Temperature changes caused by light curing units on dentine of primary teeth

ABSTRACT

AIM This was to determine the temperature changes produced in dentine discs of primary teeth placed below a glass ionomer, microhybrid flow resin or microhybrid resin during the photocuring process with conventional halogen lamps and LEDs at different distances.

Study design Experimental design.

Materials and methods This in vitro study was carried out in the research laboratory of the Universitat Internacional de Catalunya. We cut 1 mm thick dentine discs with the Isomet® 1000 cutting machine. Thereafter, we cut stainless steel rings of different heights. Subsequently, to facilitate the temperature measurement, we prepared silicone moulds, in which the dentine disc, stainless steel ring and the digital thermometer/thermocouple were positioned. Once the silicone mould was finished, a 2 mm thick layer of the restorative material was placed on the dentine disc. Finally, the polymerisation process was conducted according to the times recommended by the manufacturers, and the temperature produced was recorded at the end of the procedure.

Statistical evaluation Replies were analyzed using the STATGRAPHICS® Plus Version 5.0 statistics software system, in order to obtain comparative diagrams and graphs using the ANOVA multifactorial system.

Results The photocuring lamps used on the restorative materials produced statistically significant differences in temperature, with p = 0.00001.

Conclusion Halogen lamps cause a greater temperature rise in materials than LEDs lamps, and the greatest rise is produced when microhybrid flow resin is photocured with the Optilux 501® halogen lamp.

Keywords: Halogen light; LED; Polymerization; Primary teeth; Temperature.

Introduction

The detrimental effects caused by the increase in temperature during restorative treatment on pulp tissues have been, and remain, a concern in dentistry [McCabe and Wilson, 1980; Hannig and Bott, 1999; Goodis et al., 1990]. The cavity preparation and the polymerisation of dental composites within the cavity can increase the temperature on the cavity floor, giving rise to an indirect increase in intrapulpal temperature [Aravamudhan et al., 2006a].

The development of new curing restorative resins and light-curing lamps has revolutionised dental restoration. In recent years technological advances have been made in curing units, such as high intensity halogen lamps, LEDs and plasma arc lamps. These new instruments have been developed with the aim of obtaining a faster photopolymerisation of composite materials while generating less heat [Smial et al., 1988]. As mentioned in the literature, intrapulpal temperature increase is detrimental to pulp tissue, depending on the amount of heat emitted by the light-curing unit [Goodis et al., 1990].

Zach and Cohen, following their in vivo study, used extracted monkey teeth (Macaco Rhesus Specie), on the surface of which they placed an iron weld to increase temperature. They concluded that 15% of the pulp necrosis occurred at temperature increases of 5.5° C and that in 60% of the cases, the pulp did not recover its normal state, showing a 11° C intrapulpal temperature increase. The results of this study must be interpreted with caution, because the temperature changes were not monitored once the iron weld was removed [Zach and Cohen, 1965].

The situation differs in in vivo studies, because the presence of blood and other fluids may mitigate the heat potential generated within the dental pulp. Similar studies determined that in addition to blood and fluid circulation within the dentinal tubules, the periodontal tissues also contribute significantly to a decrease in the heat generated after photocuring the resin [Meredith et al., 1984; Hannig and Bott, 1999].

Several studies confirm how the heat emitted during composite photocuring produces an increase in the intrapulpal temperature, which is detrimental to the pulp. In order to measure this generated heat, the researchers used the differential thermal analysis (DTA) technique, which measures the temperature levels produced by the dental materials when placed under a light source. One study highlights the use of the DTA to measure the increase in temperature taking place in the pulp chamber of extracted superior central incisors [Bennet et al., 1984]; McCabe, using only the light source as an initiator, modified the procedure: once the reaction in the resin was activated, the lamp was removed and the consequent effect on the composite was measured [McCabe, 1985]. Moreover, Masutani gauged the temperature increases generated in different composites when applying various light sources in a specific exposure time [Masutani et al., 1988].

The effects of heat increase during provisional restoration are well known. The results demonstrated that the amount of heat generated during curing and its transmission into the pulp chamber is detrimental to pulpal tissues as well as to odontoblastic cells [Castelnuovo and Tjan, 1997]. Also, research indicates that temperatures are generated during the composites photocuring process, which produces adverse effects in the dental pulp [Hartanto et al., 1990; Ozturk et al., 2004].
It is important to remember, from a biological point of view, that to test the adverse effect of heat transmission, the composites must be placed in thin layers in the cavity and cured with a moderate light intensity [Masutani et al., 1988]. Some authors confirm that the resin itself has a direct proportional influence on temperature increase [Masutani et al., 1988; Goodis et al., 1990]. Another study determined that an increase in the thickness of the material had a negative effect on the depth and hardness of the dental resins, depending on the various light intensities used in the study [Jung et al., 2006].

This study aims to determine the temperature changes produced in dentine discs of primary teeth placed below a glass ionomer, a microhybrid flow resin fluid or microhybrid resin during the photocuring process with conventional halogen lamps and LEDs at different distances.

### Methods

In February 2009, an in vitro study was carried out in the research laboratory of the Universitat Internacional de Catalunya. The ambient temperature of the laboratory where the study was carried out was 16º C.

### Teeth

Fifty primary teeth, extracted in the paediatric dental clinic of the Universitat Internacional de Catalunya, were collected for the experiment. The teeth were cleaned with a wet gauze and stored in saline solution to avoid dehydration. Later, teeth, without presence of decay or any restorative material were chosen and mounted on an acrylic block, leaving only the clinical crown exposed. The assembly allowed a wider and more secure surface for cutting the 1 mm thick dentine discs in the IsoMet® 1000 cutting machine (Buehler, Düsseldorf, Germany). The dentine discs were subsequently placed again in saline solution.

### Steel rings

Next, we cut 5 mm diameter stainless steel rings of different lengths (3, 4 and 5 mm) (Fig. 1). Like the dentine discs, the rings were cut in the IsoMet® 1000 cutting machine. A 2 mm layer of restorative material (glass ionomer, microhybrid flow resin or microhybrid resin) was placed within them. The remaining millimeters of each ring constituted the distance calculated to place the light guide.

### Silicone mould

Later, to facilitate the temperature measurement, we prepared silicone moulds (Optosil®, Heraus Kulzer, Hanau, Germany), in which the dentine disc, stainless steel ring and the digital thermometer/thermocouple HT 302® (HT Italia, Faenza, RA, Italy) were placed (Fig. 2). At this stage of the procedure, an initial temperature was recorded for each one of the tests to be made. Once the silicone mould was finished, a 2 mm thick layer was placed for each test.

### Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Category</th>
<th>Formulation</th>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>Vitrebond™</td>
<td>Glass-ionomer</td>
<td>Powder: Fluoroalumosilicate (SiO₂, AlF₃, ZnO, Cr₂O₃, NH₄, MgO, P₂O₅).</td>
<td>3M Espe AG (Seefeld, Germany)</td>
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<td></td>
<td></td>
<td>Liquid: modified polyacrylic acid with HEMA</td>
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<tr>
<td>TPH® 3 Spectrum™</td>
<td>Microhybrid resin</td>
<td>Matrix: Bis-GMA, Bis-EMA, TEGDMA. Inorganic Filler, 57 vol% (77 wt%): Bariumaluminiumborosilicate, Ba-Al-Y glass, spheroid mixed oxides, dispersed SiO₂</td>
<td>Dentsply (Konstanz, Germany)</td>
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<tr>
<td>Tetric® Flow resin</td>
<td>Microhybrid flow resin</td>
<td>Matrix: Bis-GMA, UDMA, TEGDMA. Inorganic Filler, 68 wt%: Ba, Al, Yt, Ba-Al-F glass, dispersed SiO₂</td>
<td>Ivoclar/Vivadent (Schaan, Liechtenstein)</td>
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**TABLE 1** - Composition of the materials studied.

**FIG. 1** - Stainless steel rings of different depths.

**FIG. 2** - Silicone moulds (dentine disc, stainless steel ring and the digital thermometer/thermocouple (HT 302®).
The following materials were used: glass ionomer (Vitrebond™, 3M/ESPE, St. Paul, MN, USA), microhybrid flow resin (Tetric®Flow, Ivoclar Vivadent, Schaan, Liechtenstein) and microhybrid resin (TPH® 3 Spectrum™, Dentsply, Konstanz, Germany) (Table 1).

**Lamps**

Four lamps were used: Two LEDs, Elipar FreeLight 2® (3M/ESPE, St. Paul, MN, USA) and Bluephase C5® (Ivoclar Vivadent, Schaan, Liechtenstein) and the halogens, Optilux 501® (Kerr Demetron, Orange, CA, USA) and 2500® (3M/ESPE, St. Paul, MN, USA) (Table 2).

**Temperature rise**

Before conducting the photocuring process, a specific type of radiometer was used for each lamp in order to check that light intensity and optimal wavelength recommended by the manufacturers were correct. The radiometers used to control the intensity of the lamps in the study were: for the Elipar FreeLight 2® lamp, the radiometer built into the base that is used for charging the battery and for checking the intensity and working order of the lamp every day; for the Bluephase LED C5® lamp, the Bluephase® meter was used (Ivoclar Vivadent, Schaan, Liechtenstein); and for the halogen lamps, the Demetron 100® radiometer was used (Demetron-Kerr, Corp, Danbury, CT, USA). Then we placed a celluloid strip Stripmat® (Polydenta, Mezzovico, Switzerland) over the stainless steel ring, and the lamp in direct contact with the celluloid strip. At the same time, the HT 302® digital thermometer was placed in direct contact with the dentine disc. Finally, the light curing process was conducted according to the time recommended by the manufacturer, and the temperature was recorded at the end of the procedure (Table 3).

The sample was made up of a total of 108 dentine discs. The samples were subdivided into 3 groups of materials (n=12) and within each group another three groups were formed (n=3), according to the distance of the polymerisation lamp: 1, 2 or 3 mm (Fig. 3).

**Statistical evaluation**

It was necessary to take 3 test measurements in order to obtain statistically significant results. The results were analyzed using the STATGRAPHICS® Plus Version 5.0 statistics software system (Stat Point Technologies, Inc. (Warrenton, Virginia, USA), in order to obtain comparative diagrams and graphs using the ANOVA multifactorial system.

**Results**

The results of the study reveal no statistically significant differences when curing the dental materials at different...
depths and the final temperature produced (p = 0.37).

Regarding the positioning of the lamps (Halogen and LEDs) at different distances and the increase in the final curing temperature, no statistically significant differences were found (p = 0.33).

However, the lamp used for the photocuring process of the restorative materials and the respective temperature produced did show statistically significant differences (p = 0.0081).

Tables 4 and 5 show the measurements and the standard deviation of both the materials studied and the lamps used. The material undergoing the greatest change in temperature is the microhybrid flow resin, followed by the glass ionomer and lastly, the microhybrid resin (Table 4). With regard to the lamps, the results show that the lamp generating the least heat was the Elipar Free Light® and that the Optilux 501® lamp produced the most (Table 5).

In the analysis of the p values obtained from the interaction of the variables studied, it can be observed that there is an interaction between the behaviour of the materials and the photocuring lamps evaluated. However, the depth of polymerisation is a factor that has no influence, and it does not have any relationship with the heat generated by the material or with the lamp (Table 6).

**Discussion**

The research into dental material photocuring has corroborated the effectiveness of the curing units in polymerisation. Nevertheless, previous in vivo studies have shown that when the light hits the dental surface, it can cause temperature rises within the pulp chamber [Castelnuovo and Tjan, 1997; Powell et al., 1999; Powell et al., 1993; Goodis et al., 1989].

Of the 108 tests conducted in our study, only one obtained a maximum temperature increase of 9.2º C. This value was registered when we photocured the 2 mm thick microhybrid flow resin layer Tetric®Flow at 2 mm from the Optilux lamp 501®. Although only one of the tests gave this result, this fact should be kept in mind, as obtaining similar values could damage the pulp, as has been pointed out by other authors [Zach and Cohen, 1965].

This finding is similar to the value obtained by Goodis et al. [1990], in which the Optilux 400® halogen lamp produced a 9.4º C temperature rise when photocuring a 2 mm layer of composite P-30 (3M®, St. Paul, MN, USA) in class II cavities of extracted third molars. In this study, it is important to point out that the lamp was placed in direct contact with the restorative material. Hanning and Bott [1999] did an in vitro study, in which they made class II cavities in extracted permanent molars and left 1 mm of dentine between the pulp chamber and the proximal cavity wall. Subsequently they measured the temperature produced when photocuring 2 mm of composite Ecusit A2 colour (DMG®, Hamburg, Germany) with an Optilux 500® halogen lamp for 40 seconds. The temperature increase obtained was 7.3 ± 0.3 ºC. This study bears similarities to our study regarding dentine and material thickness, yet there are differences in the curing distance. Cheesman et al. [2006] used dentine discs from primary teeth and concluded that the Astralis® halogen lamp (Ivoclar Vivadent, Schaan, Liechtenstein) produced significant increases in temperature, obtaining a 9.5 ºC value when used 150% of the time recommended by the manufacturer for photocuring the microhybrid flow resins. In the present study, as the instructions of the manufacturer were followed with regard to the polymerisation times of the microhybrid flow resin, or of the other materials, histological changes in the pulp may have occurred. However, studies have not been carried out that explain the histological behaviour of the hard and soft tissues in the primary dentition exposed to photopolymerisation lamps.

It is important to bear in mind that all these studies have been made in vitro. When conducting in vivo studies, the circulation of blood and fluids within the dentinal tubules, as well as the periodontal tissues, contribute significantly to the decrease in the heat generated after photo-curing the resin [Hanning and Bott, 1999; Meredith et al., 1984; Andersen et al., 1994].

In our study, statistically significant differences with respect to the temperatures were not generated when performing the photocuring process of the three restorative materials and the distance at which the lamp...
was placed (1, 2 and 3 mm), Shortall and Harrington [1998] measured the temperature produced when photocuring empty cavities with Luxor® and Optilux® lamps at 4 different depths (0, 2, 4 and 6 mm). Later they filled the cavities with a 2 mm layer of composite and the temperatures were recorded for a second time. They concluded that there was already a significant reduction in temperature at a 2 mm distance between the curing unit and the restorative material. Rueggeberg and Jordan [1993] measured the light intensity generated by the halogen lamp that was placed at different distances when photocuring 2 mm thick composite. They concluded that a decrease in the degree of polymerisation takes place when there is a distance of 4 mm between the curing unit and the restorative material. In the present study statistically significant differences were not observed when light-curing lamps were placed at different distances (1, 2 and 3 mm). Unlike the Shortall and Harrington study [1998], in this investigation cavities were not made, although similar results were obtained to theirs when a distance of 2 mm was used, but there was no significant increase in temperature.

Furthermore, Rode et al. [2007] evaluated the distance between the light source and its effect on the micro-hardness and the conversion degrees. They found that at a distance greater than 3 mm a reduction in the measurements of these two parameters takes place regardless of the type of lamp used in their study.

On the other hand, we found no statistically significant differences between the four types of lamps used when placed at different distances and the final temperatures obtained. Although the results are not significant, the Optilux 501® halogen lamp produced greater increases in temperature in comparison with the 2500®. As far as the LEDs lamps are concerned, the Elipar FreeLight 2® registered fewer increases in temperature.

In 2006, Aravamudhan et al. conducted an in vitro study to compare the properties of the LEDs lamps with the conventional Optilux 400® halogen lamp. They measured the temperature produced when directly photocuring a 3 mm thick resin microfilled Heliomolar® layer A1 colour (Ivoclar Vivadent, Schaan, Liechtenstein). No statistically significant differences in temperature increases were found when photocuring dental material with the different lamps [Aravamudhan et al., 2006b]. The object of the present investigation was to compare the efficiency of the light-curing lamps that can be found on the market. At the present time, being familiar with the differences that exist between halogen and LEDs lamps is very important. Halogen lamps have a series of disadvantages in that halogen bulbs have a short life (40 to 100 hours), and they wear out. In addition, the filter deteriorates given its close proximity to the halogen bulb, and power efficiency is consequently reduced. Another disadvantage is that they are awkward for dentists to use as they require an energy cable [Bennet and Watts, 2004]. On the other hand, the average life of a LED lamp is over 10,000 hours with minimum performance wear. Other advantages are that filters are not required for producing the blue light spectrum, nor are ventilators needed for cooling the lamps. In addition they are vibration resistant, light-weight and cordless [Ozturk et al., 2004].

In this study, we observed a statistically significant difference (p<0.0081) between the type of curing unit used to carry out the photocuring process of the restorative materials and the final temperature produced below the dentine discs. The Optilux501® halogen lamp produced the most marked increases in temperature for the Tetric®Flow microhybrid flow resin. Hence, in the Vitrebond™ glass ionomer and TPH® 3 Spectrum™ microhybrid resin, the Bluephase C5® LED lamp generated notable increases in temperature. The differences obtained between the halogen and LEDs lamps could be due to the diameter of the light guide not being the same in all the lamps and therefore the light dispersion can be different. Another factor that should be kept in mind is that halogen lamps have a tendency to emit at a slightly higher temperature because the filters that are necessary for emitting light at the correct wavelength sometimes do not filter the light correctly. Residual light is emitted along other wavelengths leading to a minimal heat emission that does not occur with LEDs lamps which only emit in the blue wavelength.

Of the four lamps used in the study, the Elipar FreeLight 2® high intensity LED lamp registered the smallest increases in temperature for each one of the dental materials studied. The maximum temperature increases obtained with this lamp were as follows: 2.6º C for Vitrebond™ glass ionomer, 4.3 ºC for Tetric®Flow and 1.5º C for microhybrid resin TPH® Spectrum™. The smaller increases were: 0.4º C for Vitrebond™ glass ionomer, 1.4º C for Tetric®Flow and 0.2º C for microhybrid resin TPH® Spectrum™. When analysing our results, it is possible to relate them to those of Cheesman et al. [2006], who determined the temperature behaviour generated by halogen lamps and LEDs directly applied on the restorative materials (microhybrid flow resin, microhybrid resin and glass ionomer), and jointly with permanent and temporary teeth dentine discs. They concluded that the high intensity Very light® LED lamp produced significantly smaller increases in temperature with respect to the Bluephase®, and the second with respect to the conventional Astralis 5® halogen lamp. The main limitation of the present study was that only discs from primary teeth were evaluated. Carrying out the same study but with dentine discs from permanent teeth would be of interest, as would be an evaluation of the photocuring of the different materials in relation to distance and depth of polymerisation with LEDs and halogen lamps. It is important to bear in mind the anatomical differences in the primary dentition with regard to the permanent dentition. It should not be forgotten that the size of the pulp chamber is greater than that of a permanent tooth, as the horns are closer to the external surface [Ostos et al., 2005]. It is therefore important to keep in mind the distance at which the lamp is placed. In the present study statistically significant results were not obtained with regard to the relationship between an increase in temperature and the distance at which the lamps were placed. The relationship between exposure times could not be evaluated, as the exposure time for each lamp was in accordance with the manufacturers’ specifications for each of the materials studied, rather than using the same time for all the lamps.
Conclusion

- The lamp with the least temperature increase regardless of both distance and material type was, in this study, the LED Elipar Free Light 2®. As a result there is less possibility of pulp damage with this lamp than with the others that give off more heat.
- The curing distance of the materials was not directly related to temperature change.
- The halogen lamps showed a greater increase in temperature with the materials than the LEDs lamps, and the greatest increase occurred when microhybrid flow resin was photocured using the Optilux 501® halogen light.

References