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The Effect of Different Light-Curing Methods on Temperature Changes of Dual Polymerizing Agents Cemented to Human Dentin

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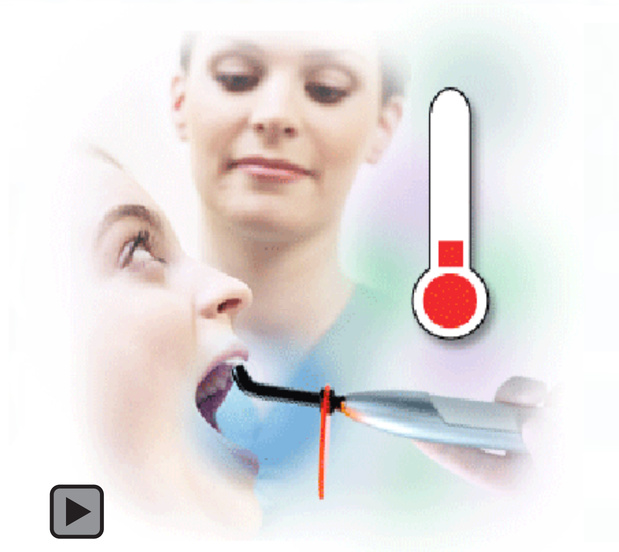

Abstract

Aim: This *in vitro* study aims to measure the temperature changes of resin luting cements cemented to human dentin when using different light curing systems for photo-activitation.

Methods and Materials: The three different types of light-curing units (LCUs) used for photoactivation were quartz-tungsten halogen (QTH), light emitting diode (LED), and plasma arc (PAC). Two types of dual cure resin cements were used [Variolink II™ (VL) and Choice™ (CH)]. Feltik Z250™ composite resin material was used to prepare composite discs. Thirty human dentin specimens were prepared for each resin luting cement (ten for each light source). A total of 60 specimens were fabricated. Resin cement was applied on a dentin bridge and covered with the prepared composite disc where specimens were fabricated. Temperature change was recorded with a digital thermometer.

Results: The lowest temperature was recorded when VL and CH were photo-activated with the PAC unit. The PAC unit produced significantly lower recorded temperatures than the LED and QTH units. No significant difference appeared between QTH and LED units in terms of recorded temperature.

Conclusion: The PAC unit produced significantly lower temperature changes compared to QTH and LED curing units. The risk for temperature rise should be taken into consideration during photo-polymerization of adhesive resins with LED or QTH in deep cavities when dentin thickness is 0.5 mm.

Keywords: Light-curing, dual polymerizing agents, temperature change

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Introduction

During the past few years there has been an increasing demand for esthetic restorations. Several available treatment options can provide pleasing results. Among these are composite veneers (either direct or indirect) which are considered a conservative approach to enhance a patient's smile, yet less expensive than other esthetic restorations.[1,2]

Cementation of indirect composite veneers can be done using several types of available cements. The choice of a luting agent is dependent on clinical factors combined with the physical, biological, and handling properties of the agent.[3-5] Dual curing resin cements have became popular for cementation of indirect ceramic and composite restorations because they fulfill the esthetic demand and minimize the disadvantages of polymerization shrinkage.[2]

The polymerization of dual curing resin cement is initiated both chemically and by visible light which provides better control during the cementation procedure.[2] In deep areas where the curing light cannot penetrate the restorative material, the self-curing mechanism hardens the cement.[6]

Various types of light curing units (LCU) such as quartz tungsten halogen light (QTH), light emitting diode (LED), and plasma arc (PAC) are available.[2,7]

Quartz Tungsten Halogen (QTH) Curing Light

The blue light emitted by a QTH curing unit is produced by heating tungsten filaments of a quartz bulb containing a halogen gas.[8] When it is heated, it becomes incandescent and emits electromagnetic radiation in the form of visible light. It also emits a large amount of infrared radiation. The emitted light is not selective so the rest of the spectrum, other than blue light, is unused and has to be filtered out.[9] The LCU has to be cooled by a ventilating fan that forces air flow through slots in the casing.[10] The intensity of light is adjustable in some QTH systems as follows:[11]

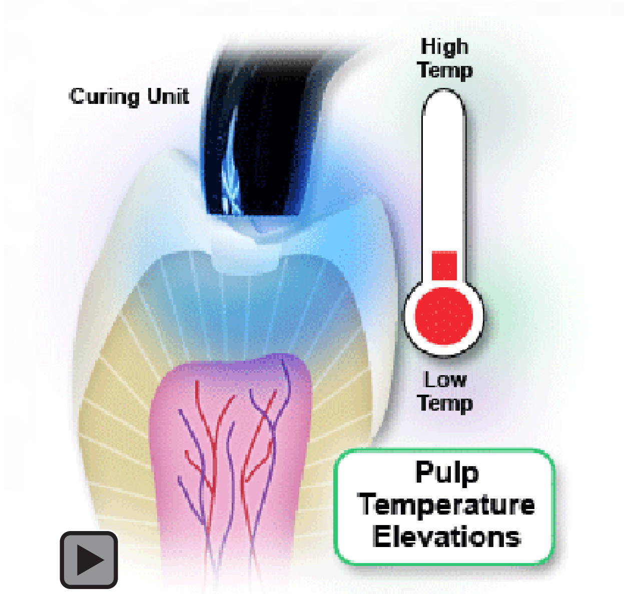
- High power (750 mW/cm²)
- Low power (400 mW/cm²)
- Pulse/soft-start, increasing from 150-400 mW/cm² during 15 seconds followed by 25 seconds pulsation between 400 and 750 mW/cm² in two seconds intervals.

Light Emitting Diode (LED) Curing Light

A LED curing unit has a voltage that is applied across the junction of two doped semiconductors resulting in the generation and emission of light in a specific wavelength range. By controlling the chemical composition of the semiconductor combination, the control wavelength range can be controlled.[12] Since a narrow band of light is emitted there is no need for a filter system.[13] Marked improvements in LED technology have resulted in the development of several types of commercial LED LCUs with an improved intensity output.[14] They are capable of delivering a power density of approximately 1000 mW/cm².[13]

Plasma Arc Curing (PAC) Light

A PAC light functions by having a high voltage applied between two electrodes resulting in a light arc between them. The PAC light has a high operating temperature which makes the use of ventilating fans essential. The spectral output of the PAC light is continuous and must be filtered to yield the useful blue light.[13] The intensity of the emitted light is high (1450 mW/cm²).[15] The PAC light is also designed for high speed curing of composite filling materials. A high energy, high pressure ionized gas in the



presence of an electrical current is used to create a high temperature light source strong enough to increase the curing rate of resin composite.[16]

The possibility of damaging effects of a temperature increase on the pulp during dental treatment have been widely investigated.[17,18] LCUs used for polymerization of resin-based composites produce heat during operation.[17] Heat has been identified as a primary cause for pulpal injury.[18] If excessive heat is generated, it could be transmitted to the surrounding tissues and cause damage to the dental pulp.[13] Zach et al.[19] reported irreversible pulpal damage in 15% of the teeth of Rhesus monkeys with a temperature elevation of 5.6°C, 60% for temperature elevations of 11°C, and 100% for temperature elevations of 16.6°C. These findings were confirmed in more recent studies.[20]

The increase in pulp chamber temperature during resin based composite polymerization can be significantly affected by several factors, but in particular the cavity remaining dentin thickness and permeability of dentin tubules.[21,22]

Therefore, this *in vitro* study aimed to measure the temperature changes of two dual-polymerizing resin luting agents cemented to human dentin and photo-activated with three different LCUs.

Methods and Materials

The study involved the luting of custom prepared discs of human dentin to fabricated composite resin discs using two resin luting cements Choice™ (CH) (BISCO, Inc. Schaumburg, IL, USA) and Variolink II VL™ (VL) (Ivoclar Vivadent, Schaan, Liechtenstein). Filtek™ Z250 (3M ESPE Dental Products, St. Paul, MN, USA) was used to fabricate the composite resin discs (Table 1).

The three types of LCUs used to cure the luting cements were QTH, LED, and PAC lights as described in Table 2.

Extracted non-carious human teeth (premolars and molars) were collected and stored in a 0.25% thymol solution. Sixty dentin discs of 0.5 mm thickness were prepared from these teeth by cutting them with an Isomet™ 2000 precision saw (Buehler Ltd., Lake Bluff, IL, USA). A Ultra-Cal Mark III Fowler-Sylvac digital gauge (Fred V. Fowler Co., Inc., Newton, MA, USA) was utilized to confirm the thickness of all the dentin discs. They were then stored in distilled water.

A circular Teflon® mold (9 mm in diameter and 1.5 mm high) was used to fabricate sixty Filtek™ Z-250 composite discs. The mold was placed on a transparent matrix strip supported by a microscopic glass slide and overfilled with composite material. The mold and resin were covered with another matrix strip and a microscopic glass slide. Light pressure was applied until the upper matrix strip and slide came into contact with the mold to expel excess composite material and to avoid air entrapment. Each specimen was polymerized through the top of the glass slide then through the bottom for 40

Table 1. Tested Materials.

Materials	Manufacturer	Shade	Lot no.
Choice™ (CH)	Bisco, Inc. Schaumburg, IL, USA	A3	0500004505
Variolink II VL™ (VL)	Ivoclar Vivadent Schaan, Liechtenstein	A3	Base = H03465 Catalyst = H22074
Feltik Z2+50	3M ESPE St. Paul, MN, USA	A2	20060508

Table 2. Characteristics of the light-curing units.

Light Curing Unit	Light Intensity	Wavelength	Manufacturer	Exposure Time
Halogen (QTH)	800 mW/cm^2	400-500 nm	ESPE Elipar High Light™ 3M Deutschland GmbH Neuss, Germany	40 Secs
Light Emitting Diode (LED)	800 mW/cm^2	400-480 nm	Ultra Lume LED 5™ Ultradent Products, Inc. South Jordan, UT, USA	40 Secs
Plasma Arc (PAC)	1370 mW/cm^2	440-490 nm	Apollo 95E Dental Medical Diagnostic Systems, Inc., Westlake Village, CA, USA	3 Secs

Table 3. The mean values of the temperature.

Light Source	Variolink II VL™	Code	Choice™ (CH)	Code
PAC	2.20+(0.63)	a	2.50+(0.53)	d
QTH	7.00+(1.33)	b	7.40+(1.26)	e
LED	7.90+(0.32)	c	7.60+(1.26)	f

Note: Identical code letters denotes no significant difference.

seconds using a LED curing unit according to the manufacturer's instructions.

Temperature Test

A total of sixty composite specimens were fabricated. Thirty specimens were prepared for each resin luting cement (ten for each light source). The temperature increase was measured with a type-K thermocouple connected to a Model 881C Digital Multimeter digital thermometer (OMEGA Engineering Inc., Stanford, CT USA). A thermocouple wire was placed under the dentin discs, and resin cement (0.5 mm) was applied and polymerized between the composite specimen and dentin discs. A circular silicon mold (2.5 mm in height and 9 mm inner diameter) was fabricated to create a supporting structure for the dentin, resin cement complex. The light tip of the LCUs tested were centered over the composite discs without any space between the tip and the disc. Photoactivation was performed for 40 seconds with the QTH and LED units and for three seconds with the PAC unit according to the manufacturer's instructions. All measurements were taken in a temperature/humidity-controlled room, with a constant temperature of 22°C±1 and a relative humidity of 30%. The initial temperature was recorded following temperature stabilization. The resin luting cement was then light cured and the temperature peak was recorded. The initial temperature was then deducted from the final temperature. The temperature change data were submitted to two-way analysis of variance (ANOVA), and the means were compared using the Tukey's and T-test at a 5% significance level.

Results

The mean values of the temperature change recorded (Celsius degree) are shown in Table 3 and Figure 1.

There was a statistically significant difference between the three different light curing systems when used for curing the two resins (VL, CH). The lowest temperature recorded when VL was photo-activated with PAC (2.20±0.63) which was lower than curing CH (2.5±0.53) with PAC. This difference was statistically significant at a 0.05 level. LED produced statistically the highest temperature change value than the other curing units. The recorded temperature change value of 7.9±0.32 when VL was polymerized with LED was significantly higher than the value of 7.6±1.26 of CH. When CH was polymerized with QTH, the recorded temperature change was 7.40±1.26 which was significantly higher than VL at 7.0±1.33. T-test showed no significant difference between QTH (p=0.126) and LED.

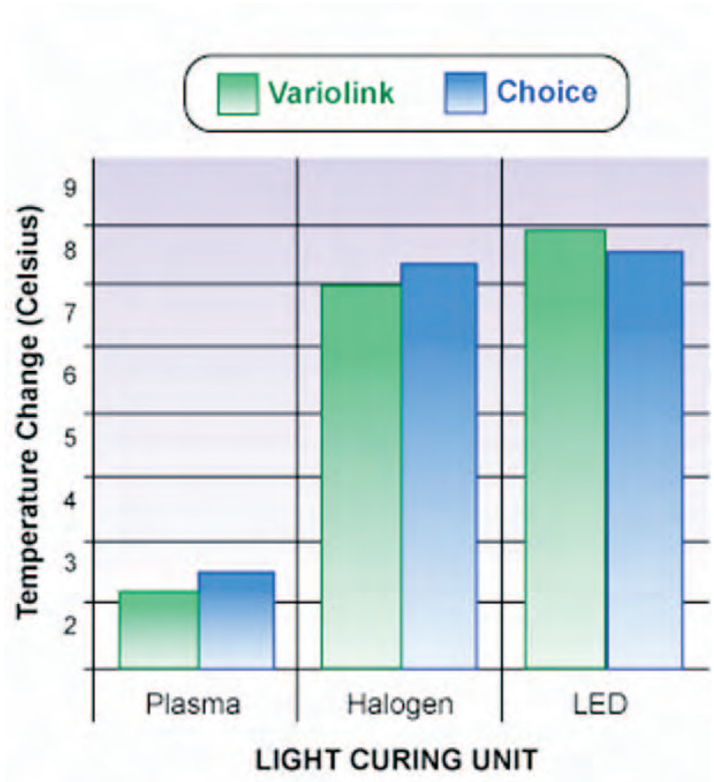


Figure 1. Mean values of temperature changes of the resin luting cements tested.

Discussion

The various *in vitro* models do not allow a perfect imitation of clinical conditions. However, it is permissible to make a relative internal comparison of *in vitro* measurements obtained under identical conditions.[23]

Commonly used methods to evaluate temperature rise utilize a digital multimeter and a thermocouple. Advantages of thermocouple devices include: cost effectiveness, durability, compactness, rapid response, wide temperature ranges, reasonable accuracy, interchangeability, and standard connections.[24] A K-type thermocouple was used in the present investigation and appeared to be suitable in yielding reproducible results in an expeditious manner.

It has been reported dentin discs obtained from caries free human molars contain minimal if any reparative dentin.[25] When composite restorations are placed in teeth whose pulps may have been affected by caries or previously placed restorations, a significant portion of the remaining dentin thickness is composed of reparative dentin.[26] Reparative dentin was found to have a significantly higher thermal conductivity, i.e., less thermal insulating properties, compared to normal dentin;[27] therefore, higher temperature values would be expected. However, it is difficult to standardize the amount of reparative dentin in the teeth with different degrees of carious involvement.[27] It was for this reason that caries-free teeth were used in the present study. As the thickness of remaining dentin decreases, the pulpal insult and response from heat increases.[16,18] In the present study a 0.5 mm thickness of the dentin disc was used which is considered as the minimum accepted clinically. Different readings might be obtained using thicker dentin discs.

Yazici et al.[16] reported a statistically significant increase using 1 mm thickness of dentin when comparing the temperature rise between 1 mm and 2 mm of remaining dentin thickness within each curing unit and mode.

The temperature increase is affected also by the thickness of the composite material and its shade. It has been reported decreasing the material thickness caused an increase in the temperature.[28] In the present study 1.5 mm of composite resin was used which is commonly used clinically for veneers.[29,30] The A2 shade was selected for resin luting agents in the present study to minimize the effects of colorants on light polymerization. No dentin treatment was used because the application of a bonding agent does not result in a statistically significant reduction of the pulp chamber temperature.[32]

Polymerization of light curing resin cement has been reported to result in a temperature increase caused by both the exothermic reaction process and light delivered from the curing unit.[30,33] The decisive factor for an increase in temperature is the energy absorbed during irradiation, whereas the exothermic composite polymerization process is of secondary importance for the temperature increase.[28] According to the total energy concept, a certain dose (intensity × time) of light is needed to adequately cure a specific material.[13]

Higher intensity lights provide higher values in terms of the degree of conversion,[34] superior physical and mechanical properties,[35] and a greater rise in temperature.[32,36]

The results of the present investigation are in agreement with Taher,[37] although the readings in the present study were lower because of the presence of a dentin bridge which was not used in that earlier study. The PAC unit produced less temperature rise with the two cements (VL and CH) because it was used for such a short duration (three seconds) which is in agreement with previous studies.[7,16,38] However, when a PAC unit was used for a longer duration (ten seconds), high temperature levels were reported.[2,39]

In this study curing with the LED unit resulted in higher temperatures compared to curing with the QTH unit used. Other studies found significantly lower temperature values were obtained when a LED unit was used compared to high power and low power modes of a QTH light cure for Tetric Ceram™ and Filtek™ Z250.[11,30] A possible explanation for this difference could be the higher light intensity (> 800 mW/cm²) of the LED unit used in our study compared with the one used in the contradicting study. Another possible cause for obtaining different results could be the use of different types and thickness of resin material.

In the present study CH produced more rise in temperature than VL when it was cured with an LED unit. The explanation could be related to the resin content and type, where the monomer of CH is Bisphenol diglycidy methacrylate (5-30% concentration range). On the other hand, the Vl resin is Bis-GMA, urethane dimethacrylate and triethylene glycol dimethacrylate with 26.3 wt% (base) and 22% wt catalyst with a high viscosity. Since the exothermic reaction is proportional to the amount of resin available for polymerization and the degree of conversion of carbon-carbon double bonds, these materials might be expected to show different temperature increases even though they were cured by the same light unit.[25]

The temperature values measured in the present study could not be directly applied to temperature changes *in vivo* because of the effect of blood circulation in the pulp chamber. Heat conduction within the tooth during *in situ* composite resin polymerization is affected also by fluid motion in the dentinal tubules. The surrounding periodontal tissues could promote heat conversion *in vivo* limiting the rise of the intra-pulpal temperature.[40] In the present study the maximum temperatures observed with the PAC unit lasted for only a very short time. In spite of the significant temperature rise caused by the energy output from the LCU a very short-term temperature peak may not be relevant to pulpal damage.[32]

Baldissara et al.[41] reported young premolars could withstand an average increase in pulpal temperature of 11.2°C without any histological evidence of pulpal damage within 68-91 days after treatment.

Manufacturers of QTH units fit a filter between the lamp and the light guide to limit radiant output to the effective curing range and to eliminate unnecessary heat and glare.[42] Studies have shown inadequate filters cause temperature rises from 18.5 to 21.2°C, whereas with adequate filters temperature rises from 12.1 to 13.2°C have been observed.[43,44] Therefore, it is necessary to regularly check not only the intensity of output light but also the filters of QTH units in order to prevent a greater heating of composite material and the tooth because it is impossible to adequately cool the QTH unit itself.

Conclusions

- The PAC unit produced significantly lower temperature changes compared to QTH and LED curing units.
- The risk for temperature rise should be taken into consideration during photo-polymerization of adhesive resins with LED or QTH in deep cavities where dentin thickness is 0.5 mm or less.

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