

**Comparison of Temperature Rise in the
Pulp Chamber with Different Light
Curing Units-An In Vitro Study**

**Dissertation submitted to
THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**

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CERTIFICATE

This is to certify that this dissertation titled **COMPARISION OF TEMPERATURE RISE IN THE PULP CHAMBER WITH DIFFERENT LIGHT CURING UNITS - AN IN VITRO STUDY** is a bonafide record of **DR.A.V.RAJESH EBENEZAR** under my guidance during his post graduate study period between 2002 – 2005.

This dissertation is submitted to **THE TAMILNADU Dr.M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the degree of Master of Dental Surgery in Branch III Conservative Dentistry and Endodontics.

It has not been submitted (partial or full) for the award of any other degree or diploma.

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INTRODUCTION

In recent years the need for tooth coloured restorations had led to an increase in the use of resin composites and they have conquered the major part of modern restorative dentistry. It is the “state of art” of 21st Century and thus it has become an essential part of the armamentarium of the restorative dentist.

The polymerization of a dental composite results from a chemical reaction between dimethacrylate resin monomers that produces a rigid and heavily cross – linked polymer network surrounding the inert filler particles (Ferracaine 1995) ³⁷. Light source of adequate intensity and wavelength from 400–500nm is required for polymerization to activate light sensitive substance camphoroquinone, with maximum absorption at 468 nm. Visible light in the blue region of the spectrum has gained popularity over ultra-violet light because of its ability to produce a greater depth of polymerization and to avoid possible eye damage. A 400 – 500 nm band pass filter is used to remove undesired wavelengths from the white halogen source, resulting in the typical blue light of the dental curing unit ⁹.

Temperature rise during curing of light activated restoratives, relates both to the polymerization exotherm of the material and also to the thermal emission from the dental light curing unit ³⁴. Since curing times upto 40 secs are often required to cure the composites to an adequate depth, high-intensity halogen lamps in the 400-500 nm range which exceeds 1000 mw/cm² have been introduced resulting in curing times of about 10 secs. The use of high – intensity lamps reduces the curing time, but also increases the risk of pulpal damage ¹⁹. Zach and Cohen (1965) stated that a

temperature rise of 5.5°C within the pulp chamber would lead to irreversible pulp damage ⁴².

Halogen bulbs generate light by electrical heating of a tungsten filament to extremely high temperatures. Mostly heat radiation, which is in infrared of the electro-magnetic spectrum, is generated and only a small percent of the light output desired for polymerization is in the visible spectrum ⁴¹. These spectral impurities induce heating of the tooth and composite during the curing process. The high operating temperatures and large quantity of heat produced during the curing cycles degrade the bulb and reflector, reducing the curing effectiveness over time. To overcome these problems inherent with halogen lights new devices based on solid-state light emitting diode (LED) technology have been developed, which use junctions of doped semiconductors (p-n junctions) for the generation of light ⁴¹.

Light curing units can cause a temperature increase that could lead to irreversible pulpal damage ¹⁴. (Chussey, Biagoni & Lamey, 1995, Hanning & Bott 1999). The potential damaging effect of temperature increase on pulp tissue during restorative treatment is a major concern in the field of dentistry for many years. Thermal transfer to pulp is influenced by material shade, thickness, composition, porosity, curing time and residual dentin thickness (Mc cabe 1985, Goodis & Ohters 1989; shortall & Harrington 1998). Temperature rise during the curing of restorative materials is however mainly contributed by the light source (Lloyd, Joshin & Mc Glynn 1986) ³⁸. It also varies with the type of curing unit, quality of light filter, output intensity and irradiation time. (Goodis et al 1997, shortall & Harrington 1998, Hanning & Bott (1999) ³⁸.

This study was designed to measure the pulpal surface temperatures when using QTH and LED light source, by quantifying and comparing the thermal emission of these light-curing sources. Temperature changes associated with varying curing modes of each light curing units were also compared in vitro. To simulate the in-vivo situation of a composite restoration, a study was also done step-wise and temperature changes were recorded after each step.

REVIEW OF LITERATURE

Leo Zach and Gerson Cohen (1965)⁴² conducted an animal study on “Pulp response to externally applied heat” Macaca rhesus monkey was selected and intra-peritoneal pentobarbital 0.5ml per body kilogram weight was the anaesthetic administered. Intrapulpal temperature rises were induced by applying a soldering iron to the labial or buccal aspects of the tested teeth approximately 1mm from the gingival crest. They reported that an intact dental pulp responds to heat in a fairly constant, predictable manner. Operative procedures performed with little regard for thermal shock result in heat insult to the pulp, which enters the critical range.

J.F.McCabe(1985)²⁷ evaluated “Cure performance of light activated composites by Differential thermal analysis”. Degree of cure and temperature rise can be readily evaluated as a function of irradiation time using differential thermal analysis. He concluded that the temperature rise for a 60 mm³ sample of material varies between 20°C and 40°C .

Lloyd C.H., Joshi A. and McGlynn E.,(1986)²³ in their in-vitro study on “ Temperature rises produced by light sources and composites during curing” modified a differential thermal analyzer to measure the temperature

rises which occur during the setting of visible light-cured composites. They reported that the rise produced by the light increases with increasing exposure time and decreasing composite thickness, to reach up to 21.4°C.

Anthony H L, Tjan James R Dunn(1988) ² in their in-vitro study on “Temperature rise produced by various light generators through dentinal barriers” measure the temperature change with a 30-gauge needle thermocouple probe placed directly beneath the light tip, the probe being connected with a digital electronic thermometer. They concluded that the thickness of a residual dentin with its low thermal conductivity is a critical factor in reducing thermal transfer to the pulp.

Masutani S, Setcos J C, Schnell R J and Phillips R W(1988) ²⁵conducted an in-vitro study on “Temperature rise during polymerization of visible light-activated composite resins”. The temperature rise was monitored during the exothermic polymerization reaction of 5 selected visible-light activated composite resins cured with 5 activator lights. They concluded that temperature peaks occurring at curing times of less than 31 secs were higher than those peaks occurring at curing times between 31-60 secs of cure. Also, a higher intensity light source is more effective in curing the resins than higher temperature generated by the light source.

Goodis H.E., White J.M., Andrews J. and Watanabe L.G.(1989) ¹² evaluated “Measurement of temperature generated by visible-light-cure lamps in an in-vitro model” by the temperature rise induced after 20-second and 60-second exposures from six Visible light curing units with and without air coolant. They also studied whether various cure units emit different amounts of heat, whether air cooling was able to lower temperatures, and the extent to which enamel and dentin thicknesses act as a thermal barrier for the pulp chamber. They concluded that

- a. The longer the cure lamp is on, the more heat develops
- b. More heat develops at 60 secs than at 20 secs
- c. The amount of heat reaching the pulp chamber was low when compared with that on the surface of the tooth.

Lauer et.al(1990) ²¹ studied the “Effects of the temperature of cooling water during high-speed and ultra-high speed tooth preparation”. They selected intact third molars for their in-vitro measurements of heat production in the pulp chamber during tooth preparation. Two drive systems, the turbine and the high-speed angle, was compared by using two ranges of cooling water temperature. They inferred that, since the temperature elevation during the turbine preparation was dependent on the diminishing thickness of remaining dentin, in preparing teeth close to the pulp, a high-speed angle was advantageous.

Hansen F K, Asmussen E(1993) ¹⁵ in their in-vitro study on “Correlation between depth of cure and temperature rise of a light activated resin” concludes the following:

- a. For all units, the temperature increase in a 60 sec cycle followed a logarithmic curve, with the most effective light sources giving the highest temperature rise.
- b. In the surface layer the change of temperature ranged between 3.6 and 29.2 °C and 3.2mm below the irradiated surface between 1.5 and 12.3°C
- c. The use of a 2mm thick isolating layer of glass ionomer resulted in a significant reduction in the temperature increase

The correlation between the depth of cure and the temperature rise was of an exponential or power failure i.e., a small increase of the depth of cure was followed by a disproportionately high increase in temperature.

Andersen E., Aars H., Brodin P(1994) ¹ conducted an in-vivo study on “ Effects of cooling and heating of the tooth on pulpal blood flow in man”. Laser Doppler flowmetry was used to study the changes in pulpal blood flow evoked by application of cold or heat to the palatal surfaces of teeth 11 or 21 in nine young subjects. They reported that both cooling and warming triggered an increase in pulpal blood flow.

Joel M White, Mark Fagan and Harold Goodis(1994) ³⁶ in their study on “ Intrapulpal temperatures during pulsed ND:YAG laser treatment of dentin, in vitro” measure the intra-pulpal temperature by inserting the copper-constantan thermocouples into the radicular pulp canals of extracted teeth. They concluded that intrapulpal temperatures decreased as remaining dentin thickness(0.2-2.0mm)increased.

Harrington E and Wilson H J(1995) ¹⁶ in their in-vitro study on “ Determination of radiation energy emitted by light activation units” evaluated the characteristics of four light by developing an equipment to measure radiation energy over a wide range of illumination. This range can be from the relatively low intensity of radiation transmitted through restorative material to the intensities of direct radiation from light activation units. They concluded that a considerable temperature rise at the light guide tip was observed for all light curing units.

D.L.Hussey, P.A.Biagoni and P.J.Lamey(1995) ¹⁸ in their study on “Thermographic measurement of temperature change during resin composite polymerization in vivo” had composite resin restorations placed in upper incisor teeth of 10 patient volunteers. During photocuring, the temperature rise within the composite was measured using the Thermovision 900 infrared scanning system. They concluded that temperature rise of $5.4^{\circ} \text{C} \pm 2.5^{\circ} \text{C}$ during composite polymerization will endangered the pulp

Goodis H E et al.,(1997) ¹³ conducted a study on “ Effects of Nd: and Ho: Yttrium-Aluminium-Garnet lasers on human dentine fluid flow and dental pulp-chamber temperature in vitro”.Dentine specimens were prepared from freshly extracted third molars and each specimen was subjected to Nd:yttrium-aluminium-garnet(YAG) laser energy while temperatures in the pulp chamber were recorded. They inferred that temperature rises were high enough to have caused pulpal damage, indicating shorter treatment times and lower power settings if used in vivo.

Jacopo Castelnuovo, Anthony H, Tijan L, (1997) ⁷ in their in-vitro study on” Temperature rise in pulpal chamber during fabrication of provisional resinous crowns “ compared the rise in temperatures in the pulpal chamber during fabrication of provisional complete veneer crowns by direct method with different autopolymerizing and photopolymerizing resins. The effect of curing resinous crowns in different matrices, such as polyvinyl-siloxane impression and a vacuum-formed polypropylene sheet, was also evaluated. They stated that the amount of heat generated during resin polymerization and transmitted to the pulpal chamber could be damaging to pulpal tissues including odontoblasts, and they highly recommend effective cooling procedures during fabricating resinous provisional crowns.

Mohamed A, Ashour and Rita, Khounganian M,(1997) ²⁸ in their animal study on “ Scanning electron microscopic study of visible light curing effects on the oral mucous membrane” demonstrate the structural changes that took place after the exposure of the gingiva to a dental visible light curing unit. The mandibular molar was exposed to radiation for 40 seconds in the selected sixteen rats. They concluded that light curing units apply enough heat to the tooth surface to potentially damage the pulp.

Wavelengths above 500nm are responsible for the heat production but contribute little to the heat curing of the composite.

Tsun et.al(1997) ²⁶ evaluated the “ In-vitro comparison of debonding force and intrapulpal temperature changes during ceramic orthodontic bracket removal using a carbon-dioxide laser “ and concluded that the intrapulpal temperature rise was only 2.2°C which is well within the pulpal physiology

Yildirim et.al(1997) ⁴ conducted an in-vitro study on “Effect of post-cure temperature and heat duration on monomer conversion of photo-activated dental resin composite”. Disc shaped composite specimens were initially light-cured and then submitted to the following post-cure conditions-50°C, 75°C,100 or 125°C for 0.5,1,3,5or 7 min. after curing, the specimens were stored in the dark at room temperature. Monomer conversion of all specimens was then determined using infra-red spectroscopy. They concluded that both post-cure temperature and heat duration significantly affect monomer conversion of post-cure heated resin composite.

Shortall A.C, Harrington E(1998) ³⁴ in their in-vitro study on “ Temperature rise during polymerization of light activated resin composites” concludes the following:

- a. Temperature rise at the base of a cavity floor relates to the light transmission characteristics of the resin composite as well as the radiant energy output from the light-curing unit.
- b. The magnitude of temperature rise also relates to the polymerization exotherm of the material.

As the extent of thermal trauma that can be tolerated by the dental pulp is unknown, consideration should be given to the choice of

light-activation unit when curing light-activated bonding agents and restoratives in deep cavities close to the pulp.

Vallitu PK,Ruyter IE, Buykuilmaz(1998) ³⁵ conducted an invitro analysis on the “Effect of polymerization temperature and time on the residual monomer content of denture base polymers” and concluded that the polymerization temperature and polymerizationtime considerably affect the residual methyl-methacrylate content of denture base polymers.

Hannig M.,Bott.B(1999) ¹⁴ in their study on “In-vitro pulp chamber temperature rise during composite resin polymerization with various light-curing sources” measured the pulp chamber temperature during polymerization using a K-type thermocouple and concluded that

- a. the potential risk for heat-induced pulpal injury during composite resin polymerization is increased when using visible light curing units with high energy output as compared to low energy output light energy sources.
- b. Assessment of the risk for heat induced pulpal damage should take into consideration both the maximum temperature increase as well as the time-dependent course of intra-pulpal temperature rises.

Lynn.G, John R, Anderson, Richard J and Blankenau J(1999) ²⁴ studied “ Laser and Curing light induced in vitro pulpal temperature changes”. A sample tooth was selected and class V cavity prepared and restored with composite. The thermometer was inserted into the cutaway pulp chamber to measure the temperature increase from stabilized room temperature, which was caused by exposure to argon laser or conventional curing unit. They concluded that at recommended curing times, the in-vitro pulpal temperature increases from argon lasers were significantly lower than those of the conventional curing lights.

Deborah S, Douglas N, Dederich and Thomas V Gardner(2000) ¹⁰ in their “ In vitro temperature change at the dentin/pulpal interface by using conventional visible light versus argon laser” study concludes the following:

- a. the argon laser causes a smaller maximal temperature rise than did the VLC unit
- b. Dentin thickness was inversely proportional to the temperature rise.
- c. Continuous exposure to either light sources produced higher temperature increases than did similar exposure times by using the interrupted cycle.
- d. Exotherm from resin polymerization did not seem to make a significant contribution to temperature rise

The temperature rise was initially rapid and diminished as thermal equilibrium is approached, tapering off at the end of the heating cycle.

Knezevic et.al(2001) ²⁰ in their in-vitro study on “ Degree of conversion and temperature rise during polymerization of composite resin samples with blue diodes” compares the degree of conversion and temperature rise of four hybrid composite materials with standard halogen curing unit HelioluxGTE of 600mW/cm/cm² intensity, Elipar highlight soft-start curing unit of 100 mW/ cm²(10s) and 700mW/cm²(30s) intensity and 16 blue super bright LED of mW/ cm² on the surface and 1mm depth. They concluded that blue LEDS of minimal intensity and wavelength of 470nm causes low temperature rise in the composite material samples.

Loney R W, Price R B T(2001) ²² in their in-vitro study on “ Temperature transmission of High-output light-curing units through dentin” measures the temperature rise at the tip of the light guide and through a sandwich composed of a 1mm thick pre-cured cylinder of resin composite and dentin. They concluded the following:

a. Thicker dentin specimens reduced temperature changes at the recording surface

b. The turbo light guide tip, when used for 40 seconds, increased the temperature rise by 42 to 56 % when compared to the standard light guide on the same light for the same curing time, depending on dentin thickness.

Nomura et.al (2001) ²⁹ studied the “Thermal analysis of Dental resins cured with blue light emitting diodes”. Thermal analysis was used to measure the characteristics of dental resins cured with the use of a new light activation unit equipped with high illuminant blue LEDs. The characteristics were compared with those of resins cured with the use of two conventional halogen lamp units. They concluded that dental resins cured using blue LEDs have a higher degree of polymerization and more stable 3-D structures than those cured with halogen lamps.

Porko C, Hietala E L(2001), ³⁰ conducted an in-vitro study on “Pulpal temperature change with visible light curing”. The temperature of the pulp was measured by a thermocouple probe that was inserted into the pulp through the apex. Standard occlusal cavities are prepared and incremental curing of composites done and the temperature rise during each incremental curing was observed. They concluded that the warming effect of light curing devices per se and in connection with composite fillings can affect pulpal temperature in vitro. The maximum difference between the lowest and highest temperature in the pulp during the whole process was as high as 7.2°C.

AUJ Yap, KEC Wee(2002) ⁴⁰ conducted an in-vitro study on the “Effects of cyclic temperature changes on water sorption and solubility of composite restoratives”. They concluded that cyclic temperature changes can compromise the longevity of the composite restorations

AUJ Yap, MS Soh, KS Siow (2002)³⁹ investigated the “Effectiveness of Composite cure with Pulse activation and Soft-start polymerization”. Effectiveness of cure with the different mode was determined by measuring the top and bottom surface hardness of 2mm thick composite. The effectiveness of cure of the bottom surface of the composite was also established by Fourier Transform Infrared Spectroscopy(FTIR) using the KB technique. They concluded that use of high energy densities during the pulse activation and soft-start polymerization regimens may adversely affect the effectiveness of cure at the bottom of composite restorations.

Pradhan R D, Melikechi N and Eichmiller F(2002)³¹ conducted an in-vitro study on “ The effect of irradiation wavelength bandwidth and spot size on the scraping depth and temperature rise in composite exposed to an argon laser or a conventional quartz-tungsten-halogen source”. Using band pass filters, the spectral outputs of an argon laser and a quartz-tungsten halogen lamp were restricted to pass selected wavelengths on to a commercial camphoroquinone –based resin composite and the depth of cure and temperature rise was measured. They stated that under emission spectrum of 400-500nm, the argon laser resulted in a lower temperature rise in the composite than the conventional QTH unit.

Yap A U J and Soh M S(2003)³⁸ in their in-vitro study on “Thermal emission by different light curing units” determines the heat emitted by using the K-type thermocouple and a digital thermometer at distances of 3mm and 6mm respectively. 3 halogen and 3 LED units were selected for the study. They concluded the following:

- a. LED lights emit significantly less heat than halogen lights

- b. The heat emitted by individual curing lights depend on the curing mode used.

The heat emitted by different LED/halogen lights varies significantly.

Norbert Hofmann, Tanja Markert, Burkard Hugo & Bernd Klaiber (2003) ¹⁷ conducted a in-vitro study on “ Effect of high intensity Vs soft-start halogen irradiation on light curedresin-based composites”. In their study, shrinkage kinetics was evaluated using the deflecting disk technique, modified for simultaneous easurement of temperature within the resin-based composite using a thermocouple. Additional irradiations after 60 and 65 minutes allowed the determination of temperature rise caused by radiation or by reaction heat. They inferred that the high intensity QTH irradiation for 10 secs resulted in rapid polymerization contraction and considerable temperature rise during polymerization.

AUJ Yap, TY Saw, Cao T,(2004) ⁴¹ conducted a study on “ Composite cure and pulp-cell cytotoxicity associated with LED curing lights”. Pulp cell cytotoxicity was assessed using a direct contact method involving incisor tooth slices dissected from 28-day old Wilsar rats maintained in Dulbecco’s Modified Eagle Medium(DMEM) and 1% agarose. They reported that composite cured with LED lights was more cytotoxic than composite cured with conventional halogen lights and the cytotoxicity of LED lights is device dependent.

Kleverlaan CJ and De Gee AJ(2004) ¹⁹ in their in-vitro study on “ Curing efficiency and heat generation of various resin composites cured with high-intensity halogen lights” assess the curing efficiency and heat generation of two high-intensity halogen lamps. Heat generation in the resin composites was studied in standardized restorations using a thermocouple. They concluded that the temperature rise in the composites during curing

was between 11.2°C and 16.2°C. At subsequent irradiation, after the composites had been cured, the temperature rise was between 8.2°C and 12.1°C.

SUMMARY

This study was done to evaluate the thermal emission of light curing units. 3 LED and 3 QTH light curing units were selected for the study. Thermal emission of each light curing unit was measured by a k-type thermocouple and a digital thermometer. The thermocouple is secured onto a groove in an acrylic base plate so that the surface of the thermocouple was flushed against the top surface of the base plate. Two clear acrylic plates of 3 mm thickness with a 7 mm diameter hole served as spacers to control the thermocouple light guide exit window distance (the study was then repeated with two 6mm clear acrylic plates). The thermocouple was positioned at the center of the 7 mm hole. The light guide exit windows of the LCU were placed over the 7 mm hole of the upper acrylic plates and activated. Temperature rise during irradiation was measured at distances of 3 mm and 6 mm away from the thermocouple. At both 3mm and 6mm distances the LED light curing units emitted significantly less heat than the QTH light curing units, for 20 and 40 sec exposures. At 6mm distance, all the light cure units emitted significantly less heat than at 3mm for both 20 and 40 sec exposures. Among the various modes in LED units the fast mode of Confident LED emit less heat than the pulse-cure and ramp modes.

To simulate the in-vivo situation, another study was done, where 12 extracted single-rooted human molars were selected(2 for each group). The teeth were cleaned with sodium-hypochlorite solution and the apical 3mm was resected to enable the thermocouple to reach the pulp chamber and the

position was verified radiographically. The occlusal cavity was prepared with the following specifications-2mm width, 5mm length and 3mm depth. Five consecutive 40 sec exposures were made on the prepared tooth and the temperature rise was measured. Etching was carried out with 37% ortho-phosphoric acid for 15 secs and rinsed with water for 5 secs, and blot-dried. Then the bonding agent was applied and curing for 20 secs is activated and the temperature rise recorded. Then, incremental composite filling was done upto 3mm and the temperature rise during each curing was recorded. The results were subjected to one-way ANOVA, Independent T-Test and Tukey-HSD test.

CONCLUSION

The thermal emission of light curing units per se and in connection with composite filling can increase pulpal temperature. The following conclusions are drawn from this in-vitro study:

1. Light emitting diode(LED) light cure units produces significantly less temperature rise than the Quartz-Tungsten-Halogen (QTH) units.
2. Among the various modes in LED units, the Fast mode produces significantly less temperature rise than the Pulse-cure and Ramp modes.
3. At 3mm and 6mm distances, the Fast mode of Confident LED light cure units, produced less temperature rise, whereas Cu-100A QTH unit produced maximum temperature rise.
4. When five consecutive light curing exposures were applied to the occlusal surface of the prepared teeth, the maximum temperature rise of 2.0°C was measured in the pulp. This could simulate the curing process of a direct inlay or onlay. When placing a direct composite restoration in three increments, the temperature difference between the start and end of the process was maximally only 3.2°C and thus within the normal range of pulpal physiology.

5. During composite filling, Satellac S.P.LED light cure unit produced the least temperature rise, while Cu-100A QTH unit recorded the maximum temperature rise.
6. The heat emitted by different LED and QTH light curing units varies significantly and it also depends on the curing modes used (in Confident and Satellac Mini LED light cure unit).

To elucidate the effect of these light-curing units, in-vivo studies have to be carried out in intact teeth marked for extractions due to orthodontic reasons and histological evaluation of pulpal changes to be observed.

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