ORIGINAL ARTICLE

Evaluation of light-curing units in rural and urban areas

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Abstract Objectives: To evaluate the distribution of light-curing units (LCU) used in an urban area (Riyadh) and a rural area (Kharj) of Saudi Arabia, and to compare their irradiance values.

Methods: The study involved three dental centers in urban areas and two in rural areas, all of which were parts of a single healthcare institution providing dental services. The light outputs (power mW) from 140 LCUs were measured by laboratory-grade spectrometry, and the irradiance (mW/cm²) was calculated from the tip area of each LCU. The minimum acceptable irradiance outputs for the quartz-tungsten-halogen (QTH) and light-emitting diode (LED) units were set at 300 and 600 mW/cm², respectively. The ages of these units and the protocol used to light-cure the resins were also determined.

Results: The total number of LCUs was 140, 112 (78%) in urban areas, and 28 (22%) in rural areas. In rural areas, only 7 of the 22 (32%) QTH units delivered irradiances greater than 300 mW/cm² and were therefore considered clinically acceptable, whereas 4 of the 6 (66.7%) LED units delivered values greater than 600 mW/cm². In urban centers, 43 of 61 (70.5%) LED units and 25 of 61 (49%) QTH units were considered clinically acceptable. Irradiance values for both QTH (P < 0.01) and LED (P < 0.05) units were significantly better in urban than in rural areas.

Conclusions: Urban areas had a greater distribution of LCUs than rural areas. Overall, irradiance values were significantly higher in urban areas.

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1. Introduction

Restorative dentistry is a major practice in most dental offices, and Saudi Arabia is no exception, with high caries prevalence (up to 91%) (Al Dosari et al., 2004; Wyne, 2008; Wyne et al., 2002). There are many ways to restore teeth. One of the most popular options chosen by patients in dental practices involves light-cured tooth-colored resins (Kramer et al., 2008; Opdam et al., 2007; Ritter, 2001). However, to polymerize a light-cured resin-based composite (RBC) and transform it into a hard restorative material that meets the manufacturer’s specifications and can withstand the challenges of the oral cavity, the resin must receive sufficient light energy at correct wavelengths. (Anusavice, 2003; Calheiros et al., 2006; Price, 2010). Many factors affect the quality of the energy delivered to RBC restorations, including: the intensity light output (irradiance value), the spectral emission from the light-curing unit (LCU), the wavelength range required by the photoinitiators to be activated within the resin, the duration of light delivery from the LCU to the resin, and the distance between the curing tip and the resin surface (Felix and Price, 2003; Price et al., 2010).
Controlling these factors will help to deliver an adequate amount of energy (6–36 J/cm²) to the resin, which is important to provide a clinically successful RBC restoration and reduce possible end-product restoration breakdown, minimize color changes in the resin, reduce wear, improve bond strengths to the tooth, decrease microleakage, and reduce secondary caries (Anusavice, 2003; Price, 2010).

There are four main types of light-curing units (LCU) used by dentists to polymerize light-cured RBCs: quartz-tungsten-halogen (QTH), light-emitting diode (LED), Plasma Arc (PAC), and Argon-Laser units. Clinically, the most popular types of LCUs used in dental practice are QTH and LED units (Antonson et al., 2008; Kramer et al., 2008; Malhotra and Mala, 2010; Rahiotis et al., 2010; Rencz et al., 2012). However, the LED units are starting to dominate the market, especially since the QTH bulbs are being phased out in many countries (Kramer et al., 2008; Rahiotis et al., 2010; Rencz et al., 2012). The newer generation of LED units is overcoming the drawbacks of QTH units. These units have a longer life expectancy (10,000 compared with 80 h for a QTH bulb) (Malhotra and Mala, 2010; Rencz et al., 2012), and since they are considered energy-efficient units used with low wattage, LEDs can be manufactured and used as cordless units (Judy et al., 2006; Jung et al., 2006).

There are several studies that have investigated the distribution and light output of LCUs in rural and urban areas, and/or compared their light intensities (irradiance values). A field analysis study in Switzerland showed that LED units were more common (67.10%) compared with QTH units (32.9%) (Sadiku et al., 2010).

Many studies that have evaluated dental LCUs have used analog dental radiometers to measure the irradiance from the LCU, and have also used different irradiance levels to determine the acceptability. The percentage of clinically acceptable LCUs found in different dental practices varied in these studies, from as low as 10% to as high as 70% (El-Mouwafy et al., 2005; Hedge et al., 2009; Santos et al., 2005). Unfortunately, the dental radiometers used in these studies have been shown to be inaccurate (Roberts et al., 2006; Rossouw, 2001). Two recent studies have used a laboratory-grade fiber-optic spectrometer to measure the power output values from LCUs. Sadiku et al. concluded that 6.4% of their evaluated LCUs delivered under 400 mW/cm² and 33.7% delivered under 800 mW/cm² (Sadiku et al., 2010). The other study, in Riyadh, Saudi Arabia, showed that 67.5% of QTH units and 15.6% of LED units delivered under 300 mW/cm² (Al Shaafi et al., 2011).

The aim of this study was to evaluate the distribution of light-curing units used in an urban area (Riyadh) and rural area (Kharj) of Saudi Arabia, and to compare their irradiance values.

### 2. Methods

A health care institution that provides dental services with branches in both urban and rural areas in the central region, Saudi Arabia was selected. All dental centers involved in this study, three in urban areas and two in rural areas were from this institution. An official permission was obtained to conduct this investigation. All the LCUs that were used on patients and had a tip diameter greater than 9.5 mm were included in the study.

The total number of LCUs involved in this investigation was 140 units. The power output from each LCU was measured by means of a laboratory-grade fiber-optic spectrometer; Mode USB4000 (Ocean Optics, Inc., Dunedin, FL, USA), with SpectraSuite Software. The age and type of the LUC, along with the curing protocol, were recorded. Each light-curing tip was inspected and cleaned with a swab saturated with ethanol–isopropanol disinfectant solution (MinutenSpray, APMD GmbH, Munich, Germany) to remove possible contaminants.

The curing time protocol used in the investigated institution (as per instructed by their administration) was 40 s for QTH and 20 s for LED, for each 2-mm RBC increment. The amount of energy density [light intensity (in mW/cm²) × duration of exposure in seconds] needed to cure resin varies from 6 to 36 J/cm², and a value of 12 J/cm² was set as a minimum energy level for acceptable curing of a 2-mm resin increment (Price, 2010). To achieve the minimum energy level necessary for these tested LCUs to be considered clinically acceptable, and depending on the curing time protocol, the QTH unit needed to deliver a minimum irradiance value of 300 mW/cm². This is also supported with ANSI/ADA Specification No. 48-1 Visible Light Curing Units: 2004 which states “The light radiation existent in the 400 to 515 nm wavelength region should be no less than 300 mW/cm².” In contrast, the value was minimally set at 600 mW/cm² when the LED units were used, since they required less than half the curing time stipulated in the protocols of the investigated centers, providing an equal energy level from both types of LCUs, representing 12 J/cm² energy delivered to the cured resin material. Due to the low number of LCUs from urban and rural areas, the Kolmogorov–Smirnov test of normality was used to examine whether our data followed a normal distribution. Since the data did not follow a normal distribution, they were statistically analyzed by the Mann–Whitney non-parametric test (P < 0.05). Comparison between urban and rural groups was statistically analyzed by Chi-squared test, and comparison within urban and rural groups was done by Z test (P < 0.05).

### 3. Results

The distribution of LCUs is shown in Table 1. Of the 140 LCUs examined, 112 units (78%) were in the urban area, whereas 28 (22%) came from the rural area. Among the units tested in rural centers, only 32% (n = 7) of QTH units were clinically acceptable, whereas 66.7% (n = 4) of LED units were considered acceptable. In the urban centers, 70.5% (n = 43) of used LED units and 49% (n = 25) of used QTH units were considered clinically acceptable. (Fig. 1).

The ages of the LCUs are shown in Table 2. Almost all of the LED units were less than 5 years old (100% for rural and 90.2% for urban areas). In contrast, QTH units less than 5 years old accounted for only 38.5% of those in rural areas and 30% of those in urban areas. When evaluating the total number of units introduced for clinical use in the past five
years, the LED units were the dominating type in urban areas with 72.36% (55 out of 76 units) and was statistically significant (P < 0.05), and in rural areas, both QTH and LED shared the same percentage (6 out of 12 units each of LCU type).

Comparison of the irradiance values between urban and rural areas showed a significant difference in both the QTH (P < 0.01) and LED (P < 0.05) groups of LCUs, all in favor of the urban area (Table 3). The mean irradiance values of tested QTH units in the urban area were 340 mW/cm², with a range between 80 and 790 mW/cm², while the irradiance values dropped in the rural area to 231 mW/cm² (range between 16 and 454 mW/cm²). For the LED units, the mean value in the urban area was 660 mW/cm², but it was 401 mW/cm² in the rural area.

4. Discussion

With the increasing population size in major cities, the Kingdom of Saudi Arabia developed a strategic plan to activate an emigration process and reduce the population numbers in those cities by relocating people to rural areas (AlAboud, 2010). To encourage the move, industrial economical cities and new universities were built in these rural areas (MOEP, 2009, 2011).

The annual Statistical Report of the Ministry of Health in Saudi Arabia for the last 8 years has ranked dental disease as 3rd or 4th for the most-treated disease in the Kingdom (MOH, 2002–2008). There were between 1,497,000 and 2,467,107 dental visits to the ministry of health dental centers annually. The report also showed that the most common dental procedures were direct or indirect restorations (MOH, 2005).

In general, implementing newer health-related technology is still a challenge in rural areas compared with urban locations (Heaton et al., 2004; Wu, 2007). Although the results show a positive shift by adding more newer LED units in the last 5 years, QTH units still represented 50% of LCUs in the rural areas, whereas in urban areas only 37.6% of the LCUs were QTH units. The urban area had more of the newer LED units, and that does not conform to governmental plans, which call for balance in all areas, whether urban or rural, in terms of equipment quality and technology (AlAboud, 2010; MOEP, 2009, 2011).

The results of this study showed that rural areas had poor distribution and quality of LCU units, compared to urban areas (Figs. 2 and 3), which may negatively affect the ability of rural areas to provide appropriate and acceptable quality of tooth-colored restorations. This finding can also be comparable to data from China and Scotland, where studies reported that rural areas must refer more restorative treatment to urban dental centers (Nuttall et al., 2002; Wu, 2007).

The irradiance values from both the QTH and LED units in rural areas were considered lower compared with those in urban locations. Many factors could have contributed to this outcome. There is no generalized guideline protocol related to LCU maintenance, especially for specifics such as how to
care for the light-curing tips and when to change the bulb of QTH units. It was also noted that the dental staff in dental service was less-well-qualified (in reference to postgraduate training in restorative dentistry) in rural centers. The age of the LCU also plays a role in favor of urban centers, where newer LCUs are used.

For dental clinics that provide permanent tooth-colored restorations, if the qualified dentist is using acceptable restorative dental materials but is using LCUs with inadequate light output, the outcome of those restorations will be compromised. If the polymer components in RBCs are not adequately polymerized, they could leach into the oral cavity, releasing both cytotoxic and genotoxic factors that may harm the oral cavity and the digestive tract (de Souza Costa et al., 2003; Knezevic et al., 2008; Moin Jan et al., 2001). Inadequate curing or polymerization will adversely affect resin bond strength, leading to marginal breakdown between the restoration and tooth structure (de Araujo et al., 2008; Hooshmand et al., 2009). This may then increase bacterial colonization and allow recurrent caries to develop (Hodson et al., 2005; Scott et al., 2004). Moreover, color stability is affected by insufficient curing of the resin, and the esthetic treatment outcome could be compromised (Kramer et al., 2008; Reges et al., 2009). For those reasons, to provide acceptable health services, dentists need to use acceptable materials and equipments, including LCUs that meet the manufacturers’ specifications.

5. Conclusions

1. The urban area had a greater distribution of LCUs compared with rural areas. (P < 0.01)
2. Mean irradiance values for QTH were low in both areas (340 mW/cm² in the urban and 231 mW/cm² in the rural areas). (P < 0.01)
3. In reference to LCUs aging 5 years or less, LED units dominated 72.4% (P < 0.05) and 50% (P < 0.99) of shares for urban and rural areas respectively.
4. In general, a standardized maintenance protocol for LCUs should be initiated to control a continuous clinically acceptable outcome from curing units.

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