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Temperature rise beneath a light–cured materials using two types of curing machines

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ABSTRCT

Aim: To measure the temperature rise induced by a light emitting diode (LED) curing unit and by quartz tungsten halogen (QTH) curing unit using two types of composite resin XRV Herculite and Venus. **Materials and Methods:** Forty extracted non–carious single canal premolars were cleaned and bisected longitudinally. Class V preparations were cut on the buccal surfaces. The teeth were divided into four groups; each of ten. The teeth in the first and second groups were restored with XR–Herculite composite resin. The teeth in the third and fourth groups were restored with Venus composite resin. The composite resin in the first and third groups were polymerized using QTH curing unit "Astralis" for 40 seconds; the light intensity was 502 mW/cm^2. The distance between the tip of the light and the composite was 3 $\pm$ 1 mm. The composite resin in the second and fourth groups was polymerized using LEDs "Ultra–Lite 200 E plus" curing unit for 20 seconds; the light intensity was 536 mW/cm^2 using the same distance as the first and third groups. The temperature rise at the pulpal wall was recorded by placing a thermocouple on the pulpal wall directly under the restoration. **Results:** The lowest temperature rise during LED irradiation with Venus composite resin followed by LED irradiation with XRV Herculite composite resin. Whereas QTH curing units with XRV Herculite composite resin produced higher values, QTH curing units with Venus composite resin produced the highest temperature rise. **Conclusion:** The temperature rise of LED curing units and QTH curing units used in this study was under the limits that affect the integrity of the dental pulp.

Key Words: Composite resin, heat generation, pulp damage.

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INTRODUCTION

The most widely used light sources for curing resin–based composites (RBC) are quartz tungsten halogen (QTH) lights. The radiation emitted by these incandescent lamps is band–pass filtered to a spectrum starting between 380 nm to 400 nm and ending between 500 to 520 nm.(1–3) The QTH units emit light intensities up to 400–800 mW/cm^2. Despite their popularity, the halogen units present several limitations, such as gradual reduction in energy output over time (due to bulb and filter degeneration). Therefore, a limited depth of cure and relatively long exposure time is required.(4, 5) In addition, a considerable amount of heat is generated, requiring the use of cooling fans. Cooling problems limit the development of higher energy lights which might allow the reduction of irradiation times so as to save the clinicians' time and at the same time preventing pulp damage due to heat generation.(6, 7)

Light emitting diodes (LEDs) feature very narrow spectral ranges and are therefore highly efficient light sources. Their spectral irradiance depends on the chemical composition of semiconductors used. Red LEDs have been widely used for quite some time, but blue LEDs providing sufficient irradiance for activating RBC have become available only recently.(8–11) The high efficiency of LEDs eliminates the need for cooling fans. The narrow bandwidth of emitted radiation should be optimally suited for activating camphorquinone (CQ) the light sensitive material in RBC, but the alternative photo–initiators absorbing at shorter wavelengths will most likely not be sufficiently activated. Heating of the irradiated objects by LEDs unit is expected to be minimal.[12]

Because of the risk of thermal damage to the pulp, the temperature rise in restorations of light cured resin composites has been the subject of numerous studies.[13–18] The heat generation in a restoration of composite resin is caused partly by the conversion of double bonds in the resin,[19] and partly by the heat produced by the radiation.[20–22] In QTH curing units, the heat generated by radiation is reduced by the use of heat absorbing filters. These filters are intended to remove the major part of the radiation outside the bulb range, in particular the radiation in the red and infrared ranges.[23]

The LED curing units are characterized by a relatively narrow emission spectrum, with wavelengths centered at the absorption maximum of CQ at 470 nm.[24] Thus, very little radiation of longer wavelengths is present in the emitting light. This fact has been offered as an explanation for the finding that LED curing units in previous investigations have resulted in less heat generation than QTH curing units.[17, 18] The resulting smaller temperature rise of light cured composite resin has been put forward as one of the clinical advantages of LED curing units.

The aim of this study was to measure the temperature rise induced by a LED curing unit and by QTH curing unit using two types of composite resin.

MATERIALS AND METHODS

Forty extracted non–carious single canal premolars were cleaned and bisected longitudinally. Class V preparations were cut on the buccal surfaces. The preparations were round in shape; the radius of 4 $\pm$ 0.2 mm. Depth of the preparation was varied to provide each tooth with remaining dentin thickness of 2 $\pm$ 0.1 mm. The remaining dentin thickness was measured directly under the preparation with micrometer.

The teeth were divided into four groups of ten each. The teeth in the first and second groups were restored with XRV Herculite shade A2 (Kerr 1717, West Collins Orange, CA92867, USA) composite resin. The teeth in the third and fourth groups were restored with Venus shade A2 (Kerr 1717, West Collins Orange, CA92867, USA) composite resin.

The composite resin in the first and third groups were polymerized using QTH curing unit Astralis (Vivadent, Schann, Liechtenstein) (Figure 1) for 40 seconds. The light intensity was 502 mW/cm^2. The light intensity was measured with curing radiometer Cromatest 7041 (Mega–Physikd–76437–Rastatt–Germany). The distance between the tip of the light and the composite was 3 $\pm$ 1 mm.

The composite resin in the second and fourth groups was polymerized using LED curing unit (Ultra–Lite 200E Plus, Taiwan) (Figure 2) for 20 seconds. The light intensity was 536 mW/cm^2. The light intensity was measured with the same device. The distance between the tip of the light and the composite was 3 $\pm$ 1 mm.

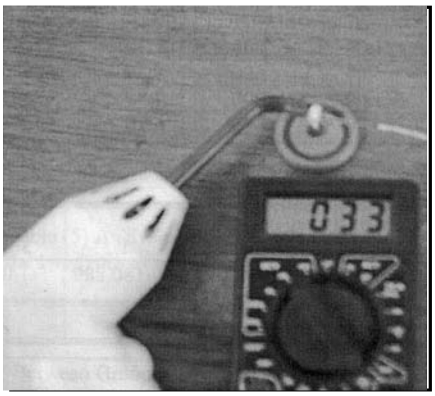

Figure (1): Quartz tungsten halogen curing unit “Astralis”, tooth sample and the Digital Multimeter

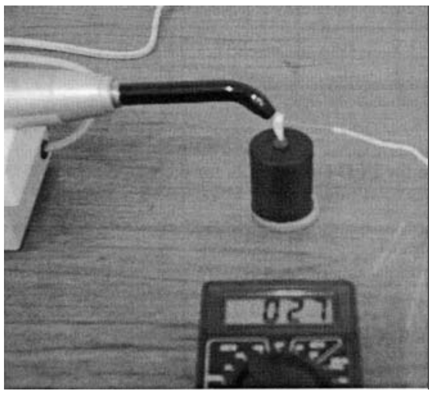

Figure (2): Light emitting diode “ Ultra–Lite“ curing unit, tooth sample and the Digital Multimeter

The temperature rise at the pulpal wall was recorded by placing thermocouple on the pulpal wall directly under the restoration. Digital Multimeter (DT–830C, China) was used to measure the temperature rise. Room temperature was selected as the baseline temperature.

Statistical analysis of data included: Descriptive statistics, one way analysis of variance (ANOVA) and Duncan's Multiple Range Test at 5% level of significance.

RESULTS

The minimum, maximum, mean and standard deviations of temperature rise for each light cure unit with each composite resin were shown in Table (1). The ANOVA for the tested groups (Table 2) showed significant differences between the tested groups. Duncan's Multiple Range Test for the tested groups showed the lowest temperature rise during LED irradiation with Venus composite resin followed by LED irradiation with XRV Herculite composite resin; whereas QTH curing units with XRV Herculite composite resin produced higher values. While QTH curing units with Venus composite resin produced the highest temperature rise.

Table (1): Descriptive statistics of temperature rise for the all groups

	No.	Mean	$\pm$ SD	Minimum	Maximum
LEDs–XRV–Herculite	10	1.40	0.51640	1.00	2.00
QTH–XRV–Herculite	10	5.80	0.63246	5.00	7.00
LEDs–Venus	10	1.30	0.48305	1.00	2.00
QTH–Venus	10	6.70	0.94868	5.00	8.00

SD: Standard deviation, LED: Light emitting diode, QTH: Quartz tungsten Halogen.

Table (2): Analysis of variance and Duncan's Multiple Range Test for the tested groups

	df	Sum of Squares	Mean Square	F–value	*p*–value
Between Groups	3	244.200	81.400	180.889	0.000*
Within Groups	36	16.200	0.450		
Total	39	260.400			

df: Degree of freedom

* Significant difference existed at $p \leq 0.05$.

Groups	No.	Mean	$\pm$ SD	Duncan's Grouping*
LEDs–Venus	10	1.30	0.48305	A
LEDs–XRV–Herculite	10	1.40	0.51640	A
QTH–XRV–Herculite	10	5.80	0.63246	B
QTH–Venus	10	6.70	0.94868	C

SD: Standard deviation

*Means with different letters were statistically significant ($p \leq 0.05$).

Table (3) showed ANOVA for LED curing units for the two composite resins. There was no statistical difference in temperature rise for both composite resins when LED curing units were used.

Table (4) showed ANOVA for temperature rise between the two composite resins when QTH curing unit was used. There was a statistical difference in temperature rise for both composite resins. The QTH curing unit with XRV Herculite composite resin showed less temperature rise than QTH curing unit with Venus composite resin.

Regardless of resin composite type, it was shown that there was a statistical difference in temperature rise between LED and QTH lights (Table 5). The LED curing unit produced less temperature rise when compared to QTH curing units.

Table (3): Analysis of variance for light emitting diode curing units for the two types of composite resin

	df	Sum of Squares	Mean Square	F–value	*p*–value
Between Groups	1	0.050	0.050	0.200	0.660
Within Groups	18	4.500	0.250		
Total	19	4.550			

df: Degree of freedom
* No significant difference existed at $p > 0.05$.

Table (4): Analysis of variance for quartz tungsten halogen curing units for the two types of composite resin

	df	Sum of Squares	Mean Square	F–value	*p*–value
Between Groups	1	4.050	4.050	6.231	0.022*
Within Groups	18	11.700	0.650		
Total	19	15.750			

df: Degree of freedom
* Significant difference existed at $p \leq 0.05$.

Table (5): Analysis of variance for light emitting diode curing unit and quartz tungsten halogen curing unit for the two types of composite

	df	Sum of Squares	Mean Square	F–value	*p*–value
Between Groups	1	240.100	240.100	449.448	0.000*
Within Groups	38	20.300	0.534		
Total	39	260.400			

df: Degree of freedom
* Significant difference existed at $p \leq 0.05$.

DISCUSSION

It is commonly believed that temperature rise associated with certain dental producers have a serious effect on vitality of the dental pulp. Pulp temperature increases of 5.5 and 11.1 ºC in Macaca Rhesus monkeys caused 15% and 60% irreversible pulpitis, respectively.[25] In the genesis of thermal damage, the extent of damage depends on the quality of heat transferred to the biological tissue. The transmission of heat is influenced by factors such as thermal conductiveness of the target, duration of the thermal impulse, contact surface, temperature and thermal capacity of the source.[26]

In the present study, the lowest temperature rise was found with LED curing unit used to cure Venus composite resin (1.3 $\pm$ 0.48 ºC), then LED curing unit with XRV–Herculite composite resin (1.4 $\pm$ 0.51 ºC). Wang and Spencer[27] showed higher temperature rise (8.9 ºC) for LED curing units.

In the present study, the temperature rise in QTH curing unit with XRV–Herculite composite resin was 5.8 $\pm$ 0.63 ºC, while QTH curing unit with Venus composite resin showed the highest temperature rise (6.7 $\pm$ 0.94 ºC). Sano *et al*.[28] showed similar temperature rise (7.1 ºC) to this study for QTH, and also there are other studies that recorded higher temperature rise.[29, 30] This may be due to experimental setup which tends to overestimate the thermal loading during polymerization, favoring larger temperature rise in the composite resin.

The temperature values measured in this study can not be directly applied to temperature changes *in vivo*. The reason is that the experimental setup of this study did not consider heat conduction within the tooth during *in situ* composite resin polymerization due to the effect of blood circulation in the pulp chamber[31] and fluid motion in the dentinal tubules. Temperature exceeding 43 ºC causes stimulation of afferent nerve fibers in connection with a reactive increase of blood circulation which dissipates the heat advancing toward the pulp chamber. In addition, the surrounding periodontal tissues could promote heat connection *in vivo*, limiting the intrapulpal temperature rise.

Clinicians should be aware of potential thermal hazard to the pulp which might result from visible light curing of composite resins in deep cavities. A simple, but effective way to protect the pulp is to apply a cement base or lining material to the cavity floor.[31] A 2–mm thick insulation layer of glass ionomer significantly reduces the intrapulpal temperature increase during composite resin polymerization.[31] However, placement of a cement base diminishes the dentinal surface area available for composite–to–dentin bonding, and therefore should be limited to deep cavities.

CONCLUSION

The LED curing units produced less temperature rise than QTH curing units when both types of composite resins were used. The temperature rise of LED curing units and QTH curing units used in this study was under the limits that affect the integrity of the dental pulp.

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