Temperature Increase During Resin Cement Polymerization Under a Ceramic Restoration: Effect of Type of Curing Unit

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Purpose: This study measured the temperature increase induced by various types of curing units during resin cement polymerization under ceramic restorations. ***Materials and Methods:*** The resin cement was polymerized between a ceramic specimen (diameter 5 mm, height 2 mm) and a dentin disk (diameter 5 mm, height 1 mm) with a conventional halogen light, a high-intensity halogen light, a plasma-arc light, and a light-emitting diode unit. The temperature increase was measured under the dentin disk with a J-type thermocouple wire connected to a data logger. Ten measurements were carried out for each curing unit. Difference between starting and highest temperature readings was measured, and the 10 calculated temperature changes were averaged. ***Results:*** Temperature increase varied significantly depending on curing unit used. The plasma-arc light induced significantly higher temperature increases than any other curing unit. The light-emitting diode unit produced the lowest temperature changes. There were no statistically significant differences between the conventional and high-intensity halogen curing units. ***Conclusion:*** Polymerization with curing units characterized by high energy output (plasma-arc light) caused higher temperature changes compared to other curing units, but the temperature increase detected was not viewed as critical for pulpal health. *Int J Prosthodont 2004;17:200–204.*

During the past few years, patients have increasingly demanded tooth-colored restorations. In many cases, the insertion of ceramic restorations using dual-curing resin cement is chosen to fulfill the demand for esthetics and minimize the disadvantage of polymerization shrinkage. Resin cements are usually hybrid-type composites based on bis-GMA. Normally, for resin cements, polymerization is initiated both chemically and by visible light using a wavelength of 400 to 500 nm.

Until recently, light emitted from a halogen light bulb was used to polymerize resin cements. These types of light sources usually operate at light intensities between 400 and 800 mW/cm^2 and polymerize resin composite filling material within 40 seconds. Halogen bulbs produce light when electric energy heats a small tungsten filament to high temperatures. Despite their common use in dentistry, halogen bulbs have several disadvantages. The basic principle of light conversion by this technique is claimed to be inefficient, as the light power output is less than 1% of the consumed electric power, and such bulbs have a limited effective lifetime of approximately 100 hours because of degradation of bulb components by the high heat generated.[1]

In the mid-1990s, xenon-arc light units were introduced in restorative dentistry as alternatives for rapid light polymerization. The plasma-arc (PAC) unit is designed for high-intensity polymerization of direct resin composite restorations and may be a time-saving alternative to conventional halogen lights.[2] As stated by the manufacturer, highly filled and pigmented composite materials can be polymerized in 10 seconds, and more transparent materials can be polymerized within 5 seconds.[3]

Solid-state light-emitting diode (LED) technology was proposed in 1995 for the polymerization of light-cured dental materials to overcome the shortcomings

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Table 1 Visible Light–Curing Units Studied

Brand, manufacturer	Type of unit	Output of light tip (mW/cm^2)	Diameter of tip (mm)	Applied polymerization time (s)
Hilux 550, Express Dental	Conventional halogen	450	10	40
Optilux 501, Kerr	High-intensity halogen	810	8	20
Power PAC, ADT	Plasma arc (PAC)	1,190	6.5	10
Elipar FreeLight, 3M/ESPE	Light-emitting diode (LED)	380	8	40

of halogen visible light–curing units.[4] LEDs use junctions of doped semiconductors instead of the hot filaments used in halogen bulbs to generate light.[5] LEDs have a lifetime of more than 10,000 hours and undergo little degradation of output over this time. LEDs require no filters to produce blue light, are resistant to shock and vibration, and take little power to operate.[3] The longer life span and more consistent light output of LEDs compared with halogen bulb technology show promise for dental applications.[6]

Polymerization of light-curing resin cements results in a temperature increase caused by both the exothermic reaction process and light delivered from the curing unit.[7–11] A further variable has been use of visible light–cured resin cements, with curing units themselves being capable of creating a temperature increase of up to 12°C.[11] This has been shown to be a major source of heat that may damage the pulp.[9] Light curing with high energy output causes significantly higher pulp chamber temperature changes compared to conventional halogen curing lights.[12]

The purpose of the present in vitro study was to measure the temperature increase induced by selected curing units—conventional halogen (40 seconds), high-intensity halogen (20 seconds), PAC (10 seconds), and LED (40 seconds)—during resin cement polymerization under ceramic restorations. The hypothesis tested assumed that there would be no difference in temperature increase under simulated ceramic restorations when resin cement was polymerized with these four curing units.

Materials and Methods

The four curing units evaluated are shown in Table 1.

Specimen Preparation

To simulate resin cement polymerization during the luting process of an inlay or onlay, a simulated ceramic restoration was prepared. It was of 2 mm thickness and 5 mm diameter. The 2-mm thickness was composed of 1-mm-thick framework material (IPS Empress 2, color 300, Ivoclar Vivadent) and 1-mm-thick layering material (IPS Empress 2), both prepared in accordance with the manufacturer's instructions. By using a slow-speed saw (Isomet, Buehler), the occlusal enamel portion of a mandibular third molar was removed to denude the dentin by sectioning it perpendicular to the long axis of the tooth. A dentin disk of 5 mm diameter and 1 mm height was prepared.

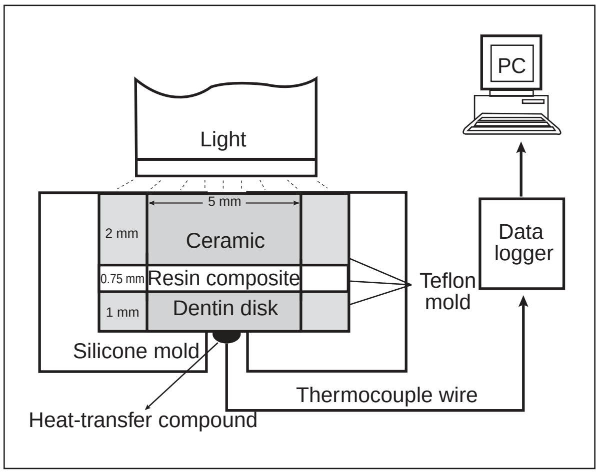

Fig 1 Experimental setup shows temperature measurement during polymerization of resin cement through ceramic specimen.

A commercially available resin cement was selected for the present study (Variolink II, Ivoclar Vivadent). To make the resin cement dual curing, the light-curing component (Variolink II Base, 340/A4, lot No. E13253, Braun) was mixed with catalyst (Variolink II Catalyst, low-viscosity type, 210/A3, lot No. E16059, Braun) in accordance with the manufacturer's instructions and then placed in a 5-mm-diameter 0.75-mm Teflon (DuPont) mold, which was then brought into contact with the dentin disk.

Temperature Measurement

The temperature increase was measured under a dentin disk to simulate the temperature increase in the pulp, and resin cement was applied and polymerized between the ceramic specimen and dentin disk. A silicone mold was prepared as the supporting structure of the dentin–resin cement–ceramic complex (Fig 1). The light tip of the curing units was centered on the ceramic restoration without any distance. No strip band was used during placement or curing of the resin cement between the dentin and ceramic restoration.

A silicone heat-transfer compound (ILC P/N 213414, Wakefield Engineering) was applied under the dentin disk. This compound facilitated the transfer of heat from the wall of the dentin disk to the thermocouple wire. A J-type 0.36-inch-diameter thermocouple wire (Omega Engineering) was connected to a data logger (XR440-M Pocket Logger, Pace Scientific) during application of curing units. The sampling rate of the data logger was set to one sample every 2 seconds for a recording period starting with light curing for approximately 60 to 90 seconds until the temperature started to decrease. The collected data, which were available in both tabular and graphic form, were monitored in real time and transferred to a computer.

The light outputs of the curing units were measured before each testing procedure using a digital curing radiometer (built-in radiometer on Optilux 501 unit). Following measurement of light output, the test was repeated 10 times for each curing unit. Difference between starting and highest temperature readings was taken, and the 10 calculated temperature changes were averaged to determine the mean temperature increase. All experimental trials were performed using the same ceramic restoration sample and dentin disk. Acid etching or enamel or dentin bonding was not applied to enable easy removal of the resin cement after polymerization. The dentin disk was observed using a stereomicroscope (SZTP, Olympus) at 22× magnification to inspect resin remnants and cleaned with a scaler when necessary.

The results of testing were entered into an Excel spreadsheet (Microsoft) for calculation of descriptive statistics. Statistical analysis was performed using analysis of variance (ANOVA) and then Tukey honestly significantly different (HSD) tests (SPSS/PC, version 10.0, SPSS) for comparisons among groups at the .05 level of significance.

Results

Temperature increase varied significantly depending on the curing unit used (ANOVA, $P < .001$). The PAC unit induced a significantly higher temperature change (3.7 $\pm$ 0.2°C) than any other curing unit (Tukey, $P < .001$). The LED unit produced the lowest temperature change (1.4 $\pm$ 0.3°C; Tukey, $P < .001$). There were no statistically significant differences between the conventional halogen (2.5 $\pm$ 0.4°C) and high-intensity halogen curing units (2.8 $\pm$ 0.6°C; Tukey, $P > .050$).

Based on the temperature at the start of light exposure, a delay in simulated pulp chamber temperature increase was detected (Fig 2). The maximum temperature increase with the PAC and high-intensity halogen units was recorded as a peak for only a few seconds at the beginning. The other curing units appeared to reach a plateau in the curves.

Discussion

This in vitro study measured the temperature changes caused by the heat generated by each of four commercially available curing units. Under the conditions of the present study, the highest temperature increase was recorded using the PAC unit for 10 seconds. The temperature increase during polymerization was statistically smaller with the LED unit than with the conventional halogen, high-intensity halogen, and PAC units. This result is in accordance with previous studies[12,13] that concluded that LED units produce the least thermal insult during photopolymerization of resin cements.

For the present comparative study, the same dentin disk was used to simulate the effect of residual dentin. This procedure was followed to eliminate any possible histochemical and/or structural variables of teeth that may manifest in differences in the thermal conductivity and specific heat. The resin cement was placed between a ceramic restoration and a dentin disk without any bonding agent. Thus, it was possible to easily remove the polymerized material during repeated measurements in the four experimental groups without alteration of the dentin disk or ceramic restoration. It could be supposed that heat transfer to the thermocouple wire would be diminished, and the data provided from temperature measurements may be lower than those actually occurring if the resin cement–dentin interface had been maintained. However, results of the preliminary experiments did not indicate statistically significant differences between measurements of pulpal chamber temperature increase during resin cement polymerization with or without previously applied bonding agents.[14]

The temperature increase during polymerization of light-cured restoratives is a result of an exothermic polymerization reaction in the material itself and energy absorbed during irradiation, as well as of the heat output from the dental curing units.[9,13,15] The speed of the exothermic reaction of visible light–cured resin cements increases with an increasing intensity of the curing unit.[10,16] PAC and high-intensity curing units are characterized by a higher energy output than conventional halogen curing units, and in the present study, the maximum temperature increase with the PAC system was recorded as a peak for only a few seconds at the beginning. The presence of a sharper peak in high-intensity halogen and PAC temperature increase graphics, compared to the plateau-type increase of LED and con-

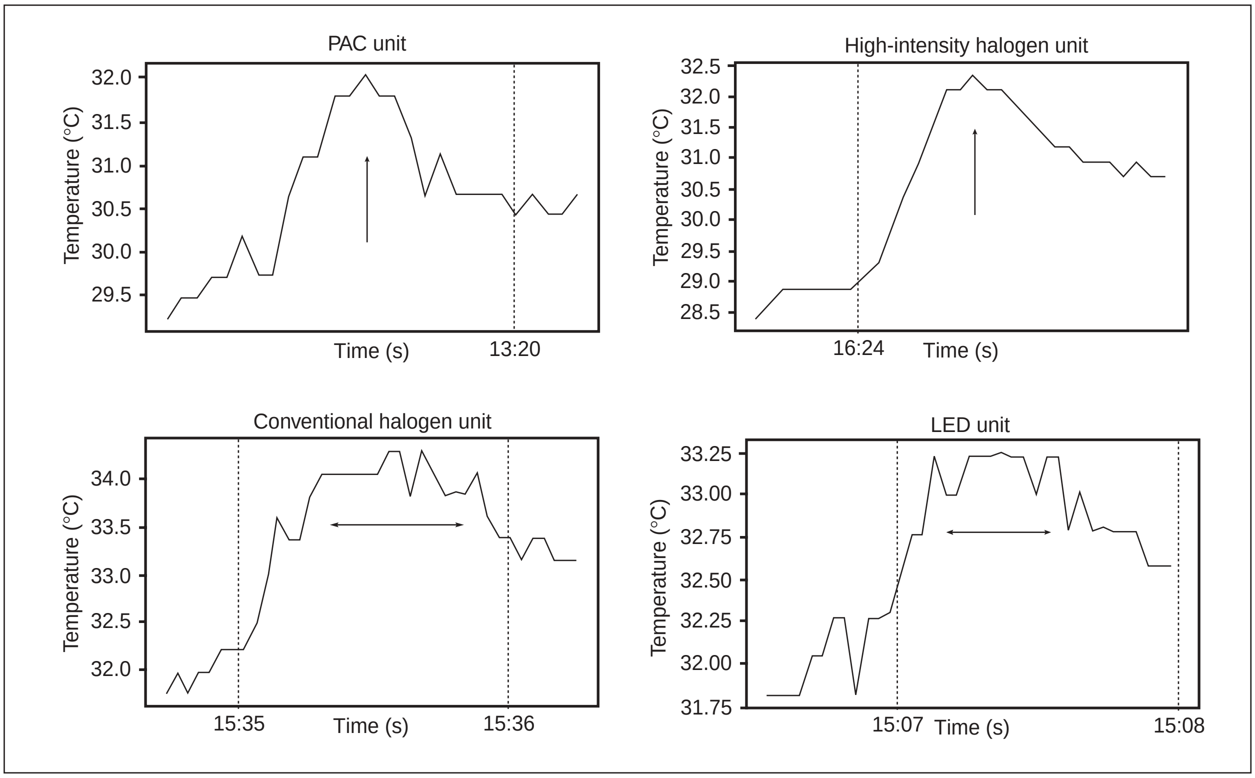

Fig 2 Temperature versus time graphs of plasma-arc *(PAC)*, high-intensity halogen, light-emitting diode *(LED)*, and conventional halogen curing units. *Arrows* = peaks for PAC and high-intensity halogen and plateaus for LED and conventional halogen curing units.

ventional halogen, is in accordance with a previous study.[14]

A temperature increase of 5.5°C has been reported to damage the pulp.[17,18] PAC exposure for 10 seconds caused a temperature increase of 3.7°C, whereas 2.5°C was recorded for the conventional halogen and 2.8°C was recorded for high-intensity halogen. Considering these values, the maximum temperature increase detected for all curing units tested in the present study was not viewed as critical.

Temperature increases reported in the present study are smaller than those in a previous study.[14] This may be a result of a larger distance from the light tip to the thermocouple wire and a possible insulation effect of the ceramic disk used. Furthermore, the temperature values measured here cannot be directly applied to temperature changes in vivo because the experimental setup did not consider heat conduction within the tooth during in situ resin cement polymerization because of the effect of blood circulation in the pulp chamber.[19] However, the maximum temperature increases determined were not viewed as critical for the pulpal health for any of the four types of curing units tested.

Conclusions

Measurements of temperature increase during resin cement polymerization under ceramic restorations in vitro indicate that:

1. The PAC unit caused significantly higher temperature changes compared to the conventional halogen, high-intensity halogen, and LED curing units.
2. The maximum temperature increases determined were not viewed as critical for the pulpal health for any of the four types of curing units tested.

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Literature Abstract

A study on the change of implant stability using resonance frequency analysis.

Resonance frequency analysis (RFA) has increasingly served as a noninvasive and objective method for clinical monitoring of implant stability. This study evaluated RFA value changes in one- and two-stage surgery groups. Forty-seven mandibles in consecutive patients were selected, and 141 implants were placed. Ninety-three implants were a double-threaded, machined surface design (Brånemark Mk III), and 48 were root-form, threaded, hydroxyapatite (HA)-coated implants (Replace). Among those, 10 were placed in one-stage patients. ISQ values were measured using Osstell during implant placement, at healing abutment connection, and in the loading period for two-stage surgery group patients and at 4, 6, 8, 10, and 12 weeks and in the loading phase for one-stage surgery group patients. Changes were evaluated according to time and implant type. In the two-stage surgery group, mean and SD of ISQ values of machined surface implants were 76.85 ± 3.74, 75.76 ± 5.04, and 75.73 ± 4.41, and those of HA-coated implants were 75.05 ± 6.23, 77.58 ± 5.23, and 78.32 ± 4.29 during implant placement, at healing abutment connection, and in the loading period, respectively. In the one-stage surgery group, ISQ values of machined surface and HA-coated implants decreased until the fourth or sixth week, were maintained for 1 to 3 weeks, and increased to the loading period. Machined and HA-coated implants showed minimal ISQ changes with time, if they were placed at sites showing at least an intact cortical plate and good bone quality. HA-coated implants had a tendency to somewhat increased ISQ values with time.

Park C-J, Kim YS, Kim CW, Cho LR, Yi YJ. *J Korean Acad Prosthodont* 2003;41:271–287. **References:** 32. **Reprints:** Dr Chan-Jin Park, Department of Prosthodontics, College of Dentistry, Kangnung National University, Jibyundong 123, Gangneung, Gangwondo, Republic of Korea. e-mail: doctorcj@chollian.net—*Myung W. Brian Chang, Lincoln, Nebraska*