness and/or the restorative material.

Based on the results analyzed and discussed, it may be concluded that:

1. The QTH LCU equipment produced a lower temperature increase when compared to LED and PAC.
2. There was no significant difference in the temperature increase among the restorative materials and between the dentin thicknesses.
3. The immediate temperature rise in all groups was significantly higher when compared to the increase in temperature after additional polymerization (24 h).

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