INFLUENCE OF LIGHT ENERGY DENSITY ON HEAT GENERATION DURING PHOTOACTIVATION OF DENTAL COMPOSITES WITH DIFFERENT DENTIN AND COMPOSITE THICKNESS

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ABSTRACT

*O*bjective: The aim of this study was to determine the influence of different energy densities on the heat generated during photoactivation of Filtek Z250 (3M/ESPE) and Z100 (3M/ESPE) composite resins with different dentin and composite thickness. Material and Methods: The temperature increase was registered with a type-K thermocouple connected to a digital thermometer (Iopetherm 46). A chemically polymerized acrylic resin base was prepared to serve as a guide for the thermocouple and as a support for 0.5-, 1.0-, and 1.5-mm-thick bovine dentin discs. Circular elastomer molds (1.0 mm-height x 3.0-mm diameter or 2.0-mm height x 3.0-mm diameter) were adapted on the acrylic resin base to standardize the composite resin thickness. A conventional halogen light-curing unit (XL 2500, 3M/ESPE) was used with light intensity of 700 mW/cm². Energy density was calculated by the light intensity applied during a certain time with values of 28 J/cm² for Z100 and 14 J/cm² for Filtek Z250. The temperature change data were subjected to three-way ANOVA and Tukey's test at 5% level. Results: The higher energy density (Z100) promoted greater temperature increase ($p < 0.05$) than the lower energy density (Filtek Z250). For both composites and all composite thicknesses, the lowest dentin thickness (0.5 mm) yielded significantly higher ($p < 0.05$) temperature increase than the other two dentin thicknesses. The 1-mm-thick composite resin layer yielded significantly higher ($p < 0.05$) temperature changes for both composites and all dentin thicknesses. Conclusions: Temperature increase was influenced by higher energy density and dentin/composite thickness.

Key words: Energy density. Dentin thickness. Composite thickness. Production of heat. Temperature increase.

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[14]. 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 making possible the chemical bonding with the load particle and the co-polymerization with the monomers of the organic matrix[14]. The resin matrix is a flowing component that becomes rigid when polymerized, due to the formation of free radicals that end up inducing covalent bonds among the organic molecules, generating macro-molecules denominated polymers[3]. For such purpose, it is necessary that an activator-initiator system generates enough energy to break the amina molecule and form free radicals[7,14].

Photoactivation is performed with visible light belonging to the blue region of the electromagnetic spectrum to excite camphorquinone, which is the most common photoinitiator present in composite resins and has an absorption spectrum in the 400 and 500 nm range. The most efficient wavelength range for polymerization would be between 468 and 470 nm[13], which excites the camphorquinone and induces the rupture of amina[16], followed by an addition reaction polymerization.

Among the light-curing units available in the market, the most traditional ones are those that use halogen lamps

as light source. However, the main irradiation produced by those lamps is in the infrared spectral region, which is absorbed by the composite and results in great molecular vibration and generation of heat[19]. Thus, light sources that use halogen lamps need absorbent filters that reduce the passage of infrared energy to the tooth[16]. The efficiency of these filters varies according to the manufacturer and, as a result, the non-absorbed energy can produce heat.

Increase in light intensity can lead to temperature rise during polymerization due to larger radiation energy supplied by the light-curing unit[6]. Polymerization of composites using visible light generates a temperature increase due to both the exothermal reaction process, which is typical of addition polymerization, and the energy absorbed during irradiation with the halogen light source[12,18]. For this reason, when the thickness of the residual dentin is small in cavities without lining and the light intensity is high, the curing time should be minimum[18].

It has been suggested that visible light photoactivation can also contribute to increase the temperature inside the pulp chamber, causing pulpal damages[9,11,12]. However, the findings of a recent study investigating the thermal variations in the pulp chamber associated with composite insertion techniques and light-curing methods showed that when the bulk-increment technique was used there was no significant difference in temperature increase among the photoactivation methods (Continuous, Intermittent light, or Soft-Start)[4], as well as between different shades of the same composite[1]. Pulp damage can occur when a source of external heat is applied on the dental structure because the increase of the temperature inside the pulp chamber can result in an irreversible inflammatory pulpal reaction[8,20].

Based on these considerations, it would be important to verify the effect of different energy densities on the heat generated during the photoactivation of Filtek Z250 and Z100 composite resins with different dentin (0.5, 1.0, and 1.5 mm) and composite (1.0 and 2.0 mm) thicknesses. The null hypothesis tested was that different energy densities influence the heat produced during composite photoactivation with different dentin and composite thicknesses.

MATERIAL AND METHODS

Two restorative composite resins were used in this study: Filtek Z250 and Z100 (Figure 1). A conventional halogen light-curing unit (XL 2500, 3M/ESPE, St. Paul, MN, USA) was used with light intensity of 700 mW/cm² checked with a curing radiometer (Model 100; Demetron Research Corporation, Danbury, CT, USA). The energy density was calculated as follows: energy density (J/cm²) is the light intensity (mW/cm²) applied during a certain time (s) divided by 1,000 (Table 1). The spectral distributions were obtained using a spectromer (USB 2000, Ocean Optics, Dunedin, FL, USA) (Figure 2).

Temperature changes were recorded using a type-K thermocouple connected to a digital thermometer (Iopetherm 46; IOPE, São Paulo, SP, Brazil) accurate to 0.1ºC. An apparatus for temperature measurement similar to that developed by Schneider, et al.[17] (2005) was used. A chemically polymerized acrylic resin base (JET; Artigos Odontológicos Clássico, São Paulo, SP, Brazil) was prepared to serve as guide for the thermocouple and as support for 0.5-, 1.0-, and 1.5-mm-thick bovine dentin discs. The discs were positioned between the acrylic resin base and an elastomer mold to simulate different dentin thicknesses remaining after cavity preparation. Circular elastomer molds measuring either 1.0 mm-height and 3.0-mm diameter or 2.0-mm height and 3.0-mm diameter were adapted on the acrylic resin base to standardize the composite resin thickness (Figure 3).

The composite was inserted in the circular elastomer mold, covered with a Mylar strip and digitally pressed. For photoactivation, the tip of the light guide of the curing unit was placed in contact with the Mylar strip. The curing time was 20 s for Filtek Z250 and 40 s for Z100 according to manufacturer's instructions, which produced different energy densities. Twelve experimental groups (n=10) were established from the interactions among 2 energy densities, 3 dentin thicknesses and 2 composite thicknesses (Table 1).

All measurements were taken in a temperature/humidity-controlled room, with a constant temperature of 20°C ± 2°C and 30% relative humidity. For temperature measurements, the initial temperature was recorded following temperature stabilization. The composite was then light-cured and the temperature peak was registered. The initial temperature was deducted from the final temperature in order to determine the temperature increase.

Composit resin	Manufacturer	Organic matrix	Filler	Shade	Batch number
Filtek Z250	3M/ESPE, St. Paul, MN, USA	BIS-GMA, UDMA and BIS-EMA	60% in volume (0.19-3.3 µm) – Zr and Si	A3	4KG (1370A3)
Z100	3M/ESPE, St. Paul, MN, USA	BIS-GMA, TEGDMA	71% in volume (maximum 4.5 µm) – Zr and Si	A3	5WE (8004A3)

FIGURE 1- Tested materials

TABLE 1 - Characteristics of the experimental groups

| Groups (n=10)	Composite resin	Dentin thickness	Composite thickness	Light intensity (mW/cm²)	Exposure (s)	Energy density (J/cm²)
I	Z250	0.5 mm	1.0 mm	700	20	14
II	Z250	0.5 mm	2.0 mm	700	20	14
III	Z250	1.0 mm	1.0 mm	700	20	14
IV	Z250	1.0 mm	2.0 mm	700	20	14
V	Z250	1.5 mm	1.0 mm	700	20	14
VI	Z250	1.5 mm	2.0 mm	700	20	14
VII	Z100	0.5 mm	1.0 mm	700	40	28
VIII	Z100	0.5 mm	2.0 mm	700	40	28
IX	Z100	1.0 mm	1.0 mm	700	40	28
X	Z100	1.0 mm	2.0 mm	700	40	28
XI	Z100	1.5 mm	1.0 mm	700	40	28
XII	Z100	1.5 mm	2.0 mm	700	40	28
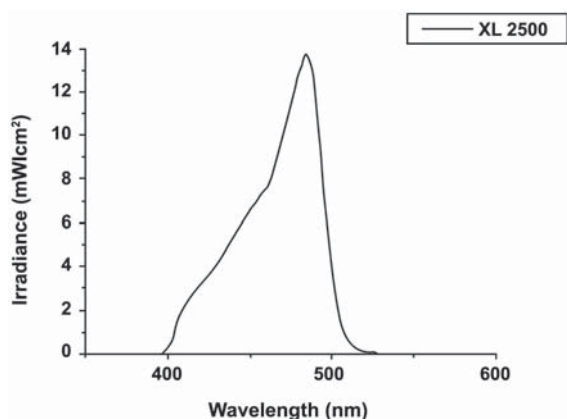
FIGURE 2- Spectral distributions of XL 2500

The temperature change data were submitted to three-way ANOVA and the means were compared by Tukey's test at 5% significance level.

RESULTS

There was statistically significant difference ($p<0.05$) for temperature increase (Table 2) between the larger energy density (Z100) and the lower energy density (Z250).

For Z250 and Z100 composites with 1.0 mm thickness, the 0.5 mm-thick dentin differed significantly from the 1.0 mm-thick dentin, which in turn was significantly different ($p<0.05$) from the 1.5 mm-thick dentin. For both composites with 2.0 mm in thickness, the 0.5 mm-thick dentin differed significantly ($p<0.05$) from the other two dentin thicknesses, which however were no significantly different ($p>.05$) from
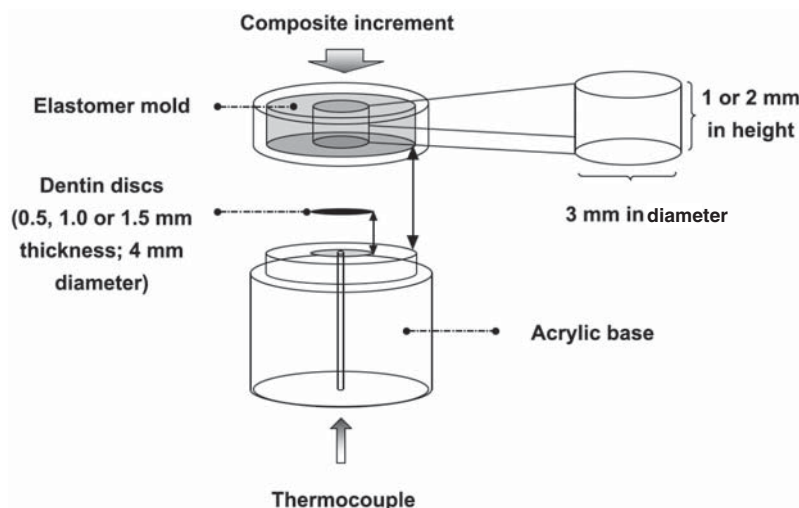

FIGURE 3- Apparatus used for measurement of temperature increase

TABLE 2- Mean temperature increase (^{0}C) for Z250 and Z100 composite resins, regardless of the dentin and composite thicknesses

Composite	Mean temperature increase
Z 100	3.18 (1.12) a
Filtek Z250	2.13 (0.92) b

Different letters indicate statistically significant difference (Tukey's test, p<0.05). Standard deviations are given in parentheses.

TABLE 3- Mean temperature increase (^{0}C) for Z250 composite resin for each dentin and composite thickness

Composite	Dentin thickness	Composite thickness	
		1.0 mm	2.0 mm
Filtek Z250	0.5 mm	3.87 (0.38) a,A	1.97 (0.20) a,B
	1.0 mm	2.56 (0.39) b,A	1.34 (0.17) b,B
	1.5 mm	1.81 (0.15) c,A	1.26 (0.09) b,B

Different lowercase letters in columns and uppercase letters in rows indicate statistically significant difference (Tukey's test, p<0.05). Standard deviations are given in parentheses.

TABLE 4- Mean temperature increase (^{0}C) for the composite Filtek Z100 for each dentin and composite thickness

Composite	Dentin thickness	Composite thickness	
		1.0 mm	2.0 mm
Z100	0.5 mm	5.01 (0.19) a,A	2.95 (0.30) a,B
	1.0 mm	4.24 (0.12) b,A	2.10 (0.21) b,B
	1.5 mm	2.85 (0.19) c,A	1.97 (0.18) b,B

Different lowercase letters in columns and uppercase letters in rows indicate statistically significant difference (Tukey's test, p<0.05). Standard deviations are given in parentheses.

restorative materials or heat generated by light-curing units[18,19]. Photoactivation of composites using visible light can also contribute to the increase in temperature inside the pulp chamber, with potential thermal damages to the pulp[11,12].

The increase of the temperature caused by photoactivation would result from the energy density emitted by the light-curing units[5,16]. Table 2 shows that the temperature increase produced by higher energy density (Z100) was significantly higher when compared to the lower energy density (Filtek Z250). It is likely the reason why in this study Z100 with energy density of 28 J/cm^2 promoted higher temperature increase than Z250 with energy density of 14J/cm^2. As the same light-curing unit (700 mW/cm^2)

each other. For both composites and all dentin thicknesses, the 1.0 mm-thick composite layer presented significantly greater temperature changes (p<0.05) than the 2.0 mm-thick composite increment (Tables 3 and 4).

DISCUSSION

The null hypothesis that different energy densities influence the heat produced during composite photoactivation with different dentin and composite thicknesses was accepted.

External heat applied to the tooth can increase the temperature in the pulp chamber resulting in irreversible damage to the pulp tissue[8,20]. Trauma can be induced by the cavity preparation, exothermal reaction of cements,

was used for both materials, the difference in the exposure time s (40 s for Z100 and 20 s for Filtek Z250, as *per* manufacturer's instructions) seems to be the main responsible for the differences in heat generation by altering the energy density. Z100 and Z250 composites were used in this study because they possess similar organic matrixes and different filler volumes, which did not influence the increase of temperature. In this situation, the results suggest that energy density was the major factor accounting for temperature rise.

The heat that reaches the pulp can be minimized by the dentin thickness remaining after cavity preparation. The thicker the dentin layer the greater the minimization temperature that reaches the pulp because the dentin has low thermal conductivity[10]. This situation was observed in this study as smaller thickness of residual dentin yielded

higher temperature increase values with statistically significant difference for both Filtek Z250 (Table 3) and Z100 (Table 4), except for the 1.0- and 1.5-mm-thick dentin discs with 2 mm-thick composite layer. This exception suggests that the resulting heat can be lessened by using a thickest composite layer. The light passing through the polymerized composite is absorbed and reflected, thus loosing intensity[7,15], which can generate similar temperature increase. Similarly, for both Filtek Z250 (Table 3) and Z100 (Table 4) composites and for all dentin thicknesses (0.5, 1.0 and 1.5 mm), the 1.0-mm-thick composite layer always resulted in significantly higher temperature increase than the thickness of 2.0 mm. A previous study showed that the heat produced in an irradiated empty cavity was always higher when compared to the polymerization of a 2.0-mm-thick composite increment. This is due to the extenuating capacity of the material to exceed the exothermal effect of the polymerization[18].

Within the limitations of this study, the results seem to indicate that the temperature increase resulting from the photoactivation of composites would be well tolerable by the dental pulp, even considering the extreme condition observed with Z100 composite, in which a higher energy density (28 J/cm^2) was used with 0.5 mm-thick dentin and 1.0 mm-thick composite increment. It has been demonstrated that temperature changes over 5.5ºC would be necessary to induce pulp alterations in monkey's teeth[20].

CONCLUSIONS

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

1 - The higher energy density (Z100) promoted higher temperature increase than the lower energy density (Z250).

2 - For both composites and all composite thicknesses, the lowest dentin thickness yielded significantly higher temperature increase than the other two dentin thicknesses..

3 - For both composites and all dentin thicknesses, the 1.0 mm-thick composite layer presented significantly greater temperature changes than the 2.0 mm-thick composite increment.

4 -Temperature increase was influenced by higher energy density and dentin/composite thickness

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