Pulp Chamber Temperature Increase from Curing Light Units: An In Vitro Study

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ABSTRACT

Purpose: The purpose of this study was to compare temperature rises in the pulp chamber induced by halogen, plasma arc, and conventional light-emitting diode (LED) curing units with that induced via a new generation LED-curing unit (VALO) in extra power mode.
Methods: A Class I cavity was prepared on the occlusal surface of 80 extracted caries-free mandibular third molars, which were filled with a microhybrid composite. A thermocouple wire was inserted into the pulp chamber of each tooth to measure temperature changes.
Results: The greatest temperature increases were observed during polymerization of composite resin with a halogen curing unit (3.2 degrees Celsius), followed by plasma arc curing (2.07 degrees Celsius) and VALO curing (1.44 degrees Celsius); the lowest temperature rise was with conventional LED curing (1.01 degrees Celsius).
Conclusion: There were no statistically significant differences between conventional LED and VALO curing in extra power mode regarding pulp chamber temperature increases when polymerizing composite resin. (J Dent Child 2014;81(3):128-32)

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The placement of multi-increment resin composite restorations is time-consuming for dental practitioners. Improvements in the dental resin light activation process are needed due to the growing demand for shorter polymerization time to minimize chairside procedures. There have been many advances in light activation processes, such as the introduction of plasma arc curing units with high intensities and short exposure times, which are marketed by manufacturers as reducing polymerization shrinkage and saving time.[1,2]

Light-emitting diode (**LED**) technology has become available as an alternative energy source for polymerizing dental restorative materials.[3] One advantage attributed to the LED is the coincidence of peak irradiance of LED light with camphorquinone, a photoinitiator agent commonly found in composite resin formulations used in dentistry.[4-11] Other LED benefits include possible reduced curing time,[9,12] a lamp duration time of approximately 10,000 hours,[3] no heat generation, and resistance to impact.[3,13,14] Additionally, LED appliances consume minimal power and can run on rechargeable batteries, allowing them to have a light weight and ergonomic designs.[9]

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A new generation LED curing unit (VALO, Ultradent, South Jordan, Utah, USA) with extra power mode (4,500 mW/cm²) was introduced in the market in recent years. VALO claims that highly filled and pigmented composite materials can be cured in two sequential three-second applications, while more transparent materials can be cured within three seconds. VALO is designed to polymerize composite resin using three modes of light-curing: standard, high, and extra power, which polymerize the composite resin with an intensity of 1,000 mw/cm², 1,440 mw/cm², and 4,500 mw/cm² respectively.

The dental pulp is highly susceptible to thermal damage. Therefore, the potentially damaging effect of temperature increases on pulp tissue induced from light-curing unit (**LCU**) irradiations is still a great concern to dentists. Zach and Cohen,[15] using a Rhesus monkey as an in vivo model, determined that a temperature rise of 5.5 degrees Celsius in the pulp is the limit at which the pulp can recover from thermal damage.

The purpose of this study was to compare temperature rises in the pulp chamber induced by halogen, plasma arc, and conventional LED curing units with that induced by a new generation LED curing unit (VALO) in extra power mode to determine whether the latter is suitable for operative and pediatric dentistry.

METHODS

This study was approved by the Ethical Board of Erciyes University, Kayseri, Turkey. Eighty extracted caries-free mandibular third molars were used. A Class I cavity was prepared on the occlusal surface of teeth, which were stored in a phosphate-buffered saline solution containing 0.2 percent sodium azide. The remaining dentin thickness between the pulp chamber and occlusal cavity floor was two mm. The mesial root was cut with carborundum disks approximately two mm apically to the cemento-enamel junction, and the apical orifice of the root canal was enlarged.

Pulp residue was removed from in a retrograde manner after root resection, and a thermocouple wire (AB 25 NN, Thermocoax, Heidelberg, Germany) was inserted into the pulp chamber of each tooth to measure temperature changes. The wire maintained immediate contact with the dentin via a thin layer of silicon oil-based thermal joint compound. The position of the wire and remaining dentin thickness was checked with periapical images. The root surfaces and lower portion of the tooth crown were submerged in a water bath (37.0±0.1 degrees Celsius) during the testing procedure.

The third molars were divided into four groups of 20 teeth each. The Class I cavity preparations were acid etched with 37 percent phosphoric acid (Dentsply Caulk, Petropolis, Rio de Janeiro, Brazil) for 30 seconds on enamel and 15 seconds on dentin, and washed with a water stream for 30 seconds. The etched areas were gently dried with sterile cotton, removing only the excess water, following the adhesive/resin manufacturer's instructions. The bonding system (Single Bond, 3M ESPE, St. Paul, Minn., USA) was applied to all cavities, and each tooth was polymerized with different LCUs (Table 1). Light curing was done as follows: Group 1—Halogen light cure (QTH [Hilux, Benlioğlu Dental, Ankara, Turkey]) for 20 seconds; Group 2—conventional LED (Ledmax, Benlioğlu Dental, Ankara, Turkey) for 10 seconds; Group 3—VALO in extra power mode for three seconds; and Group 4—plasma arc (Power PAC, ADT, San Carlos, Calif., USA) for five seconds.

The same cavities used in the previous step were bulk-filled with microhybrid composite (Z100; 3M ESPE, St. Paul, Minn., USA). This resin layer was then polymerized with halogen light at 500 mW/cm² for 40 seconds (Group 1); conventional LED at 850 mW/cm² for 20 seconds (Group 2); VALO at 4,500 mW/cm² for two sequential three-second applications between curing cycles (Group 3); and plasma arc at 1,200-1,500 mW/cm² for 10 seconds (Group 4).

Table 1. Light Sources and Light Curing Mode Used in the Study

Group	Light curing unit	Manufacturer	Diameter of light tip	Power intensity (mW/cm²)	Exposure time (secs)	
					Bond	Composite
1	Halogen	Hilux, Benlioğlu Dental, Ankara, Turkey	10	500	20	40
2	Conventional LED	Ledmax, Benlioğlu Dental	8	850	10	20
3	LED plasma emulation mode	VALO, Ultradent, South Jordan, Utah	8	4,500	3	2 x 3*
4	Plasma arc	Power PAC, ADT, San Carlos, Calif	6.5	1,200-1,500	5	10

** Two sequential applications each lasting three seconds.*

STATISTICAL ANALYSES

Descriptive statistics, including means, standard deviations, and minimum and maximum values, were calculated for each group. The Kolmogorov-Smirnov test was used to assess whether the data followed a normal (Gaussian) distribution, whereas Bartlett's test was used to confirm the equal variances between the groups. Analysis of variance (ANOVA) followed by Tukey's honestly significant difference test (SPSS Inc, version 15.0, Chicago, Ill., USA) were used to analyze temperature changes between the groups at a significance level of $P<.05$.

RESULTS

The Kolmogorov-Smirnov test confirmed a Gaussian distribution ($P>.15$), and Bartlett's test confirmed equal variances between the groups ($P>.05$). Therefore, one-way ANOVA was used to assess the differences between the groups. ANOVA and the post hoc tests showed that pulp chamber temperature changes were influenced by the type of light source.

Temperature increases in the pulp chamber during polymerization of composite resin were observed (Table 2). The greatest temperature rise was with QTH curing (3.2 degrees Celsius), followed by plasma ARC curing (2.07 degrees Celsius) and VALO curing (1.44 degrees Celsius). The lowest temperature rise was with conventional LED curing (1.01 degrees Celsius).

Significant differences were observed among the tested curing lights for composite polymerization ($P<.05$). However, the multiple comparison test did not show statistically significant differences between the mean temperature rise for VALO in extra power mode and conventional LED, as well as VALO in extra power mode and plasma arc curing ($P>.05$).

DISCUSSION

The dental pulp is greatly susceptible to thermal damage, which has been identified as a primary cause of pulpal injury.[16-20] A temperature rise during the polymerization of light-activated restorative materials is attributed to both the polymerization exotherm of materials and the energy absorbed during irradiation from LCUs. Temperature increases determined in previous studies ranged from 1.5 degrees Celsius to more than four degrees Celsius in the pulp chamber of extracted teeth during light curing of resin composites.[7,21]

Zach and Cohen[15] determined that a temperature rise of 5.5 degrees Celsius within the dental pulp chamber resulted in irreversible damage. Additionally, Pohto and Scheinin[22] suggested that the critical temperature for irreversible damage to the dental pulp begins between 42 degrees and 42.5 degrees Celsius. Even though the real value of the critical temperature rise that causes pulp damage is still controversial, it can be concluded that the pulp temperature rise should be kept as low as possible during polymerization of the resin composites to avoid any risk of harming the pulp.

So far, several studies have investigated the influence of LCUs and LC modes with irradiance power ranging from 550 to 1,980 mW/cm^2 (such as halogen, plasma arc, and conventional LED) on pulp chamber temperature increases during resin composite polymerization.[23-31] However, currently there is no known published study that has examined the influence of VALO's extra power irradiance (4500 mW/cm^2) on this phenomenon. Therefore, it is difficult to make a true comparison between our findings and those of other studies. The present study was designed to simulate a clinical situation as closely as possible and showed that VALO in extra power mode and the other LCUs (conventional LED, plasma arc, and halogen) did not have any potential to cause damage in terms of temperature increases in pulp chambers.

We found statistically significant differences in temperature increases among halogen units and the other LCUs, as well as between conventional LED and plasma arc LCUs. However, the difference between conventional LED and VALO in extra power mode did not reach statistical significance. Although there was a tendency toward higher temperature values for the

Table 2. Temperature Increase in Pulp Chamber during Polymerization by Curing Units for Composite Polymerization

Light curing unit	N	Temperature increase (°C) Mean±(SD)	Minimum temperature increase (°C)	Maximum temperature increase (°C)	Tukey's honestly significant difference test
QTH	20	3.20±1.08	1.40	5.20	A
LED standard	20	1.01±0.16	0.80	1.30	B
LED plasma emulation mode	20	1.44±0.25	1.20	2.00	B, C
Plasma ARC	20	2.07±0.29	1.90	2.90	C

halogen units, the average temperature increase for every LCU was lower than the critical temperature rise that can cause irreversible damage to the pulp as reported by Zach and Cohen.[15] This might have occurred because of the in vitro test conditions. There was no pulp tissue with intact blood circulation within the pulp chamber that might help to draw off heat generated from the LCU.

Interestingly, after using VALO in extra power mode, which had the highest irradiance power, the average temperature rise was lower than for halogen and plasma arc LCUs. Similarly, Knezevic et al.[32] and Danesh et al.[33] reported that temperature increase was significantly lower for a composite cured with a plasma arc unit, which had higher irradiance power compared to a halogen LCU. A possible explanation for this may be duration of curing time. In this study, irradiation times were three seconds (twice), 10 seconds, and 40 seconds for VALO in extra power mode, plasma arc, and halogen light LCUs, respectively.

Both plasma arc and VALO LCUs have demonstrated markedly reduced curing times (10 and six seconds, respectively). However, LED lights have certain advantages over halogen and plasma arc lights: they are cordless, smaller, and lighter, do not require a noisy cooling fan, and have estimated lifespans of more than 10,000 hours. Moreover, LED technology is still developing, and high-intensity LED LCUs are forthcoming. According to Dunn and Taloumis,[34] halogen-based LCUs might be replaced by LED LCUs as semiconductor technology improves.[35]

These results of this study may help in the planning of further clinical studies. However, in vitro testing of bond strength cannot completely predict clinical efficiency because of the limitations of laboratory assessments and the different intraoral factors. For instance, stringent tooth selection criteria were used in this study, whereby teeth with enamel defects or fractures were eliminated. In actual clinical situations, imperfect teeth are the ones typically encountered. Additionally, patient-based factors, such as toothbrushing or oral habits, could affect treatment outcome.

Decreasing the total cure time would be beneficial for the clinician and the patient. Other important considerations are light curing time and degree of conversion of composite resin, which is a major factor that influences the physical properties of composites. Additionally, unreacted monomer could leach from the polymerized material and irritate the soft tissues. Finally, dental practitioners must be aware of the potential risk when using LCUs, particularly those with powerful halogen lights in deep preparations. Long-term clinical studies are needed to ensure the biological safety of the products tested in this study under laboratory conditions.

CONCLUSIONS

Based on the results of this study, the following conclusions can be made:

1. VALO in extra power mode caused a significantly lower increase in pulpal temperature than the halogen LCU.
2. There was no significant difference between conventional LED and VALO in extra power mode in terms of temperature increase in pulp chamber when polymerizing composite resin as tested.
3. All tested LCUs maintained pulpal temperature under safe limits, with temperature increases not exceeding 5.58 degrees Celsius.

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