

Pulp Chamber Temperature Rise during Resin Composite Polymerization

SUMMARY

Objectives: To compare the pulp chamber temperature during illumination of resin-based composites using different light-curing units, and to assess the effects of a glass-ionomer (GI) base on the increase of pulp chamber temperature during polymerization.

Material and Method: Standard occlusal cavities were prepared and restored with the adhesive bonding agent Clearfil Liner Bond 2V and the composite resin Clearfil AP-X. The GI base, Aqua Ionobond, was pre-applied. Groups were polymerized with a halogen-curing lamp (QTH) and with a LED lamp. Intrapulpal temperature rises were measured at 60sec intervals and data analyzed using ANOVA, Post-Hoc Scheffé and t-test.

Results: The smallest rise was recorded when a GI base was applied to the cavity floor and the halogen curing lamp used, while the highest rise occurred when the LED curing lamp used directly over the bonding agent.

Conclusion: Visible light-cure lamps varied greatly in the amount of heat emitted and judicious choice of lamps can minimize the potential for pulpal damage. The GI liner lowered the pulp chamber temperature rise occurring during the illumination of composite restoration significantly.

Keywords: Light Curing; Composite Resin; Intrapulpal Temperature; Light-Curing Unit

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Introduction

Dental pulp is a specialized tissue, which performs its vital functional mission within a specific temperature range. An intrapulpal temperature increase of 5.6°C, resulting in a critical temperature of 42.5°C, could cause irreversible damage to the pulpal tissue³³. However, this threshold remains controversial in the light of most recent studies³. Cavity preparation, polymerization of lining and restorative materials, with or without the use of light-curing systems, all serve as potential sources of temperature increase at the cavity floor level²⁴.

Temperature increases during the curing of light-activated resin-based composites are related both to the exothermic composite polymerization process and to the energy absorbed during irradiation with light-curing units¹³. According to Lloyd et al¹⁸, the decisive

factor in temperature increase during light-activated polymerization of resin composites is the energy absorbed during irradiation, whereas the exothermic composite polymerization process is of secondary importance in temperature increase. Nevertheless, contrary to them, Hofmann et al¹⁵, found that a rise in temperature during polymerization was caused equally by radiation and by reaction heat.

Quartz-tungsten-halogen (QTH) lamps are the most frequently used sources for light curing. Typically, 500-800 mW/cm² of light intensity for 30-40sec is necessary from QTH sources to polymerize composites to a depth of 2mm, but the amount of curing time also is a function of type, shade and thickness of the material. Newer QTH sources with intensities in excess of 1500 mW/cm² have been developed to cure thicker layers of composite in shorter periods of time. The wavelengths of their light

range from 400 to 500nm³⁰. However, heat generation is their major disadvantage²⁶.

A different type of light source is the blue Light-Emitting-Diodes (LED) curing unit. It features very narrow spectral ranges. Specifically, the wavelength of their light is around 470 nm and this coincides with the camphor-quinone absorption peak^{26,30}.

Several studies claim that all light sources might potentially generate injurious temperatures in the pulp^{4,13,17,32}. The increase in temperature in the pulp chamber during illumination can be affected by several factors. The light-curing unit type, its power density, the duration of exposure, the distance between the tooth or composite surface and the light guide tip end, the composite shade, the thickness of the composite material, and the remaining dentin thickness^{5,6,20,29,31}.

The placement of a cement base is often proposed as a thermal barrier to protect the pulp tissue from thermal shock^{7,12}. However, the efficiency of the cement base, in providing thermal insulation, is dependent on its thickness²⁴. The objectives of this *in vitro* study were: (1) to measure the increase of pulp chamber temperature induced during light-curing with 2 different curing lamps, a QTH light unit and a LED light unit, and (2) to examine the effect of a previously applied glass ionomer (GI) base on temperature rise in the pulp chamber during polymerization.

Material and Method

32 freshly extracted human upper premolars, free of caries and other defects, extracted for orthodontic purposes, were used in this study. Patient age range was 11-18 years. The teeth were stored in 0.2% thymol for not more than 4 months, and randomly assigned to 8 groups of 4 teeth each. Prior to the study the teeth were cleaned of all superficial debris using an ultrasonic scaler. The teeth were kept in distilled water at $37\pm 1^{\circ}\text{C}$ to ensure hydration of the dental tissues. The roots of the premolars were rejected below the dental-enamel junction (DEJ), so that the coronal pulp chamber was accessible and the pulp tissue was removed from the pulp chamber.

For each tooth, a class I cavity preparation was cut in the occlusal surface of the tooth. The approximate dimensions of the cavity preparations were 3mm mesiodistally, 1.5mm buccolingually, and 2mm depth. The remaining dentin thickness between pulp chamber and occlusal cavity floor was approximately $1\pm 0.1\text{mm}$ as assessed by radiographs^{12,13}. For the cavity preparation, a high-speed handpiece and a new regular grit diamond bur (#842, Komet, Lemgo, Germany) were used. The bur was changed after the preparation of every third cavity.

A thermocouple thermometer (SDT 358, Type K, Korea) was used to measure the temperature in the pulp

chamber. The probe of the thermocouple thermometer was pushed through the apical foramen into the coronal pulp chamber until resistance was felt. The exact location of the probe was checked radiographically (Fig. 1). The rise in temperature within the pulp chamber was recorded continuously and evaluated at a stabilized room temperature ($20\pm 0.1^{\circ}\text{C}$) at 60sec interval, after the light-curing had begun.

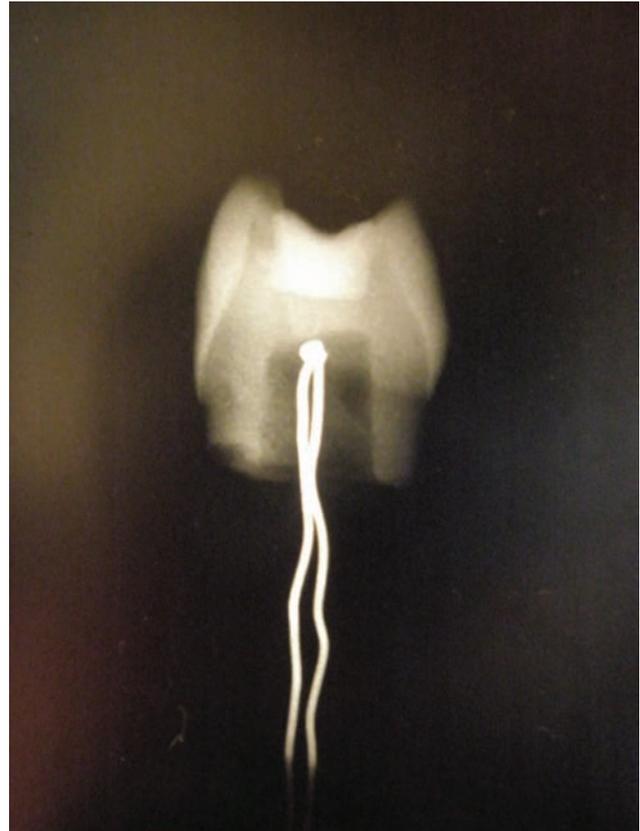


Figure 1. The radiograph of the right position of the thermocouple probe into the coronal pulp chamber of the tooth

To measure the increase in temperature in the pulp chamber during illumination, the bonding agent Clearfil Liner Bond 2V (Kuraray, Japan) and the composite resin Clearfil AP-X, A3 shade (Kuraray, Japan) were used in all the experimental trials. Each cavity was filled with composite resin in 2 increments and each increment was light-cured immediately after application.

The light sources used in this study are sited in table 1. The curing radiometer Curing Light Meter 200 (Rolence Enterprise Inc, Chungli, Taiwan R.O.C.) was used to measure the intensity output of each light unit.

Table 1. Light sources used in this study

Material Brand	Power Density	Manufacturer
Elipar 2500	810mW/cm ²	3M ESPE, Seefeld, Germany
Ledemetron 1	1220mW/cm ²	Kerr Corp. Danbury, USA

Both the resin-based composites and the light-curing units were used according to the manufacturer's instructions. In all trials, the lamp tip was positioned directly over the cavity.

The eight groups were: **Group A** (A₁ and A₂) - measurement of the pulp chamber temperature during adhesive bonding agent polymerization for 20sec (Group A₁), and during composite polymerization for 40sec (Group A₂) with the LED curing lamp (Ledemetron 1). The composite was applied in the cavity in 2 layers and each layer was cured in the standard programme for 40sec. For each curing, the temperature increase was measured for 60sec as mentioned above; **Group B** (B₁ and B₂) - measurement of the pulp chamber temperature during adhesive bonding agent polymerization for 20sec (Group B₁) and during composite polymerization for 40sec (Group B₂) with the QTH curing lamp (Elipar 2500). The application and the curing of the composite were the same as described for Group A; **Group C** (C₁ and C₂) - measurement of the pulp chamber temperature during adhesive bonding agent polymerization for 20sec (Group C₁) and during composite polymerization for 40sec (Group C₂) with the LED curing lamp (Ledemetron 1) in the standard programme, in cavities lined with a GI base (Aqua Ionobond, Voco), which had been previously applied. The thickness of the GI base was 1mm and it was radiographically checked. The application and the curing of the composite were the same as described for Group A; **Group D** (D₁ and D₂) - measurement of the pulp chamber temperature during adhesive bonding agent polymerization for 20sec (Group D₁) and during composite polymerization for 40sec (Group D₂) with the QTH curing lamp (Elipar 2500), in cavities lined with a pre-applied GI base (1mm). The application and the curing of the composite were the same as described for Group A.

The data were statistically analyzed using ANOVA, Post-Hoc Scheffé and t-test, with p<0.05.

Results

Radiographs revealed that the end of the thermocouple probe was situated in the pulp just beneath the dentin. Table 2 shows mean values and standard deviations of temperature increases in adhesive and resin

composites polymerized by different light sources. The mean pulp chamber temperature increase ranged between 3.4°C and 11.4°C, depending on the light curing unit and the placement of a GI base. The smallest temperature rise was recorded when a GI base was applied to the cavity floor and the QTH curing lamp was used (Group D₂; p<0.05). The highest temperature rise was induced when the LED unit was used directly over the bonding agent (Group A₁; p<0.05). When a GI base was applied to the cavity floor, all the temperature rises were significantly lower (Groups C and D; p<0.05).

Table 2. Mean temperature rises, and standard deviation.

Groups	Mean	S.D.
Group A (adhesive) (A1)	11.4	1.2
Group A (composite) (A2)	7.1	0.7
Group B (adhesive) (B1)	7.6	1.2
Group B (composite) (B2)	5.1	0.9
Group C (adhesive) (C1)	5.0	0.5
Group C (composite) (C2)	4.1	0.6
Group D (adhesive) (D1)	3.9	0.5
Group D (composite) (D2)	3.4	0.5

Discussion

Curing lamps produce heat during their operation^{13,25}. Manufacturers of composite resins recommend a specific curing time that it is unwise to exceed. For conventional halogen light sources this time is 40 sec¹³. However, new curing lamps like LED may require shorter curing times because of their high intensity output^{13,19,23,25}. The higher the radiation time and the irradiance are, the higher the increase in temperature is^{6,26}.

The temperature of 20 ± 0.1° C was used as a baseline in this *in vitro* study. The same starting point was used as in other studies, so that comparison would be easier^{5,7,11}. Perhaps the temperature of 37° C (the normal intrapulpal temperature) might have been more appropriate^{13,25}.

In the present study the highest rise in temperature was induced by the LED curing system. The mean values ranged from 7.1°C (Group A₂) to 11.4°C (Group A₁). The last temperature (11.4°C) was significantly higher than all the others (p<0.05). It was also obvious that even if a GI base had previously been applied, the LED curing system still induced the highest temperature rises between the two groups (C and D), ranging from 4.1°C (Group C₂) to 5.0°C (Group C₁). In agreement with the findings of previous studies, the higher intensity LED light produced a larger interpulpal temperature rise compared with the lower intensity halogen light^{14,17}. This finding supports the work

of Hanning and Bott¹³, who found that light intensity rather than the type of light source was important.

The results of this study do not correspond with the low temperature rise induced by LED curing units revealed in other studies^{26,27,32}. This could be due to the high intensity output of the LED lamp used in the present study (1220mW/cm²), whereas in other studies LED lamps with much lower output were used^{1,22,26-28,32}.

Moreover, the LED curing units led to a lower degree of converse for resin-based composites, compared to conventional QTH lamps^{8,26}. The less successful polymerization in addition to the relatively high temperature increase, which was found in the present study (11.4°C), indicate the need of further development of LED lamps². Nevertheless, LED curing units have many advantages, such as their specific spectral emission, small size, long-lasting quality, and the fact that they are battery-powered and totally silent. They have all the features to rival the QTH light curing units¹⁴.

Concerning the application of the GI base to the cavity floor, the statistically significant lower intrapulpal temperature during composite curing is obvious, taking into account 2 curing lamps that were used in this study ($p < 0.05$). These results agree with those of 2 other studies^{5,14} that the GI base seems to be a reasonably good thermal insulator.

Under the conditions of this study, the temperature increase during bonding agent curing (Groups A₁, B₁, C₁, D₁) was higher than the increase during composite resin curing (Groups A₂, B₂, C₂, D₂). This can be attributed to the thickness of the material, because adhesives form a very thin layer, whereas the resin-based composites form much thicker layers. This finding corresponds to that of an older *in vitro* study¹. As mentioned in the introduction, material thickness affects the temperature rise in the pulp chamber⁶. More specifically, temperature increases correspond with decreased material thickness²⁶. Moreover, the differences between Groups A₁ and A₂, and B₁ and B₂ are statistically significant ($p < 0.05$). On the other hand, no statistically significant differences were found between Groups C₁ and C₂, and D₁ and D₂ concerning temperature rises during curing, when a GI base had been applied previously to the cavity floor ($p > 0.05$). These findings seem to show that the pre-application of a cement base can change the participation of the material thickness in the temperature rise during polymerization.

Although it is accepted that iatrogenic increases in pulpal temperature are undesirable, the threshold above which significant damage occurs remains controversial. Many papers investigating temperature rise within the pulp cite Zach and Cohen³³ as evidence that heat can seriously affect pulpal health. It should be noted that this study is very old and that the method can be criticized, and that other researchers have failed to demonstrate the loss of vitality experienced in the Zach

and Cohen study. Nyborg and Brännström²¹ reported that pathologic changes with aspiration and loss of odontoblasts occurred in all teeth subjected to heat. Baldissara et al³ reported no necrotic or reparative changes in teeth following intrapulpal temperature increases averaging 11.2°C. These discrepancies in the long-term outcome were attributed to the differences in the nature of heat application. A more recent work done by Eberhard et al¹⁰ focused on the detection of inflammatory mediators produced in response to heat as a noxious stimulus. This study demonstrated 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 practice¹³. The significance of the levels of mediator produced remains unknown. However, as leukotriene B₄ has the ability to induce inflammation, it seems logical that exposure to procedures that results in its synthesis should be limited.

With respect to clinical experience, even with the use of the high intensity LED lamps, which induced high temperature rises (11.4°C) the pulp tissue seems to be able to recover from the high thermal irritation.

Conclusion

Clinicians should be aware of the possible thermal hazard to the pulp, as a result of the composite resin illumination process. Visible light-cure lamps varied greatly in the amount of heat emitted, and judicious choice of lamps can minimize the possibility of pulpal damage during placement of the composite system. Within the limits of the present study, the high intensity LED curing system seems to lead to the highest temperature increase. On the other hand, the lower intensity QTH lamp seems to induce lower temperature rise.

The GI liner lowered the pulp chamber temperature rise occurring during the illumination of composite restorations significantly, regardless of the light source used.

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