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The Heat Emitted from Some Qth and Led Light Curing Units in Consecutive Activations A Laboratory Assessment

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Abstract - *The temperature rises produced by two Quartz-Tungsten-Halogen (QTH) bulb and four solid-state light emitting diode (LED) light curing units (LCU's) was measured on five separate occasions following (i) activation for 40 seconds and (ii) three consecutive activations of 40 seconds.*
For both periods of activation evaluated the Luxor QTH LCU exhibited significantly ($P < 0.01$) lower temperature rises (1.2 (0.2) – 2.5 (0.4) °C) than all other LCU's. In the case of the consecutive applications the temperature rises, for the other units, exceeded known threshold temperatures for pulpitis to be risked.

KEY WORDS: Restorative Dentistry, Resin Composite, Light curing units, temperature rise.

INTRODUCTION

Since the conception and development of resin composites, that stemmed from the pioneering work of Bowen[1], such materials have found widespread clinical acceptance. Although, in part, improved mechanical properties are responsible for this clinical popularity it is undoubtedly also attributable to the development of visible blue light initiation of the polymerisation setting reaction of this type of material that was undertaken by Dart and Nemcek [2]. This permitted the clinician to set the material on demand upon exposure to an active curing unit. The light source of the early curing units was a quartz-tungsten-halogen (QTH) bulb, either housed in a bulky light wand itself or in a remote base unit connected to the wand by a fibre optic cable. This emitted light of the appropriate wavelength. Such units lacked portability and concerns were also raised about the heat emitted from the units upon the tooth [3-6]. This in part arose from the exothermic polymerisation reaction of the resin composite being cured and also from the heat produced by the QTH light itself [7]. It was a problem known to the manufacturers and they attempted to reduce heat output by the incorporation of filters in the curing units in an endeavour to remove the wavelengths that lay in the responsible red and infrared spectrum [8]. In recent years the development of solid-state light emitting diode (LED) curing units has claimed to offer greater portability, by virtue of decreased size and lower power consumption, and negligible heat output [9]. Although much of the scientific literature agrees that the thermal emission of LED curing units is significantly lower than those whose light source is QTH [4, 10-12] others [13] have found this not to be the case. Anecdotally, it has been brought to the attention of the authors, by their dental nurses, that on incrementally placing and curing large resin composite restorations some of the LED curing units become warm.

Previous research, conducted in animals, concluded that a temperature rise of 5.5 – 11.1 ºC caused irreversible pulpitis in 15 and 60 % of Macaca Rhesus monkey teeth [14]. Such a threshold for damage to occur, although adopted in many studies, has been questioned in more recent years when reporting human studies [15]. A rise of 11.2 ºC did not damage the pulp in the study of Baldissara *et al* [15]. Notwithstanding this however, it would seem prudent to keep the temperature rise as low as possible for it is known that the actual heat transmitted to the pulp increases with reducing residual dentine thickness [16]. Furthermore the time of light application must also be considered for this increases the total heat of the tooth [17]. Some report that this temperature rise continues once the light curing unit has been turned off [18], as equilibrium is reached, although others dispute this [19] stating that the highest rise occurs during the first 20 seconds of illumination. Heat build up, in the opinion of the authors, is likely to occur when incrementally building up a resin composite with multiple successive curing light activations. This investigation therefore sought to investigate this, in a carefully controlled laboratory situation, by measuring the temperature rises produced by six LCU's (two QTH and four LED units) when activated for (i) 40 seconds and (ii) for a period of 120 seconds comprising three successive 40 second activations.

MATERIALS AND METHODS

Table 1 gives details of the six LCU's tested.

Measurement of the temperature rise, produced upon both a single activation of 40 seconds and a run of three consecutive activations of 40 seconds each (total time of activation = 120 seconds) were made for each unit on five separate occasions. The automated timer of each LCU was used to effect the desired duration of activation. All measurements were made under ambient laboratory conditions. The temperature rise of the various LCU's was recorded by applying the light through a transparent

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Table 1. *The Light curing units (LCU's) evaluated in this study*

Name of Light Curing Unit	Manufacturer	Type of Curing Light
Luxor Lamp	ICI Dental, Macclesfield, UK	QTH
Hilux	Benlioglu Dental, Ankara, Turkey	QTH
Smart Light	DENTSPLY De Trey, GmbH, Konstant, Germany	LED
Mini-LED Ortho Bleu	Satalec, Merignac, France	LED
Smartlite PS	DENTSPLY De Trey, GmbH, Konstant, Germany	LED
Mini-LED Ortho Grise	Satalec, Merignac, France	LED

Table 2. *The mean and standard deviations of the temperature rises recorded as a result of (i) a 40 second activation of each unit and of (ii) a 120 second period of activation.*

Name of Light Curing Unit	Mean Temperature Rise (ºC) for 40 s activation	Mean Temperature Rise (ºC) for 120 s activation
Luxor	1.2 (0.2)	2.5 (0.4)
Hilux	5.8 (0.5)	11.7 (0.4)
Smart Light	6.9 (0.5)	15.2 (0.5)
Mini-LED Ortho Bleu	3.8 (0.2)	8.7 (0.6)
Smartlite PS	4.7 (0.7)	11.5 (1.4)
Mini-LED Ortho Grise	2.9 (0.1)	7.2 (0.5)

Parenthesised values are the standard deviation of the mean. This is a product of five observations in all cases.

Table 3. *Summary of Tukey's Multiple Comparison of the mean temperature rises recorded following a 40 second activation of the curing units.*

Name of Light Curing Unit /Versus	Hilux	Smart Light	Mini–LED Ortho Bleu	Smartlite PS	Mini-LED Ortho Grise
Luxor	***	***	***	***	***
Hilux	-	**	***	**	***
Smart Light	-	-	***	***	***
Mini LED Ortho Bleu	-	-	-	*	*
Smartlite PS	-	-	-	-	***

*Key: Within the body of the table * = P < 0.05, ** = P < 0.01, *** = P < 0.001.*

Table 4. *Summary of Tukey's Multiple Comparison of the mean temperature rises recorded following a three consecutive 40 second activations of the curing units (120 seconds in total),*

Name of Light Curing Unit /Versus	Hilux	Smart Light	Mini – LED Ortho Bleu	Smartlite PS	Mini-LED Ortho Grise
Luxor	***	***	***	***	***
Hilux	-	***	***	NS	***
Smart Light	-	-	***	***	***
Mini-LED Ortho Bleu	-	-	-	***	*
Smartlite PS	-	-	-	-	***

*Key: Within the body of the table NS = no statistically significant difference, * = P < 0.05, ** = P < 0.01, *** = P < 0.001.*

sheet of plastic (1 mm thick) that overlay the opening to a copper cylinder (Diameter = 12 mm, Length = 10 mm, Copper thickness = 1 mm), embedded in the centre of a polystyrene block. This was closed on its base where an iron/constantan thermocouple, connected to a factory calibrated mv/temperature converter and chart recorder was located. For each measurement the light wand of the LCU was applied to the surface of the transparent plastic sheet to standardise the distance of application. For each LCU and period of activation the mean temperature rise and standard deviation of these measurements were calculated. Comparisons of these quantities, for each activation duration and make of light curing unit, were made by analyses of variance with Tukeys multiple comparison post testing. The level of statistical significance was at the conventional threshold of $P < 0.05$. All statistical testing was performed using the statistical package Prism (Version 4.0, Graphpad Software Inc., San Diego, CA, USA).

RESULTS

Table 2 gives the mean and standard deviations of the temperature rises recorded as a result of a 40 second activation of each LCU on 5 separate occasions. This table also contains the mean and standard deviations of the temperature rises recorded as a result of three consecutive 40 second activations of each LCU on 5 separate occasions.

A one way analysis of variance of the temperature rises recorded as a result of a 40 second activation revealed highly significant ($P < 0.0001$) differences between the LCU's. These were localised by a Tukey's Multiple Comparison Test whose outcome is contained in Table 3.

A one way analysis of variance of the temperature rises recorded as a result of three consecutive 40 second activations of each LCU on 5 separate occasions revealed highly significant ($P < 0.0001$) differences between the LCU's. These were localised by a Tukey's Multiple Comparison Test whose outcome is contained in Table 4.

DISCUSSION

This was an *in vitro* study designed to determine the temperature rise produced by a variety of LCU's when used under conditions, typical of clinical use, that contravene the manufacturers instructions for use. It is acknowledged that the experimental model, with its polystyrene insulation and copper conductor, does not reflect the clinical scenario where it has been suggested that increases in temperature are ameliorated by the low thermal conductivity of dentine [20] and heat dissipation effect of pulpal blood flow [17]. The carefully constructed apparatus does however permit an objective assessment of the temperature rise produced solely by activation of the curing units. The exclusion of resin composite from this work is helpful in this regard for it does not permit the exothermic polymerisation reaction of this material to contribute to the observed temperature rise. As some [12] have suggested that LED light sources have both a narrow light emission spectrum and range of peak wavelength (470 nm to 500 nm) it is conceivable that had resin composite been used its level of activation would have varied according to the curing unit applied. This would have manifested as variation in the polymerisation exotherm of the resin composite thus introducing an uncontrolled source of experimental variation into the recorded temperature rises. Another potential source of variation was the distance between the light source and detector. This was set at a constant distance in the present work for it is a known variable affecting the degree of resin composite conversion [21, 22].

It is interesting to note the comparatively low temperature rises recorded for the Luxor curing unit. For both activation types evaluated these lie below the threshold temperature, as reported by Zach and Cohen [14] to cause irreversible pulpitis and well below that of 11.2 °C as reported by Baldissara *et al* [15] in humans. The Luxor light was one of the earliest curing units developed and its light source is housed in a well ventilated base unit that is remote from the light tip. This contrasts with the other QTH curing unit evaluated (Hilux) whose temperature rise exceeds these values. In this unit however, the light source is housed in the light wand itself and its proximity to the measuring thermocouple almost certainly accounts for the observed heat build up. Although at 40 second activation the LED curing units produced significantly lower temperature rises than the Hilux QTH based unit this did not apply to the Smart Light. This, coupled with the significantly lower temperature rises recorded for the Luxor QTH based lamp, indicates that thermal emissions of LED LCU's are not necessarily lower than those based upon QTH confirming the findings of others [13]. Of greater clinical concern however are the high temperature rises recorded for all units, other than the Luxor unit, when activated for 120 seconds in 40 second successive bursts. These all exceed the lower 5.5 °C damage threshold [14]. In the cases of the Hilux, Smart Light and Smart Light PS the higher threshold of 11.2 °C reported by Baldissara *et al* [15] is exceeded. This should caution clinicians against excessively long activation periods particularly when there is little residual dentine thickness, for this is associated with an increased risk of pulpal trauma [20]. In common with others [18] we observed that the temperature rise continued in our experimental system after the curing unit was turned off. This suggests time is required for measurement system equilibrium to be reached.

It was interesting to note that the two Mini-LED units evaluated (Ortho Bleu and Ortho Grise), although apparently identical other than case colour, gave different temperature rises. These units are marketed for bonding orthodontic brackets where curing times are generally short. Such variation possibly arises from variations in component specifications but a full explanation is outwith the scope of this investigation.

CONCLUSIONS

Although in our experience many dentists are aware of the activation times of resin composite (typically 30 – 40 seconds) it is perhaps less well known that the specification section of some LED LCU's recommends downtime between periods of activation. For example, in the instructions for use of the Smartlite PS, it is stated "…for continuous operation, wait for at least 30 seconds between curing cycles. If time intervals between curing cycles are too short, this will result in heat build up of the LED tip which may cause discomfort or tissue irritation." In light of the results presented here this is sound advice and we would advocate that it be followed for all LED LCU's. This will minimise the potential for pulpal damage to occur from this source of heat.

MANUFACTURERS' DETAILS

- Luxor Lamp, ICI Dental, Macclesfield, UK.
- Hilux, Benlioglu Dental, Ankara, Turkey.
- Smart Light, DENTSPLY De Trey, GmbH, Konstant, Germany.
- Mini-LED Ortho Bleu, Satalec, Merignac, France.
- Smartlite PS, DENTSPLY De Trey, GmbH, Konstant, Germany.
- Mini-LED Ortho Grise, Satalec, Merignac, France.
- Iron/constantan thermocouple, RS Components Ltd., Northamptonshire, UK.
- mv/Temperature Converter, Rikadenki Mitsui Electronics Ltd., Surrey, UK.
- Chart Recorder, Rikadenki Mitsui Electronics Ltd., Surrey, UK.

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