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Original Article

A survey on light intensity outputs of QTH, cabled and cordless LED light curing units

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Abstract Light intensity output is one of the determinants for adequate curing of visible light-cured materials. The aim of this survey was to evaluate the light intensity outputs (LIOs) of light curing units (LCUs) in dental clinics of Hospital Universiti Sains Malaysia (HUSM) and School of Dental Sciences, Universiti Sains Malaysia (USM). The respective LIOs of all functioning Quartz Tungsten Halogen (QTH) and Light Emitting Diode (LED) LCUs were tested using two light radiometers. For cordless LED LCUs, the testing procedure was done *in situ* and after being fully charged. Statistical analysis using Kruskal Wallis and Wilcoxon signed ranks tests were performed to compare the LIOs between groups and between the LIOs of *in situ* and post-charged cordless LED LCUs, respectively. The level of significance was set at 0.05 ($p<0.05$). The results revealed that 72.72%, 42.47% and 92% of QTH, cabled LED and cordless LED LCUs exhibited acceptable LIOs, respectively. Data analysis using Kruskal Wallis test showed a statistically significant difference between groups ($p<0.05$). The intergroup comparisons using multiple Mann Whitney test with Bonferroni correction revealed a significant difference between the LIOs of cordless LED and both QTH and cabled LED ($p<0.017$). The difference between the LIOs of *in situ* and post charged cordless LED LCUs was also significant ($p<0.05$). In conclusion, both QTH and cordless LED LCUs performed better in term of LIOs than cabled LED LCUs. Periodic testing of LCUs is essential to ensure optimal performance.

Keywords: Light curing unit; light intensity output; radiometer; light emitting diode; quartz tungsten halogen.

Introduction

The rapid development of tooth-colored restorations in dentistry since the 1970s has facilitated the introduction of visible light-cured resin composites into the market to overcome the disadvantages of auto-polymerized resin composites (Mills *et al.*, 1999; Mills *et al.*, 2002). Curing technology regularly underwent changes over the past decades. Starting with the introduction of the quartz tungsten halogen (QTH) type, followed by the era of light-emitting diode (LED) type, the light curing system industry has been revolutionized (Mills *et al.*, 1999; Mills *et al.*, 2002).

Unlike the halogen bulb, light generation in LEDs does not involve a thermal process. Light is generated by electrons passing through holes and then recombining at a junction of modified semi-conductor material (Stahl *et al.*, 2000; Campregher *et al.*, 2007). The effective useful life of LEDs is estimated in terms of several thousand hours, with reduced light flux degradation over time (Stahl *et al.*, 2000). Furthermore, low energy consumption lends feasibility to the production of cordless LED light curing units (LCUs), which are powered by rechargeable batteries (Campregher *et al.*, 2007). Moreover, LED LCUs require no filters because the spectral output of the produced light falls within the absorption spectrum of camphorquinone, which is the photo-initiator present in the majority of dental composites (Campregher *et al.*, 2007). In addition, the thermal emission of LED LCUs is significantly lower than that of conventional halogen LCUs (Yap and Soh, 2003).

Light intensity output (LIO) is a key factor that affects the longevity of resin composite restorations (Martin, 1998; Hegde *et al.*, 2009). A number of studies compared the LIOs of QTH and LED LCUs (Mills *et al.*, 2002; Hegde *et al.*, 2009; Al Shaafi *et al.*, 2011; Hao *et al*., 2013), and the effectiveness of such LCUs on a number of dental applications, such as post-endodontic procedures, including sealing capability and push-out bond strength of fiber posts (Beriat *et al.*, 2012). Al Shaafi *et al.* (2011) reported that the percentages of QTH and LED devices with unsatisfactory LIOs (<300 mW/cm^2) were 67.5% and 15.6%, respectively. In addition, Hegde *et al.* (2009) found that 98% of QTH and 90% of LED units were below 400 mW/cm^2. Interestingly, Beriat *et al.* (2012) found that the sealing capability of QTH-cured fiber posts is significantly better than that of LED-cured specimens despite being comparable in terms of push-out bond strength.

Previous investigations give rise to the conclusion that monitoring the LIOs of LCUs is crucial to ensure satisfactory performance (Martin, 1998; Al Shaafi *et al*., 2011; Hao *et al.*, 2013). Surveys in Australia (Martin, 1998), Canada (El-Mowafy *et al.*, 2005), USA (Barghi *et al.*, 1994; Barghi *et al.*, 2007), Saudi Arabia (Al Shaafi, 2012), India (Hegde *et al.*, 2009), Japan (Miyazaki *et al*., 1998) and China (Hao *et al.,* 2013) have been undertaken; however, there is no relevant information in Malaysia. Accordingly, this study aimed to evaluate and compare the intensity outputs of QTH and LED (cabled and cordless) LCUs that are used in the dental clinics of Hospital Universiti Sains Malaysia (HUSM) and School of Dental Sciences, Universiti Sains Malaysia (USM). It is hoped this study will encourage Malaysian dental operators to monitor the performance of LCUs frequently.

Materials and methods

This was an experimental laboratory study conducted at the HUSM and the School of Dental Sciences dental clinics, USM. A total of 109 functioning QTH (n= 11) and LED LCUs were included in the study (Cabled n= 73, Cordless n= 25) (Table 1), located at nine locations: 1-4) Polyclinics A, B, C and D; 5) Family Dental Clinic (KRK); 6) Dental Specialist Clinic (KPP); 7) Screening Clinic; 8) Multi-disciplinary Laboratory and 9) Skills Laboratory. The LCUs were numbered and the respective light intensity outputs were measured using a pair of light radiometer units (CureRite, Dentsply Caulk, USA) according to the manufacturer's instructions.

For cordless LED LCUs, the testing procedure was done twice (*in situ* and after the LCUs were fully charged). Other LCUs were tested once (*in situ*). Initially, the LCUs were switched on for about 10 seconds, and the tip was then placed 1 mm from the center of the sensor window of the radiometer until the static intensity reading is displayed. The value of LIO of every LCU was determined five times and the average was then calculated.

For quality control, the radiometers were calibrated prior to each session, and compared with another unit of radiometer. The standard for acceptable intensity light output was set at 400 mW/cm², and the intensity recordings has been divided into three categories: a) acceptable (≥400 mW/cm²), b) marginal (201-399 mW/cm²), and unacceptable (≤200 mW/cm²) (Martin, 1998).

Kruskal Wallis and Wilcoxon signed ranks tests were performed to compare the LIOs between groups and between the LIOs of *in situ* and post-charged cordless LED LCUs, respectively. The level of significance was set at 0.05 (p<0.05).

Results

The results showed that the LIOs of over 70% and as high as 92% of QTH and cordless LCUs were acceptable, respectively (Table 2). On the contrary, less than half of cabled LCUs were only observed in the acceptable range (Table 2). Table 2 demonstrates the LIOs and the ratings (acceptable, marginal and unacceptable) of LCUs.

Data analysis using Kruskal Wallis test showed a statistical difference between groups (p<0.05) (Table 3). The intergroup comparison using multiple Mann Whitney test with Bonferroni correction revealed a significant difference between the intensity outputs of cordless LED and both QTH and cabled LED (p<0.017) (Table 4). However, the results were not significant between QTH and cabled LED LCUs (p>0.017) (Table 4). Wilcoxon signed ranks test showed that the LIOs of *in situ* and post-charged cordless LED LCUs were significantly different (p=0.019), despite being in the same acceptable rate (92%) of the *in situ* category (Table 5).

Table 1 Types and manufacturers of LCUs (n = 109)

Types (n)	Manufacturer
Cabled LED (n = 73)	
- Gnatus	Gnatus
- Starlight	Mectron
- Unilite II	Bein Air
- Mini LED	Satelec, Kavo Corp.
- PoliLED	Faro
Cordless LED (n = 25)	
- Coolight CL-100C	3A MEDES
- SmartlitePS	Dentsply, Caulk Inter.
- Raci- cal	SDI Corp.
- Otrholux	3M Unitek
QTH (n = 11)	
- QHL75	Dentsply, Caulk
- Litex 680A	Dentamerica Corp.
- Unilite	Mectron
- Astralis 3	Ivoclar Vivadent

Table 2 The ratings of light intensity outputs of LCUs from all locations

Groups	Intensity		
	Acceptable (≥ 400) N (%)	Marginal (201 – 399) N (%)	Unacceptable (≤ 200) N (%)
QTH	8 (72.72)	1 (9.09)	2 (18.18)
Cabled	31 (42.47)	12 (16.44)	30 (41.10)
Cordless Pre	23 (92)	0(0)	2(8)
Cordless Post	23 (92)	0(0)	2(8)

Table 3 Statistical analysis between the intensity of LCUs (*in situ*) using Kruskal Wallis test

Groups	Median (IQR)	Stats (Kruskal Wallis Test)*
QTH	645.00 (519.60)	<0.001*
Cabled	321.60 (786.80)	
Cordless	1114.80 (345.60)	

*Statistically significant *p*-value ≤ 0.05.

Table 4 Inter-group comparisons using Mann Whitney test with Bonferroni correction

Comparison	Z-stat	*p*-value
QTH Vs Cabled	-1.320	0.187
QTH Vs Cordless	-3.657	<0.001*
Cabled Vs Cordless	-5.808	<0.001*

*Statistically significant *p*-value ≤ 0.017

Table 5 Wilcoxon signed ranks test of *in situ* and post-charged LED LCUs

Cordless LED	Median (IQR)	Z-stat	*p*-value
Pre-charged Reading (*in situ*)	1114.80 (345.60)	-2.354	0.019*
Post-charged Reading	1178.40 (233.00)		

*Statistically significant *p*-value ≤ 0.05

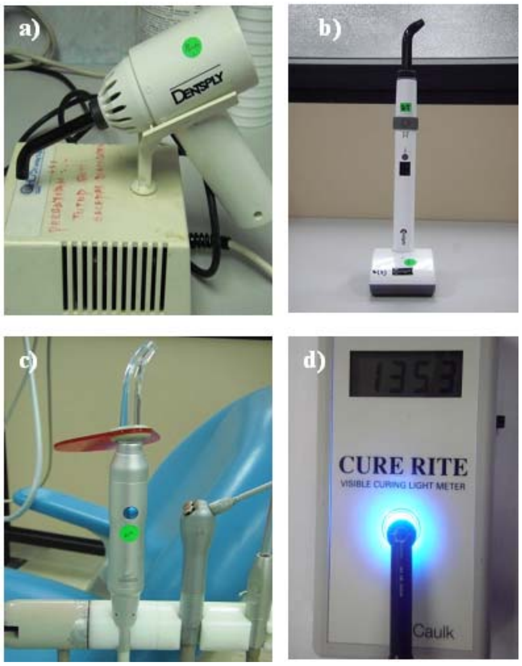

Fig. 1 a) QTH LCU. b) Cordless LED LCU. c) Cabled LED LCU. d) Measuring the light intensity output using a radiometer.

Discussion

QTH technology is considered the original and is thus the most widely used by dentists worldwide (Krämer *et al.*, 2008). Perhaps the main reason for the wide use of QTH LCUs is the lower cost compared with plasma arc and laser units. In addition, some of these other LCUs have limited applications, unlike QTH units, which have virtually unlimited capability to polymerize different brands of resin-based composites (Ferracane *et al.*, 2013). However, QTH units are inappropriate for dental setting with a large group of operators because of the presence of some inherent limitations, such as heat generation after multiple usage and longer operative time than other LCUs. The halogen bulb generates high heat, which degrades the bulb components over time, thus limiting the effective lifetime of halogen bulbs to approximately 100 hours. Nevertheless, LED LCUs is less energy-consuming than QTH, do not require external cooling, have lifetimes of more than 10,000 hours and undergo minimal degradation of output over this time (Mills *et al.*, 2002; Krämer *et al.*, 2008).

A number of studies have been conducted on the performance of LCUs and their capability to polymerize light-cured resin materials completely. In 1994, Barghi *et al.,* evaluated the LIOs of LCUs in private dental offices in Texas, and found that nearly 30% of dental office curing lights had an intensity output of <200 mW/cm^2. However another survey was undertaken in the same locations in 2007 and an overall improvement of the LIOs was reported (Barghi *et al.*, 2007). Martin (1998) performed a survey amongst dentists in Australia and found that over half of LCUs were not functioning satisfactorily, and nearly half of the responders have never checked the LIOs of their LCUs. Similar observations have been reported in other surveys (Miyazaki *et al.*, 1998; El-Mowafy *et al.*, 2005; Hegde *et al.*, 2009; Hao *et al.*, 2013), especially in rural areas (Al Shaafi, 2012).

The majority of new LCUs initially possess an adequate intensity to polymerize resin composite to a thickness of 2 mm (Caughman *et al.*, 1995). However, researchers observed a significant drop in intensity over time and reported a negative correlation between intensity and increasing age of the units (Poulos and Styner, 1997; Martin, 1998). This study found that only 42.47% of cabled LED LCUs were within the acceptable range (Table 2). However, this finding is not a true reflection of the performance of cabled LED LCUs because different locations produce different results. In Poly A (a student clinic), none of the units is within the acceptable category. The majority of units in Poly A are approximately eight years old. Moreover, such units are being used daily by students for their daily clinical practice. By contrast, in MDL, the units are only three years old, and the usage duration is only two hours per week. Thus, in MDL, over 85% (n=30) of the units are within the acceptable range of light-intensity output. This finding reveals that the performance of cabled LED LCUs could be influenced by the duration of use, age of the units, and maintenance program.

The intensity of emission also is reduced by debris adherent to the light guide tip, repeated sterilization of the light guide, damaged or chipped light guides, broken or excessive bending of fiber optics, and variations in the input voltage of the bulb (Mitton and Wilson, 2001). Maintenance program records and the actual readings on delivery and during commissioning of the units were unavailable, making further analysis impossible. In the future, the performance of every unit upon delivery and during commissioning should be noted for comparison at a later date. In addition, regular checking and maintenance are important to ensure the satisfactory performance of the units.

The results of this study demonstrated that the performance of cordless LED and QTH LCUs are better than those of cabled LED LCUs, despite being not statistically significant relative to QTH LCUs. Ninety-two percent of the cordless LED units in this study were recorded to have acceptable LIOs either *in situ* or post-charged (as compared to 42 % of cabled units). A statistically significant difference in the LIOs was found between *in situ* and post-charged units (p<0.05). Considering that the intensity values are within the acceptable range, it seems that the results are not clinically significant. However, the results indicate that the intensity may deteriorate over time.

Conclusions

Both QTH and cordless LED LCUs generally outperformed cabled LED LCUs in terms of LIO. Periodic testing of LCUs is essential to ensure optimal performance.

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