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Parameters Influencing Increase in Pulp Chamber Temperature with Light-curing Devices: Curing Lights and Pulpal Flow Rates

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Clinical Relevance

Because increase in temperature is related directly to light intensity and exposure time, curing devices with high power density (>1200 mW/cm^2) should only be activated for a short time (<15 seconds), even in teeth without cavity preparation.

SUMMARY

This laboratory study examined the effects of curing lights with different light intensities and changing flow rate on the increase in pulpal temperature during the light curing process and the rate of the subsequent decrease in temperature after the termination of light curing.

The tip of a temperature sensor was positioned on the pulpal dentinal wall of the buccal side of the maxillary premolar. Metal tubes were inserted in the palatal and buccal root of the tooth, one for water inflow and the other for water outflow. The tubes were connected to a pump to control the flow rate. The water flow rate was set to 4.2 µl/minute, 28 µl/minute or 70 µl/minute. At each flow rate, the unprepared tooth was light cured from the buccal side 1 mm from the buccal surface, using four different curing lights. The temperature data were recorded and stored on a computer every second for three minutes. The curing lights that were used were: Astralis 10 (QTH$_{high}$, Ivoclar Vivadent), Bluephase 16i (LED$_{conv}$, Ivoclar Vivadent) and two experimental LED-curing lights (LED$_{exp2000}$, LED$_{exp3000}$, Ivoclar Vivadent). The power densities were 1200 mW/cm^2, 1600 mW/cm^2, 2000 mW/cm^2 and 3000 mW/cm^2, respectively. The curing lights, LED$_{conv}$, LED$_{exp2000}$ and LED$_{exp3000}$ were activated for 60 seconds, and the QTH$_{high}$ was activated for 30 sec-

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onds. The maximum intrapulpal temperature (T_{MAX}) and rate of temperature change at 30 seconds after turning off the light (S_{30LO}) were analyzed by two-way ANOVA with a post-hoc Tukey test (p<0.05). The influencing factors were the flow rates and curing lights.

Results: The T_{MAX} ranged from 41.0°C to 53.5°C. There was a difference between the curing lights (*p*<0.05), with $LED_{exp3000}$> $LED_{exp2000}$> LED_{conv}> QTH_{high}. There was no difference in T_{MAX} between the different flow rates (*p*>0.05). Both the curing lights and flow rates affected the S_{30LO} (*p*<0.05). The S_{30LO} was $LED_{exp3000}$> $LED_{exp2000}$> LED_{conv}, QTH_{high} (*p*<0.05). The S_{30LO} at 70 µl/minutes was higher than at 4.2 µl/minutes and 28 µl/minutes (*p*<0.05).

Clinical Implication: Because the increase in temperature is directly related to the light intensity and exposure time, curing devices with high power density (>1200 mW/cm²) should only be activated for a short period of time (<15 seconds) even in teeth without cavity preparation. The flow rate had only a negligible effect on the temperature increase.

INTRODUCTION

Curing lights have become an indispensable tool in dentistry. Many dental materials are polymerized by them, including bonding materials, direct composite materials, luting materials for inlays and crowns, fissure sealants, bonding materials for orthodontic brackets and more. They are also used to bleach vital teeth, even though it has been reported that these devices do not enhance the bleaching outcome.[1]

Currently, LED lights have virtually replaced halogen lights and have a number of advantages, such as a longer service life without a decrease in performance, which is a problem frequently encountered with halogen lights, as well as a lower rate of battery discharge. The number of polymerization lights with high light intensities is increasing and units with a light output of 3000 mW/cm² and higher are now available. However, dentists have become concerned with the possibility of these high-performance lights heating the pulp to such an extent that they could cause pulpal necrosis. The critical threshold value for pulpal necrosis in human teeth is not completely understood. Most studies refer to a study carried out more than 40 years ago. In that trial, the teeth in five Rhesus monkeys were heated using a soldering gun for 5 to 20 seconds; the soldering gun exerted a temperature of 275°C (± 50°C). The results showed that, with a temperature increase of 5.5°C and 11°C, 15% and 60% of the pulpal tissues became necrotic after three months.[2] However, it is highly questionable as to whether the values obtained in monkeys are also valid for human beings. A clinical study in volunteers indicated that even a temperature rise of 9°C-15°C did not cause histologically verified pulpal necrosis after three months.[3] In that study, heat was applied to the occulsal surface of six premolars and six molars, with individually fitted supports, until the subject complained of a toothache. The contralateral tooth was extracted and the increase in temperature in the pulp was measured using the same parameters as those under *in vivo* conditions. After three months, the other teeth were extracted and examined histologically. The results indicated that the pulpal tissues could tolerate a temperature rise > 5.5°C without damage. The temperature rise was only for a short-term duration.

There are no reports of pulpal necrosis caused by high-intensity curing lights, even though these devices have been widely used for many years. However, pulpal necrosis due to heat trauma does not involve bacteria and may only be noticed many months or years after the heat exposure has occurred, at which point the dentist would probably relate the pulpal necrosis to other factors, such as possible secondary caries, preparation trauma, fabrication of self-curing tooth temporaries and testing of a pulp reaction using hot gutta purcha. The results of the laboratory tests are difficult to interpret, because the ultimate threshold value for a temperature rise for pulpal necrosis to occur is unknown.

Although the issue of increasing temperature in relation to curing lights has been studied extensively in the laboratory using different models,[4-14] the factors influencing the outcome variable have not been investigated systematically. An increase in pulpal temperature can be affected by dentin thickness,[8,11,14] duration of light exposure and the type of light-curing device used in the curing process.[4,9,12]

The pulpal blood flow rate changes in many clinical situations, such as local anaesthesia,[15-17] trauma to the tooth,[18-21] orthodontic movement[22-24] and age [18]. Many composite restorations are placed under these circumstances. It is well known that the blood flow rate affects the thermal response of living tissue. Heat exchange between the living tissue and blood vessels depends on the geometry of the surrounding tissue and the blood flow rate.[25] The difference in pulpal blood flow rate can affect the increase in pulpal temperature during the light curing process. The pulp has the highest blood flow per unit weight compared to other oral tissues. Furthermore, capillary blood flow in the coronal portion of pulp is almost double that found in the radicular portion.[26] The abundant blood flow in pulp may also help to disperse heat and help to prevent pulpal damage due to heating.

The current laboratory study examined the effect of curing lights with different light intensities and the changing flow rate on the increase in pulpal temperature during the light curing process and the rate of temperature decrease after the termination of light curing.

The null hypotheses in this study were as follows:

1) There is no difference in intrapulpal peak temperature during the light curing process between curing lights with different power densities.
2) There is no difference in intrapulpal peak temperature in pulp during the light curing process between groups with different flow rates.
3) There is no difference in the rate of temperature decrease in pulp after turning off the device between curing lights with different power densities.
4) There is no difference in the rate of temperature decrease in pulp after turning off the device between groups with different pulpal flow rates.

METHODS AND MATERIALS

The experimental setup used in the current study is similar to one proposed by Daronch and others.[5]

A. Preparation of Tooth

A maxillary premolar with two separate roots, without caries and/or restorations, was used. No cavity preparation or filling procedures were carried out on the buccal surface, which was exposed to the light curing units. The roots were cut by one-third of their length to expose the canal spaces for metal tube insertion. After checking whether the root canals were free of debris, two metal tubes (diameter 2 mm) were inserted into the apices of both roots about 2 mm and fixed into position using Syntac Classic (Ivoclar Vivadent, Schaan, Liechtenstein) and Heliobond (Ivoclar Vivadent) (Figure 1). The two polyethylene tubes, one for water outflow and one for water inflow, were connected to the metal tubes.

B. Insertion of Thermocouples

On the palatal side of the premolar, a hole (diameter 2 mm) was drilled into the pulp chamber with a cylindrical diamond bur (FG 8614, Intensiv, Grancia, Switzerland). After beveling the orifice, the enamel surrounding the hole was etched with Total Etch (Ivoclar Vivadent) for 30 seconds, then rinsed with water. Heliobond was applied to the etched enamel, gently air-dried, then light-cured for 10 seconds (Astralis 10, 650 mW/cm^2). A K-type thermocouple (CHAL-003; OMEGA Engineering, Inc, Stamford, CT, USA) was positioned in the hole, while attention was paid to bringing the tip into contact with the dentin that was opposed to the buccal cavity. Furthermore, care was taken not to insert the thermocouple with too much force in order to avoid bending it. The thermocouple was fixed in position using Variolink II Base material and light-cured for 30 seconds (Astralis 10, 650 mW/cm^2). A radiograph was taken to confirm the position of the thermocouple (Figure 2). Other thermocouples for water and air were placed in the water bath and air. All three thermocouples were connected to a computer via a data logger (Agilent 34970A, Agilent Technologies Santa Clara, CA, USA). Software (Agilent BenchLink DataLogger, version 1.4) was used to measure the temperatures at a frequency of 1 Hz.

Figure 1. *Prepared tooth with tubes for water circulation.*

Figure 2. *Radiograph of a tooth with a temperature sensor.*

C. Connection to Water Cycle and Controlling Flow Rates

The polyethylene tube for the water outlet was connected to the pump, and the one for water inflow was placed in the water bath with deionized water. To mimic blood flow in the tooth, the tube for water outflow was connected to the pump. Negative pressure from the pump induced water outflow from the pulp space through the polyethylene tube used for water outflow. At the same time, it also caused water inflow from the water bath into the pulp space through another tube used for water inflow. The flow rate was controlled by a regulator in the pump, and regulator levels 1, 2 and 4 were used. At each level, the amount of water drained from the tooth was collected over a one-minute period and measured. The flow rates in levels

1, 2 and 4, were 4.2 µl/minute(A), 28 µl/minute(B) and 70 µl/minute(C), respectively.

D. Taking the Curing Light's Spectral Radiant Emittance Plot and Power Density

The integration power and its spectral radiant emittance plot of the curing light were measured using an integration sphere and its software (Gigahertz-Optic GmbH, Puchheim, Germany). The curing lights were Astralis 10 (QTH_{high}, Ivoclar Vivadent), Bluephase 16i (LED_{conv}, Ivoclar Vivadent) and two experimental LED curing lights ($LED_{exp2000}$, $LED_{exp3000}$, Ivoclar Vivadent). AS10 was a halogen type light and the other three devices were LED curing lights. The diameter of the light-curing tip was 8 mm in all groups. For $LED_{exp3000}$, a cooling system that was specially designed for this unit was installed, which blew a constant stream of cool air in the direction of the light-curing tip. The power density of each curing light was calculated by dividing the integration powers of each curing light by fiber bundle area of each curing light.

E. Measurement of Pulpal Temperature in Relation to the Different Curing Lights and Flow Rates

I. Maximum Intrapulpal Temperature (T_{MAX})

When the pulp temperature was stabilized between 33°C and 34°C, the tooth was exposed to the four curing lights at each flow rate:

For each curing light, the distance from the light tip to the tooth was set to 1 mm using a metal spacer. The LED_{conv}, $LED_{exp2000}$ and $LED_{exp3000}$ curing lights were activated for 60 seconds but QTH_{high} was activated for 30 seconds. Subsequently, the decrease in temperature of LED_{conv}, $LED_{exp2000}$ and $LED_{exp3000}$ was monitored for an additional 2 minutes and 2.5 minutes for QTH_{high}. The temperature data of the pulp, water and air were stored in a computer every second from the start of the light-curing procedure. Five measurements were taken in each group. The highest temperature of the pulp (T_{MAX}) was registered and used for a statistical comparison (Figure 3). The T_{MAX} were compared between groups using two-way ANOVA with a post hoc Tukey test with two fixed variables (flow rate, curing lights) at the 95% confidence level.

II. Calculation of the Rate of Temperature Change at 30 Seconds After Turning Off the Light (S_{30LO})

In the time-temperature diagram, which shows the results of experiment I (T_{MAX} study), the rate of the temperature change at 30 seconds after turning off the light (S_{30LO}) was calculated. The rate for LED_{conv}, $LED_{exp2000}$ and $LED_{exp3000}$ was calculated at 90 seconds and 60 seconds for QTH_{high}.

Figure 3. *Tooth fixed in a water bath.*

The rate of the temperature change (S) at time x and the temperature T_x were defined using the following equation:

$$S_x = |T_{x+1} - T_{x-1}| / \{(x+1)-(x-1)\} = |T_{x+1} - T_{x-1}| / 2$$

The S_{30LO} were compared between groups using two-way ANOVA with a post hoc Tukey test with two fixed variables (flow rate, curing lights) at the 95% confidence level.

RESULTS

Table 1 summarizes the means and standard deviations of T_{MAX}. The temperature increased to a range between 41.0 °C and 53.5°C, depending on the curing light used. Table 2 lists the results of two-way ANOVA

Table 1: *Maximum Intrapulpal Temperature (T_{max}) Reached During Different Applied Curing Lights and Flow Rates (mean[sd])*

Curing Light	Flow Rate	T_{max}
QTH_{high}	A	41.0 (0.83)
	B	41.5 (0.36)
	C	41.4 (0.21)
LED_{conv}	A	46.0 (0.16)
	B	45.3 (0.30)
	C	45.4 (0.42)
$LED_{exp2000}$	A	50.9 (0.16)
	B	51.2 (0.36)
	C	51.0 (0.34)
$LED_{exp3000}$	A	53.7 (1.09)
	B	52.8 (1.04)
	C	53.5 (1.10)

Flow rate A: 4.2 µl/minute, B: 28 µl/minute, C: 70 µl/minute.

Table 2: *Results of Two-way ANOVA for T_{max}*

Source	Sum of Square	df	Mean Square	F	*p*-value
Curing light	1320.559	3	440.186	1078.296*	.000
Flow rate	.355	2	.177	.434	.650
Curing light * Flow rate	4.331	6	.722	1.768	.126
Error	19.595	48	.408		
Total	138524.258	60			

Table 3: *Temperature Decline Rate (°C/seconds) at 30 Seconds After Light Termination [S_{30LO}] (mean[sd])*

	A	B	C
QTH_{high}	0.11 (0.01)	0.13 (0.01)	0.11 (0.001)
LED_{conv}	0.13 (0.01)	0.11 (0.01)	0.13 (0.001)
$LED_{exp2000}$	0.16 (0.01)	0.18 (0.01)	0.18 (0.001)
$LED_{exp3000}$	0.24 (0.01)	0.25 (0.01)	0.27 (0.02)

Flow rate A: 4.2μl/minute, B: 28μl/minute, C: 70μl/minute.

Table 4: *Results of Two-way ANOVA for S_{30LO}*

Source	Sum of Square	df	Mean Square	F	*p*-value
Curing light	.173	3	.058	526.358	.000
Flow rate	.003	2	.001	12.475	.000
Curing light * Flow rate	.004	6	.001	6.029	.000
Error	.005	48	.000		
Total	.185	59			

on the effects of the curing light and flow rate on the maximum intrapulpal temperature and their interaction effect. The curing light had a significant statistical effect on the T_{MAX} ($p<0.05$), whereas the flow rate did not ($p>0.05$). There was no interaction between the curing light and flow rate ($p>0.05$). The results of a post hoc multi-comparison Tukey test indicated the following ranking of T_{MAX}: EX2> EX1>BP>AS10 ($p<0.05$).

Table 3 shows the means and standard deviations of S_{30LO}. S_{30LO} ranged from 0.11 (A) to 0.27. Table 4 summarizes the results of the two-way ANOVA regarding the effects of the curing light and flow rate on S_{30LO}, along with its correlation. Both the curing light and flow rate had a significant statistical effect on the S_{30LO} ($p<0.05$). However, Figure 5 suggests that the interaction was minimal, because all lines ran practically parallel. The results of the Tukey test for the curing light factor indicated that the S_{30LO} was $LED_{exp3000}$> $LED_{exp2000}$> LED_{conv}, QTH_{high} ($p<0.05$). The results of the Tukey test for the flow rate indicated that the S_{30LO} at 70 μl/minute was higher than that at 4.2 μl/minute and 28 μl/minute ($p<0.05$).

DISCUSSION

In the current study, the flow rate did not affect the highest temperature in pulp (T_{MAX}) but influenced the decrease in temperature once the device was switched off. The T_{MAX} ranged from 41°C to 53.7°C when it was monitored under a controlled flow rate and curing light exposure. As the initial temperature was approximately 34°C, the amount of increase ranged from approximately 7°C to 19.7°C (Figures 6 and 7; Table 1). In a pilot study, the temperature in pulp was monitored, while changing only the flow rate with the curing light in the turned-off state. The temperature increased with increasing flow rates but the increase was very limited. Considering the results of the current study, the effect of the flow rate appeared to be masked by T_{MAX}, because the temperature changes induced by the curing light were much greater than those induced by the flow rate. If the *in vitro* results are applied to *in vivo* conditions, it may be concluded that the flow rate in blood vessels has a negligible effect on the rapid increase in temperature in pulp during the critical phase when the curing light is activated.

When the curing light was turned off, the decrease in pulp temperature was more pronounced in the test group with higher flow rates. It appears that a higher flow rate removed heat more quickly, which affects the S_{30LO}.

The influence of the flow rates on T_{MAX} was quite limited. This phenomenon may be explained by the Womersley number, which is a dimensionless number in biofluid mechanics and describes the heat transfer between a vessel and tissue[27]: $\alpha = R\ (w/v)1/2$, where α is the Womersley number, R is the vessel radius, W is the radial frequency (rad/s) and V is the kinematic viscosity (m^2/s). From this equation, the change in flow rate due to pulsating blood, which affects the radial frequency, has a very limited or negligible effect on the heat transfer in small vessels. However, it would be inappropriate to apply this equation directly to the current study, because the canal space and pulp chamber

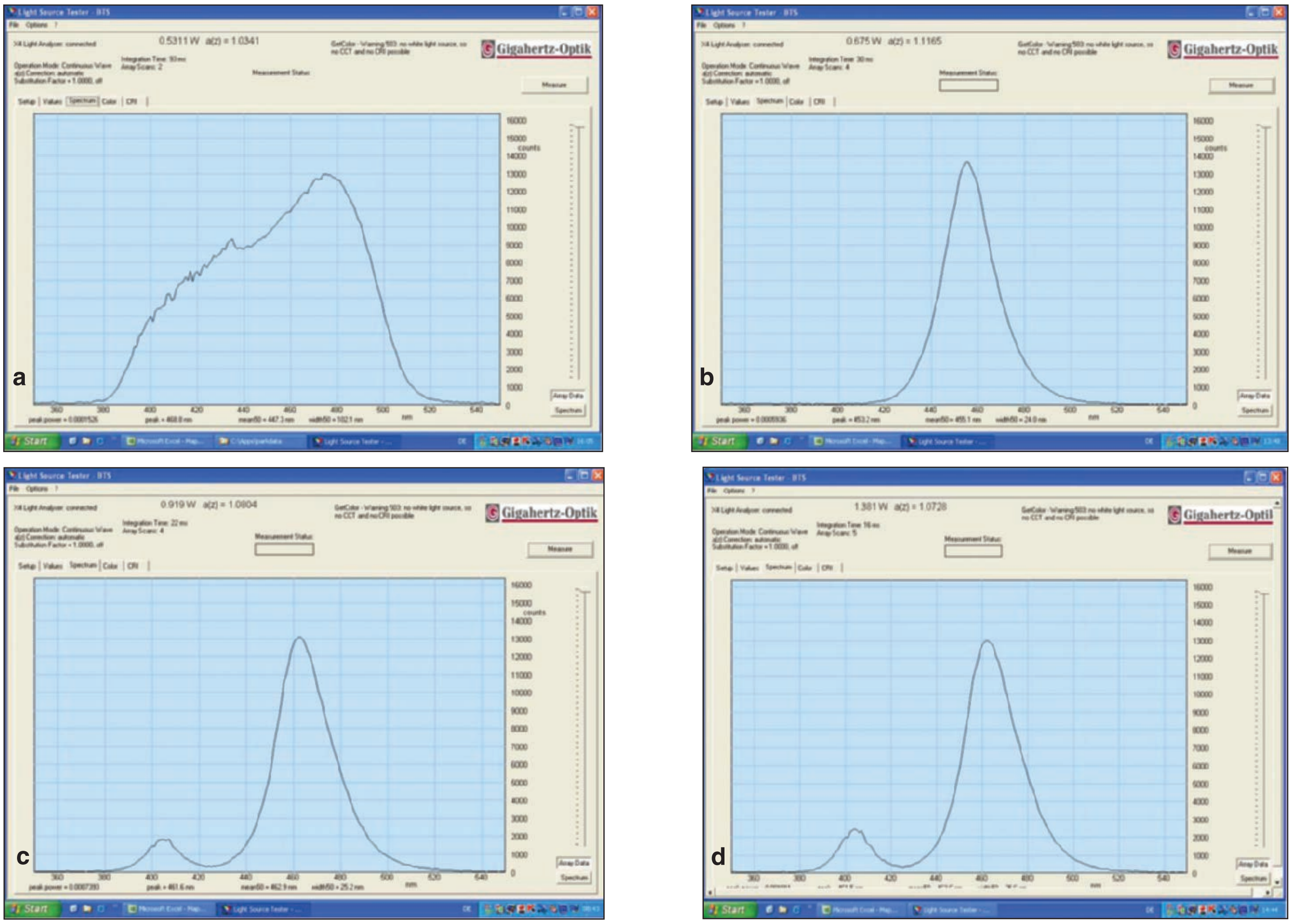

Figure 4. *Curing light's spectral radiant mission plot. QTH_{high} (Figure 4a), LED_{conv} (Figure 4b), $LED_{exp2000}$ (Figure 4c), $LED_{exp3000}$ (Figure 4d).*

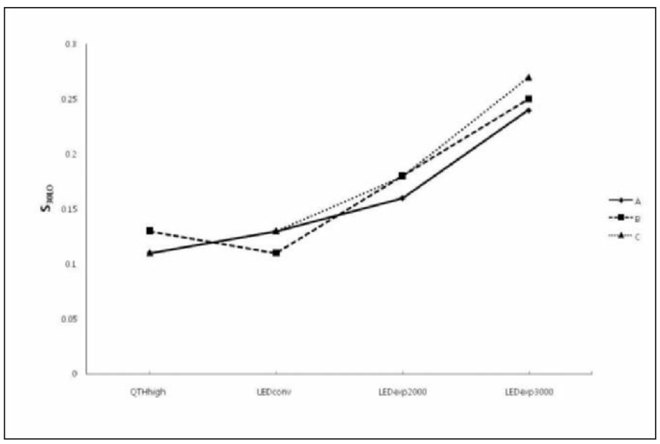

Figure 5. *Profile plot for S_{30LO} in relation to the curing lights and flow rates. A, B and C represent the flow rates, 4.2 µl/minute, 28 µl/minute and 70 µl/minute, respectively.*

geometry were not circular or consistent. Nevertheless, this equation can explain why the flow rate had such little influence on pulp temperature.

The T_{MAX} data in this study was consistent with that reported in other studies, showing a large increase in temperature with light curing units that have a high power density.[3,8,10,12] Considering the initial temperature in pulp (approximately 34°C), the increase in pulp temperature after exposure to QTH_{high} (30 seconds), LED_{conv} (60 seconds), $LED_{exp2000}$ (60 seconds) and $LED_{exp3000}$ (60 seconds) was 7°C, 11°C, 17°C and 19°C, respectively. According to Zach and Cohen, a 5°C increase in temperature could cause histological changes to the pulp. In the current study, the intrapulpal temperature increased by more than 5°C when the exposure time was extended by more than 20 seconds in QTH_{high} and LED_{conv}, and more than 10 seconds in $LED_{exp2000}$ and $LED_{exp3000}$ (Figure 6). Although the critical threshold value for pulpal necrosis in human teeth is not completely understood, it would be advisable to limit the exposure time to 20 seconds for a curing device whose power density is between 1200 and 1600 $mWcm^2$, and to 10 seconds for a curing device whose power density is between 2000 and 3000 mW/cm^2.

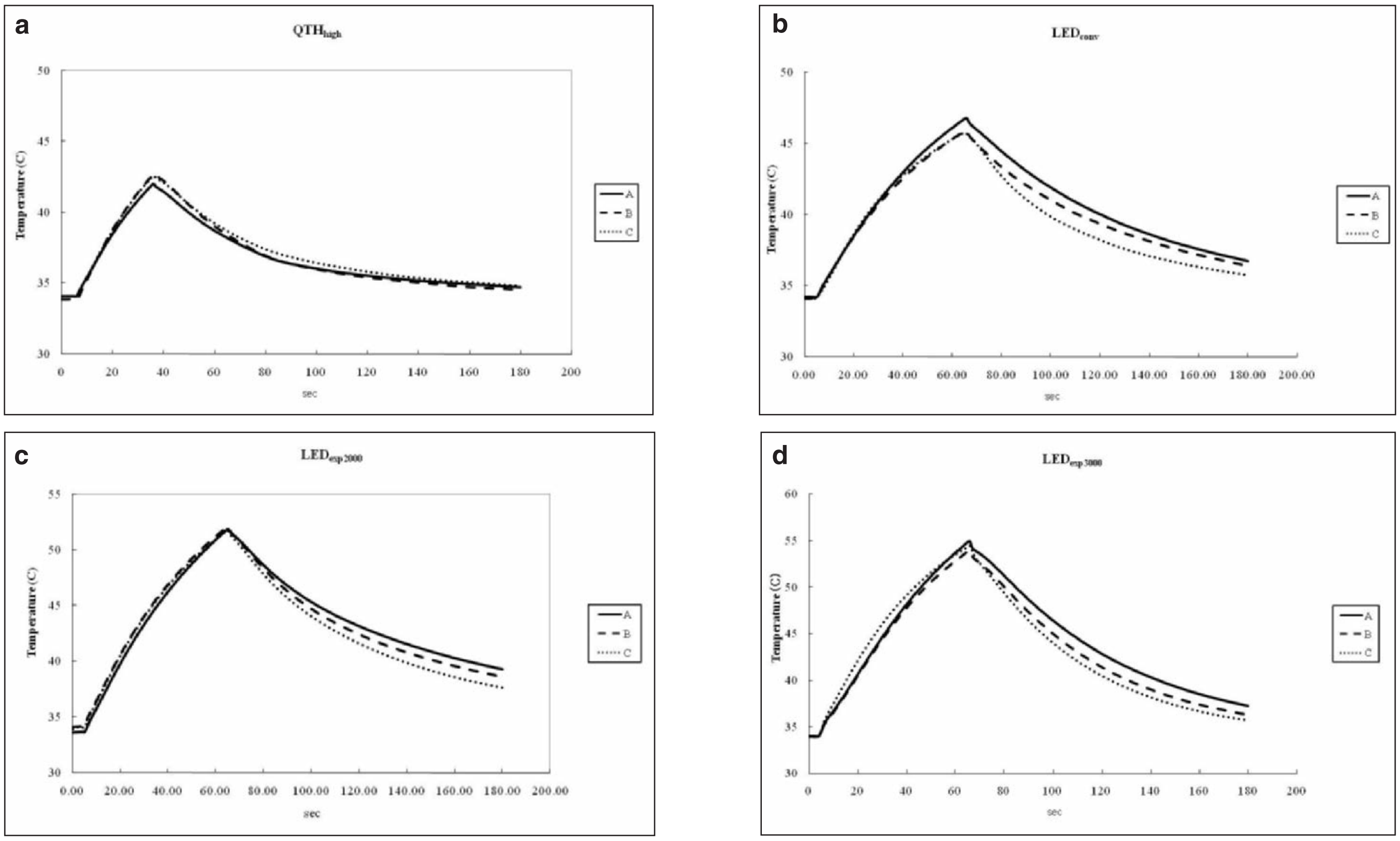

Figure 6. *Temperature change (°C) in the pulp according to the curing lights used, QTH$_{high}$ (6a), LED$_{conv}$ (6b), LED$_{exp2000}$ (6c), LED$_{exp3000}$ (6d) and different flow rates A, B and C represent the flow rates, 4.2 µl/minute, 28 µl/minute and 70 µl/minute, respectively.*

Figures 6 and 7 show that the temperature decreased effectively after the curing light was switched off. This effective cooling in the tooth may help to limit the temperature increase in pulp in multiple light curing procedures in clinical situations.

The baseline temperature value of 34°C was reached in QTH$_{high}$ only 2.5 minutes after the curing light was turned off. Therefore, the pulpal temperature would be well above 34°C when the second or third exposure to light occurs. Whether multiple exposures lead to a greater increase in pulpal temperature is unknown and should be investigated further.

It should be noted that cavity preparation was not performed prior to light exposure in this study. In some clinical procedures, such as the placement of orthodontic brackets with light-curing materials and the acceleration of bleaching products, the cavity is not prepared. A future study will examine whether a reduced thickness of the remaining hard tissue leads to a greater increase in pulpal temperature.

Another variable is the distance of the light tip to the tooth, which will also be evaluated in another study. Operational measures that may be helpful in reducing the temperature increase include the use of base materials,[4] modulation of the light intensity,[7] as well as curing tip design and diameter.[8]

A comparison of QTH$_{high}$ and LED$_{conv}$ in Figure 7 showed that the pattern of the temperature increase was quite similar—from two seconds to 30 seconds—despite the difference in power density of approximately 313mW/cm^2 between these two curing lights. This might be because QTH$_{high}$ produced a broader spectrum and a slightly greater red shift than LED$_{conv}$ (Figure 4). Therefore, LED$_{conv}$ might produce comparatively less heat than QTH$_{high}$, which would eventually result in a similar increase in temperature.[10,12]

Although T_{MAX} was higher in LED$_{exp3000}$ than LED$_{exp2000}$, the difference was not great, considering that the difference in power density between the two was approximately 1000mW/cm^2 (Figure 7, Table 1). The S_{30LO} was much higher in LED$_{exp3000}$ than LED$_{exp2000}$ (Figure 7, Table 3). This appears to be related to the cooling system in LED$_{exp3000}$. This cooling system is effective in reducing the T_{MAX} and increasing the cooling speed, because it is also activated after the light was switched off.

The flow rates (4.2 µl/minute, 28 µl/minute or 70 µl/minute) set in the current study did not represent a

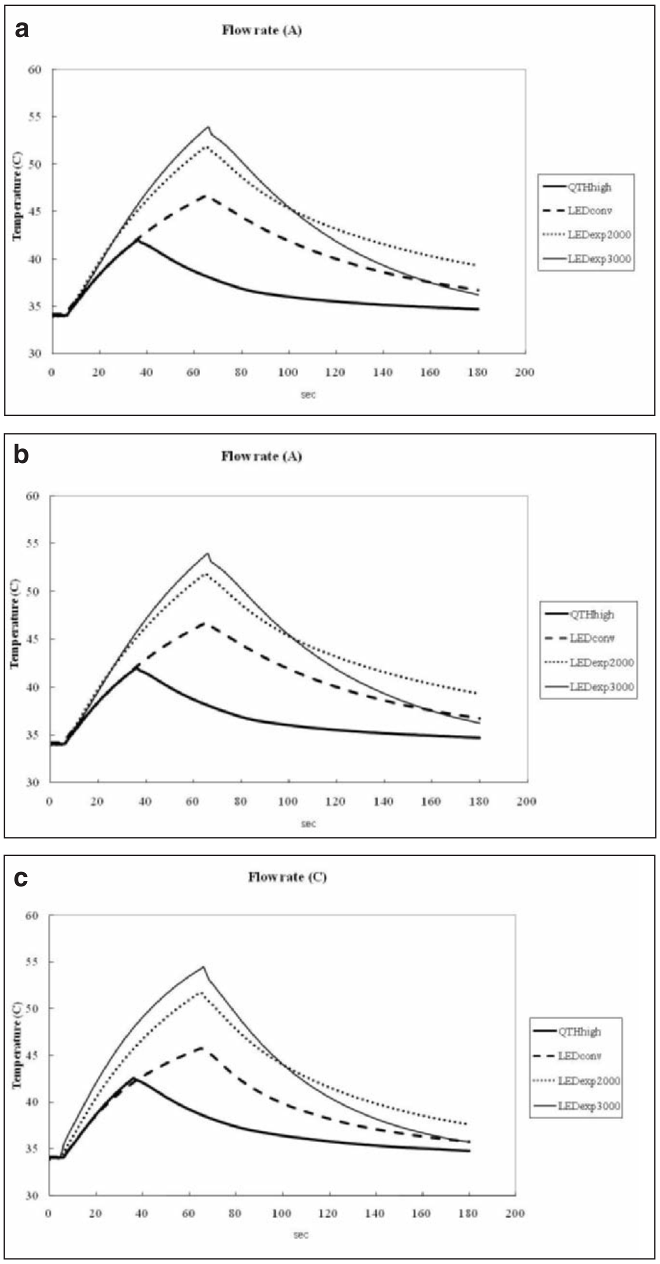

Figure 7. *Temperature change (°C) in the pulp according to the flow rates: 4.2 µl/minute (7a), 28 µl/minute (7b) or 70 µl/minute (Figure 7c) and different curing lights.*

real clinical situation, because the real pulpal blood flow rates in humans is unknown. Kim and others[17] reported that the pulpal flow in dogs was 33.32 ml/minute in 100g of pulp tissue and was reduced to 7.72 ml/minute after local infiltration anesthesia using 1:100,000 epinephrine with 2% lidocaine. Lustig and others[28] reported in their ultrasound/doppler imaging study that the blood flow rate of the sublingual artery that penetrates the bone through the lingual foramen at the midline of the mandible was 0.7-3.7ml/minute. Pitt Ford and others[29] reported a significant decrease (31%) in pulpal blood flow after an injection of 1 ml of 2% lidocaine with 1:80,000 adrenaline.

The interaction between curing lights and flow rates was statistically significant (Table 4). The medium flow rate B seems to be responsible for it, as the S_{30LO} of LED_{conv} was lower for the medium flow rate than for the higher flow rate and the S_{30LO} of QTH_{high} was higher for the medium than for the higher flow rate. The reason for that is unclear.

As only one upper premolar was used in this study, the data would vary according to the tooth size and shape. A future study should examine the effect of these factors.

This is the first report in a series of studies that evaluated the effects of the following factors: 1) flow rate, 2) thickness of the overlaying dental hard tissue, 3) distance from the light source to the tooth and 4) presence of composite filling material. All these factors may affect the increase in temperature in pulp during the curing process.

Of the four null hypotheses, the second held and the other three were rejected.

CONCLUSIONS

Within the limits of this study, in which one maxillary premolar was used, the following conclusions were made.

There was a difference in intrapulpal peak temperature during the light-curing process between curing lights with different power densities.

There was no difference in intrapulpal peak temperature in pulp during the light-curing process between groups with different flow rates.

There was a difference in the rate of temperature decrease in pulp after switching off the device between the curing lights with different power densities.

There was a difference in the rate of temperature decrease in pulp after switching off the device between groups with different pulpal flow rates.

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Departments

Faculty Positions

East Carolina University School of Dentistry
Greenville, North Carolina
Chief, Biomedical Materials Science
Vacancy #000928

East Carolina University's (ECU) new dental school in Greenville, NC invites applications for the position of Chief of Biomedical Materials Science. This unit is responsible for curriculum in the area of biomedical and dental materials science. Curricular innovation is a hallmark of the new school, with the first students beginning in 2011. ECU is the third largest public university in North Carolina.

The Chief of Biomedical Materials Sciences provides leadership in areas related to materials science. It is expected that this individual will conduct funded research related to materials science. Tenure track is available. Salary will be commensurate with qualifications.

Required Qualifications: PhD in Materials Science or Engineering, with a focus on materials (or equivalent) from an appropriately accredited institution.

Screening will begin August 1, 2010 and continue until the position is filled. Candidates should submit a candidate profile, curriculum vitae, letter of interest and the names and contact information for three references to ECU Human Resources at: www.jobs.ecu.edu.

Any questions about the position can be sent to Dean James R Hupp at: huppj@ecu.edu. Members of historically underrepresented groups and women are strongly encouraged to apply.

ECU is an Equal Opportunity/Affirmative Action Employer.

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Erratum

In *Operative Dentistry,* 2010, **35-3**, 308-313, Microleakage in Class II Restorations: Open vs Closed Centripetal Build-up Technique, the correct order of the authors is: A Fabianelli, A Sgarr, C Goracci, A Cantoro, S Pollington & M Ferrari. This update has been posted online.

Also in *Operative Dentistry,* 2010, **35-3**, 353-361, Parameters Influencing Increase in Pulp Chamber Temperature with Light-curing Devices: Curing Lights and Pulpal Flow Rates, S-H Park, J-F Roulet & SD Heintze, Figures 1-3 have been updated online.