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Author(s)	Guiraldo, RD; Consani, S; Mastrofrancisco, S; Consani, RL; Sinhoreti, MA; Correr-Sobrinho, L
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Original Article

Influence of Light Curing Unit and Ceramic Thickness on Temperature Rise during Resin Cement Photo-activation

Ricardo Danil Guiraldo, Simonides Consani, Sarina Mastrofrancisco, Rafael Leonardo Xediek Consani*, Mario Alexandre Coelho Sinhoreti and Lourenço Correr-Sobrinho

Department of Restorative Dentistry, Piracicaba Dental School,
State University of Campinas, Piracicaba, São Paulo, Brazil
*Department of Prosthodontics and Periodontics, Piracicaba Dental School,
State University of Campinas, Piracicaba, São Paulo, Brazil

Abstract

The aim of this study was to determine the effect of different ceramic thickness on heat generation during resin cement photo-activation by QTH (quartz-tungsten-halogen), LED (light emitting diode), and PAC (plasma arc-curing) LCUs (light curing units). The resin cement used was Rely X ARC (3M-ESPE), and the ceramic was IPS Empress Esthetic (Ivoclar-Vivadent), of which 0.7-, 1.4- and 2.0-mm thick disks, 0.8 mm in diameter were made. Temperature increase was recorded with a type-K thermocouple connected to a digital thermometer (Iopetherm 46). An acrylic resin base was built to guide the thermocouple and support the 1.0-mm thick dentin disk. A 0.1-mm thick black adhesive paper matrix with a perforation 6 mm in diameter was placed on the dentin to contain the resin cement and support the ceramic disks of different thicknesses. Three LCUs were used: QTH, LED and PAC. Nine groups were formed (n=10) according to the interaction: 3 ceramic thicknesses, 1 resin cement and 3 photo-activation methods. Temperature increase data were submitted to Tukey's test (5%). For all ceramic thicknesses, a statistically significant difference in temperature increase was observed among the LCUs, with the highest mean value for the QTH LCU (p<0.05). For all the LCUs, a thickness of 0.7 mm produced the highest temperatures (1.4 and 2.0 mm, p<0.05). There was no difference in temperature values between the latter two thicknesses (p>0.05). The interaction of higher energy density with smaller ceramic thickness showed higher temperature increase values.

Key words: Ceramic thickness—Photo-activation methods—
           Temperature increase—Resin cement

Introduction

In recent years, there has been increasing demand by patients for treatment with esthetic restorations. In many cases, dual-cured resin cements are the best choice for luting ceramic dentures to obtain an esthetically pleasing result, as well as to minimize the disadvantage

of polymerization shrinkage of composites[24].

With light-cured resin cements there is a temperature increase caused by the exothermal reaction of the material and heat from the curing unit light[22], and when some of the light cured cements are polymerized with certain LCUs, temperature increases exceeding 12°C can be produced[22].

Photo-activation is performed with visible light belonging to the blue area of the electromagnetic spectrum to excite camphorquinone (the most commonly used photo initiator in resin cement), which has an absorption spectrum in the interval between 400 and 500 nm[9]. The most efficient wavelength for polymerization would be 468–470 nm[17], which induces rupture of benzoate peroxide molecules together with a tertiary amine[19], followed by additional polymerization. Among the photo-activation units available on the market, the most traditional are those that use halogen lamps as light source.

According to Uhl *et al.*[23], the most important irradiation produced by these lamps is the infrared spectrum, which is absorbed by the composite, resulting in great molecular vibration and generation of heat. The thermal-absorbent filters reduce the passage of infra-red energy to the tooth when light passes through them[19]. However, the efficiency of these filters varies according to the manufacturer, and the energy that is not absorbed can result in heat.

The light emitting diode was developed in order to minimize the heat generated by the halogen light during photo-activation[23]. The emission wavelength of from 455 to 486 nm is related to the absorption spectrum of camphorquinone[18]. Plasma arc curing units are designed for high-speed curing of composites in direct restorations. However, the increased power of commercially available dental-curing units has also increased the potential for generating unacceptable temperatures in pulp tissue[6,7,13].

An *in vivo* experiment by Zach and Cohen[25] using *Rhesus* monkey teeth submitted to different temperature increases showed that irreversible pulp alteration may occur due to high temperatures in the pulp chamber. Thermal trauma can be induced by cavity preparation, the curing reaction of liners or restoration materials[15].

Studies have suggested that visible light photo-activation can also contribute to increasing the temperature inside the pulp chamber, causing damage to the pulp[12,14,16]. However, when the bulk increment technique was used, previous studies showed that there was no difference in temperature increase among the photoactivation methods (Continuous, Intermittent light, or Soft-Start)[5], and among different colors of the same composite[2].

In view of these considerations, it would be interesting to verify the effect of ceramic thickness on resin cement photo-activation when using different LCUs. The hypothesis of this study was that the thermal variations in the resin cement polymerization would depend on the interaction between the type of photo-activator and ceramic thickness. Therefore, the aim of this study was to verify the temperature rise during the light curing of the resin cement Rely X ARC with different ceramic thicknesses (0.7, 1.4 and 2.0 mm), using sources of QTH, LED and PAC.

Materials and Methods

The Rely X ARC (3M-ESPE, St. Paul, MN, USA) dual cure resin cement (Shade A3, bath FKGB) and IPS Empress Esthetic ceramic (Ivoclar-Vivadent, Schaan, Liechtenstein, Shade ETC2, Bath JM0552) were used to make ceramic disks 0.8 mm in diameter, with thicknesses of 0.7, 1.4 and 2.0 mm.

Three light curing sources were used: QTH (XL 2500, 3M/ESPE) LCU, an emitting diode LCU (Ultrablue Is, D.M.C. Equipamentos LTDA. São Carlos, SP, Brazil) and a PAC unit (Apollo 95E, DMD, Westlake Village, CA, USA). The powers (mW) of the three light sources were measured with a power meter (Ophir Optronics, Har-Hotzvim, Jerusalem, Israel). The tip diameters were measured with a digital caliper (Digital caliper, model CD-15C, Mitutoyo, Japan) to determine the

Table 1 Characteristics of light curing units (LCUs)

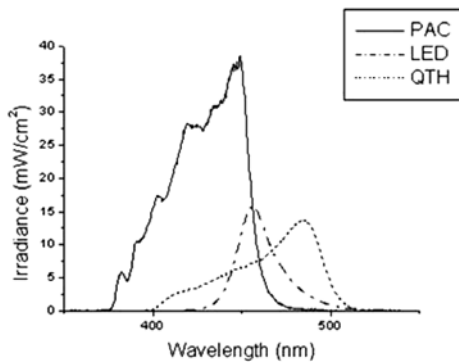| LCUs	Equipment	Irradiance (mW/cm^2)	Exposure (s)	Energy density (J/cm^2)
QTH	XL 2500	700	40	28
LED	Ultrablue Is	450	40	18
PAC	Apollo 95E	1,800	10	18

Fig. 1 Wavelength distributions of the light curing units

tip areas and calculate the irradiance by dividing the power by the area. It was possible to determine the energy density through the following calculation: energy density (J/cm^2) is the irradiance (mW/cm^2) applied during a certain time (seconds) divided by 1,000. The characteristics of the LCUs are shown in Table 1. The spectral distributions were obtained using a spectrometer (USB 2000, Ocean Optics, Dunedin, FL, USA)—Fig. 1 (6.01 by 8.0 cm).

Temperature increase was recorded with a type-K thermocouple connected to the digital thermometer (Iopetherm 46, IOPE, São Paulo, Brazil), with an accuracy of 0.1°C. A chemically polymerized acrylic resin base was built to guide the thermocouple and support a 1.0-mm thick dentin disk. The disk was used to simulate the thickness of the leftover dentin of a cavity preparation. A matrix of black adhesive paper (0.1 mm thick) with a perforation 6 mm in diameter was placed on the dentin to contain the resin cement and support the ceramic disks of different thicknesses.

After inserting the resin cement in the matrix, the ceramic disk was placed on the set (Fig. 2 (10.92 by 14.59 cm)). A polyester strip was put between the dentin and the resin cement and another between the resin cement and the ceramic disk. Photo-activation was performed with the LCUs tip touching the ceramic. Light curing time was 40 seconds with the QTH and LED LCUs and 10 seconds with the PAC LCU, in agreement with the study developed by Usumez and Ozturk[24]. It is important to ensure that adequate energy density reaches the luting agents to complete the polymerization, because early bond failure to enamel has been attributed to incomplete polymerization of the luting agent[10]. Thus, insufficient exposure time could cause damage in a clinical setting. A previous study showed that PAC exposure should be of at least 10 seconds duration to provide hardness equivalent to that achieved with conventional 40-second QTH exposure[20]. Nine groups were formed (n = 10) according to the interaction: 3 ceramic thicknesses, 1 resin cement and 3 photo-activation methods.

All measurements were taken in a temperature/humidity controlled room, with a constant temperature of 20°C ± 1°C and 30% relative humidity. For the temperature measurements, the initial temperature was recorded after temperature stabilization, the resin cement was then light-cured and the peak recorded. The initial temperature was deducted from the final in order to determine temperature increase.

The temperature change data were submitted to a two-way ANOVA and the means were compared by Tukey's test (5% level of significance).
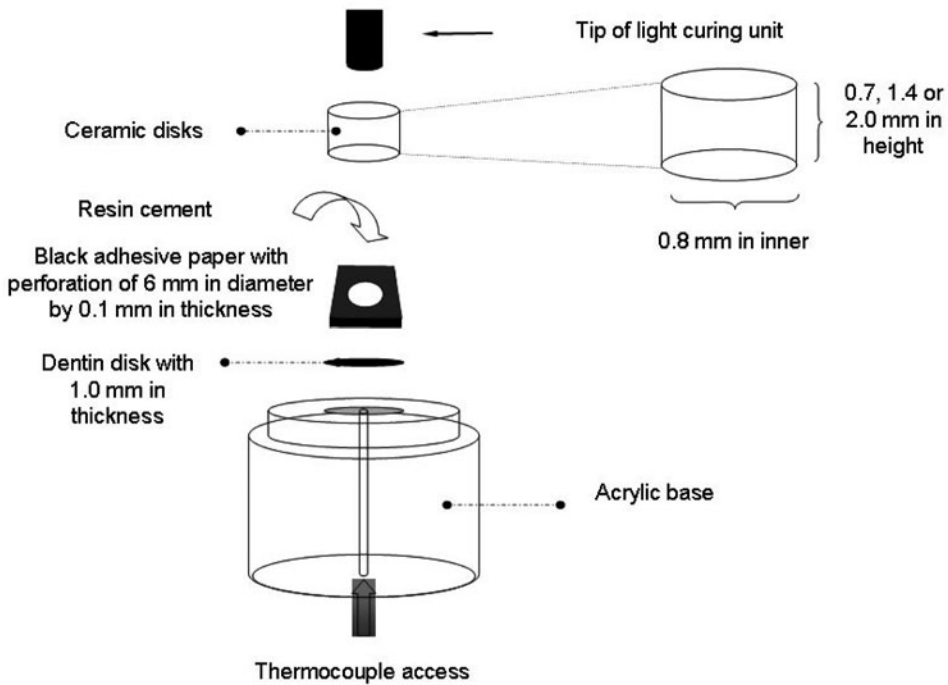
Fig. 2   Apparatus for temperature increase measurement

Table 2   Mean temperature increase (°C)

Ceramic thickness	Light curing units (LCUs)		
	QTH	LED	PAC
0.7 mm	2.97 (0.27) a A	2.08 (0.35) b A	1.85 (0.23) b A
1.4 mm	1.94 (0.34) a B	1.49 (0.28) b B	1.22 (0.27) b B
2.0 mm	2.16 (0.36) a B	1.41 (0.15) b B	0.96 (0.06) c B

Mean values followed by different lowercase letters in row and mean values followed by different capital letters in each column differed statistically by Tukey's test at 5% level. ( ) indicates Standard Deviation.

Results

Table 2 shows that at all ceramic thicknesses (0.7, 1.4, and 2.0 mm) there was a statistically significant difference in temperature increase values among the LCUs, with a higher mean value for the QTH LCU ($p<0.05$). The LED and PAC did not differ statistically with ceramic thicknesses of 0.7 and 1.4 mm ($p>0.05$), but did with 2.0 mm ($p<0.05$).

For all the LCUs, a thickness of 0.7 mm produced higher values ($p<0.05$) than the other thicknesses (1.4 and 2.0 mm). There was no difference between the latter two thicknesses ($p>0.05$).

Discussion

The *in vitro* hypothesis of this study that the thermal variations in resin cement polymerization would depend on the type of inter-

action between LCU and ceramic thickness was partially accepted.

The high demand for esthetic restorations has increased the use of composites and ceramics and diminished the use of amalgam. To fix these restorations to the dental substrate, the material of choice is resin cement. The advantages of this material are its bonding to the substrate, low solubility, easy handling and good esthetics. Nevertheless, the application of these cements can also result in higher values of resistance to fracture by fatigue of all-ceramic crowns, in comparison with glass ionomer and zinc phosphate cements[3]. External heat applied to the tooth can increase the temperature of the pulp, resulting in damage considered irreversible[11,25]. Thermal trauma can be induced by cavity preparation, exothermal reaction of polymerizing cements, restorative materials and heat generated by LCUs[21,23].

An increase in temperature caused by photo-activation may result from energy density emitted by LCUs[4,19]. Table 2 shows that the temperature increase produced by the QTH was higher and statistically significant when compared with that produced by the other LCUs at all ceramic thicknesses (0.7, 1.4 and 2.0 mm). In this study, this was probably the reason the QTH with an energy density of 28 J/cm^2 produced a higher temperature increase. The LED and PAC units did not differ statistically at thicknesses of 0.7 and 1.4 mm, perhaps due to the similarity of energy density (Table 1), although the highest temperature increase at a thickness of 2.0 mm was produced by the LED in comparison with the PAC. This was probably due to the high irradiance produced by the PAC (1,800 mW/cm^2) in a very short time (10 seconds), which was not long enough for the heat to penetrate through to a deeper ceramic thickness (2.0 mm) in a material with little thermal conductivity.

When light is transmitted through a ceramic, it is absorbed and reflected, losing its intensity. A reduction in light when transmitted through laminated veneers during resin cement polymerization was observed by Hasegawa *et al.*[8]. In a previous study, Brodbelt *et al.*[1]

verified that, on an average, only 26.8% of the light emitted by a LCU was transmitted through a 1-mm thick laminated veneer. In the present study, a ceramic thickness of 0.7 mm showed a higher temperature increase value for all LCUs when compared with other thicknesses (1.4 and 2.0 mm), probably because of the lower light transmission.

Although this study was performed in a matrix, the result can be considered clinically relevant. According to Zach and Cohen[25], it would require an increase of 5.5°C to cause irreversible trauma to the pulp. In this study, the LCU with an energy density of 28 J/cm^2 at a ceramic thickness of 0.7 mm did not produce temperature increases that would cause damage to the pulp tissue. The interaction of higher energy density with smaller ceramic thickness showed higher temperature increase values.

Clinically, even under high energy density conditions such as those produced by the QTH in this study, the heat developed would probably not cause irreversible damage to the pulp because, according to Zach and Cohen[25], it was below the temperature at which this could occur.

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Reprint requests to:
     Dr. Simonides Consani
     Dental Materials,
     Department of Restorative Dentistry,
     Piracicaba Dental School,
     Av. Limeira 901, 13414-903,
     Piracicaba, São Paulo, Brazil
     Tel: +55-19-2106-5345
     Fax: +55-19-3421-5218
     E-mail: consani@fop.unicamp.br