Abstract: The light intensity of a light-curing unit is a crucial factor that affects the clinical longevity of resin composites. This study aimed to investigate the efficiency of light-curing units in use at a local governmental dental school for curing conventional and bulk-fill resin materials. A total of 166 light-curing units at three locations were examined, and the brand, type, clinic location, diameter of curing tip, tip cleanliness (using a visual score), and the output (in mW/cm² using a digital radiometer) were recorded. Only 23.5% of the units examined had clean tips, with the graduate student clinical area containing the highest percentage of clean tips. Further, tips with poor cleanliness score values were associated with significantly lower output intensities. A small percentage (9.4%) of units was capable of producing intensities higher than 1,200 mW/cm² and lower than 600 mW/cm² (7.6%). The majority of the low intensity units were located in the undergraduate student area, which also contained the highest number of units with intensities between 900 and 1,200 mW/cm². The output of all the units in service was satisfactory for curing conventional resin composites, and most units were capable of curing bulk-fill resin materials.

Keywords: light curing; efficiency; resin-based composites.

Introduction

Resin-composite materials are the most common materials used for anterior and posterior direct restorations (1). It is estimated that approximately 5,000 composite restorations are placed annually at King Abdulaziz University Faculty of Dentistry by undergraduate students alone. The advantages of resin-composite materials include superior esthetics, improved physical and mechanical properties, and better operator control over the working period (2,3).

The clinical performance and longevity of resin-composite restorations are dependent on several factors, many of which are related to the use and efficacy of light-curing units (3,4). Resin-composite materials set by addition polymerization reactions are activated by visible light. A minimum light intensity of 300 mW/cm² is required for reliable curing of resin composites placed in 2-mm increments. Further, a curing time of 60 s is necessary (5). Light intensities between 200 and 300 mW/cm² require longer exposure duration while values below 200 mW/cm² are not only insufficient for composite curing but might potentially have negative effects (5,6).

One of the most common photoinitiators used in resin composites is camphorquinone (7,8), which is activated at wavelengths between 420 and 580 nm. A new group of resin materials termed bulk-fill composites were recently introduced containing additional photoinitiators that enable adequate curing at depths >2 mm. These photoinitiators generally require light-curing units with wider wavelength ranges to match their absorbance (9-11). These materials require light intensities >1,000 mW/cm² for 10 s of curing according to the manufacturer’s instructions.

The most common light-curing units utilize quartz halogen tungsten (QHT) and light-emitting diodes...
The main objective of this study was to investigate the efficiency of the light-curing units in service at a local government dental school with regard to their ability to deliver optimal light intensities suitable for adequate curing of conventional and bulk-fill resin materials.

**Materials and Methods**

Light-curing units located within the Dental School at King Abdulaziz University were examined in the study. For each unit, the following parameters were recorded: brand, type, clinic location, diameter of curing tip, and tip cleanliness. During the test, the tip of the curing unit was placed flat on the sensor of a digital radiometer (Bluephase Meter II, Ivoclar Vivadent Inc., Amherst, NY, USA), and the unit was operated for 10 s. The output on the radiometer screen was recorded in mW/cm², and the reading for each unit was taken as the average of three runs. Before testing each unit, the diameter of the light-curing unit tip was measured using the radiometer’s built-in gauge, and the value was entered into the radiometer to guide the light intensity reading. One investigator (HN) performed all the tests while another investigator (FH) recorded the results using a standardized electronic form.

A visual scoring scale was developed to guide scoring of the amount of resin or adhesive residue on the tip of the light-curing unit. The scale had three possible values: 0 (tip is clean with no residue), 1 (minimal residues covering less than half of the tip surface), and 2 (residues covering more than half of the tip surface).

For quantitative variables, one way analysis of variance was used to test the equality of means followed by a multiple comparison Bonferroni procedure to test the significance difference for any two mean values. For qualitative categorical variables, a chi-squared test was performed. Statistical analysis was performed with IBM SPSS Statistics Version 17 for Windows (IBM Corporation, New York, NY, USA) at a significance level of 0.05.

**Results**

A total of 166 light-curing units located in 13 clinical areas were tested. For simplicity, the clinical areas were grouped into three locations: undergraduate, graduate/residents, and specialty areas. Table 1 shows the number and percentage of units subdivided by type, brand, and tip cleanliness. The majority of light-curing units in the Dental School were LED based (82.9%), and among these, Acteon (A-dec Dental UK Ltd., Warwickshire, UK) and E-Morlit (Apoza Enterprise Co. Ltd., New Taipei, Taiwan, ROC) were the most common at 40.0% and 34.1%, respectively. The newer DemiUltra (Kerr Dental, Orange, CA, USA) was found in graduate and specialty clinics and accounted for the smallest percentage of LEDs. Polylux II (KaVo Dental GmbH, Bismarckring, Germany) was the only QTH type found, constituting 17.1% of the units and was found only in the undergraduate student area.

Only 23.5% of the units had clean tips and more than 75% had residue covering at least some parts of the curing tip. Half of these were located in the undergraduate clinics. These clinics contained the units with the highest and lowest output. The graduate student clinical area had the highest percentage of clean tips (32%). Only

| Clinical area | Type of light | Brand | Tip cleanliness* |
|---------------|--------------|-------|------------------|
| Undergraduate | Halogen      | Acteon | 0 (12.0%) 20 (12.0%) |
| Graduate      | Light-emitting diode | E-Morlit | 31 (18.7%) 16 (9.6%) |
| Specialty     | Polylux II   | Demi Ultra | 55 (33.1%) 28 (16.9%) |
| Total         | 26 (15.7%)   | 17 (10.2%) 13 (7.8%) 4 (2.4%) 19 (11.4%) 2 (1.2%) 20 (12.0%) 15 (9.0%) 17 (10.2%) 13 (7.8%) 4 (2.4%) 19 (11.4%) 2 (1.2%) 20 (12.0%) 15 (9.0%) |
| Clinical area | 26 (15.7%)   | 17 (10.2%) 63 (38.4%) 15 (9.0%) 4 (2.4%) 19 (11.4%) 2 (1.2%) 20 (12.0%) 15 (9.0%) 4 (2.4%) 19 (11.4%) 2 (1.2%) 20 (12.0%) 15 (9.0%) |

*Tip cleanliness scale used: 0 (tip is clean with no residue), 1 (minimal residues covering less than half of the tip surface), and 2 (residues covering more than half of the tip surface).
a small portion \((n = 13, 7.6\%)\) of the units evaluated produced output \(<600\ \text{mW/cm}^2\), and the majority of these were located in the undergraduate clinical area (Fig. 1). Nevertheless, these clinics contained the highest number of units with intensities between 900 and 1,200 mW/cm\(^2\).

The total number of units capable of producing higher intensities was relatively small \((n = 16, 9.4\%)\).

The effect of clinic location and tip cleanliness on light intensity is illustrated in Figs. 2 and 3, respectively. Graduate clinics had higher mean light intensity than specialty clinics \((P = 0.027)\), whereas units in the undergraduate area with no residues on the tips produced significantly higher output \((P = 0.028)\) than tips with residues covering half or more of the surface area. There were a higher percentage of LED units compared with halogens in all areas \((P < 0.001)\).

### Discussion

Studies have found that despite the potential for long-lasting restoration, composite fillings are being replaced earlier than expected, with 6 years being the average time for replacement in one study. Poor curing results in multiple negative consequences that can ultimately lead to restoration failure (3). Thus, an inadequately functioning light-curing unit may be a key causative factor in the ultimate failure of the restoration. The current study was performed in a government dental school with the aim of ensuring that all the dental curing light units produced continuous and adequate spectral output. The main objective of this study was to investigate the efficiency of in service light-curing units with regard to their ability to deliver optimum light intensity suitable for adequate curing of conventional composites placed incrementally. Per American National Standards Institution/American Dental Association (ANSI/ADA) specification No. 48-2, the required intensity is 300 mW/cm\(^2\) (6). All the light-curing units tested were used multiple times a day, and their output was tested annually.

The current investigation found that all the light-curing units tested, irrespective of whether they were LED or QTH, emitted light intensity over 300 mW/cm\(^2\), with the majority being well over this threshold. This provided the researchers with the knowledge that all units in the institution are capable of completely curing incrementally placed composite restorations. This result is different from those obtained in several similar studies performed regarding light intensity (15-18), despite the similarity in findings regarding the residue on the light-curing unit tip (14,18).

In the literature reviewed, the average number of light-curing units tested ranged from 109 to 295. ElMawafy et al. (15) found approximately 12% of the units tested had an output below 300 mW/cm\(^2\). Santos et al. (16) found that 48% of the light-curing units tested had values equal to or below 200 mW/cm\(^2\) while Barghi et al. (17) found the number to be 30%. In a follow-up study, only 8.6% of units tested had an output <250 mW/cm\(^2\) and a total of 14.8% had an output <350 mW/cm\(^2\) (15). Hegde et al.
(18) found that 90% of the LEDs and 98% of the QTHs had outputs below 400 mW/cm². Maghaireh et al. (14) found that 46% had an intensity <300 mW/cm².

The previous studies all investigated light-curing units in private dental offices. In contrast, findings from educational or governmental institutions (19-21) were more specific to the type of light-curing unit. AlShaafi et al. (19) found that 67.5% of QTH devices and 15.6% of LEDs had outputs <300 mW/cm². Ab Rahman et al. (21) reported output above 400 mW/cm² for approximately 72.7% of QTH, 42.5% of cabled LEDs, and 92% of cordless LEDs. Their study was also conducted in a dental school setting, which may explain the higher percentage of units with acceptable output. AlSamadani et al. (20) also studied dental schools along with governmental institutions and found that approximately 77.2% of the light-curing units emitted light over 300 mW/cm².

Of the studies that mentioned the existence of composite residue on the light-curing unit tips, Hegde et al. (18) reported that most of the tips had some residue but did not specify the percentage, while Maghaireh et al. (14) found that approximately 40% had residue. Our findings fall between those of the previous two studies, with a similar percentage of tips containing residue (75%) as Barghi et al. (17), who found approximately 77% of tips with residue. Despite the resin deposits, all of the light-curing units tested in our study were above the required threshold of intensity. Nevertheless, our findings suggest that the presence of residue on half the surface area of the tip or more can affect the light intensity. It would be interesting to determine the difference in output once the tips are cleaned, but this study was intended to evaluate the light-curing units in service rather than in idealized conditions.

Even though tip cleanliness was not different among the different clinical areas, light intensity was higher in graduate clinics than in specialty wards. This may be due to the fact that all the units in the newly renovated graduate area are new. Further, some units in the specialty wards are used sporadically, especially in disciplines with less focus on restorative dentistry.

A light intensity of 300 mW/cm² is merely a guideline for incrementally placed composites. Most bulk-fill composites currently on the market have a recommended light intensity of over 1,000 mW/cm² for a 10-s cure or over 600 mW/cm² for a 20-s cure. It is clear that most light-curing units in the dental school fall well within the recommended range and may be used for bulk-fill restorations (Fig. 1). This was a pleasantly surprising finding considering that the majority of composites were placed using the incremental technique. However, there is no area in which all the light-curing units were above the required threshold. Therefore, it is imperative that the dentist or dental student be certain of the light intensity before placing a bulk-filled composite filling, ideally by measuring the intensity just prior to the dental visit in which the treatment will take place. This is recommended to exclude units with low output due to the deterioration of the light-curing unit components or due to chipping or fracture of the tip.

It was also interesting to note that the dental school had significantly more LED curing lights than QTH, showing a shift toward LED curing lights, even in an educational institution. This could be due to the perceived advantages of LEDs such as longer lifespan of up to 10,000 h compared with 40-100 h in QTHs (22). LED units also degage less over time, produce less heat, have higher efficiency, and consume less power; thus allowing them to be made into portable cordless units (23). All of the previous factors may have influenced the decision to choose LED over QTH. It must be noted, however, that narrower spectrum LEDs (420-490 nm) fall within the CQ absorption spectrum, which explains their high efficacy in most commonly used dental resin composites (22-24). In resin-composite materials that do not use CQ as an initiator, this narrow spectral output may be considered a disadvantage, depending on the exact absorption rate of the photoinitiator used. Wide-spectrum LED lights have been introduced to the market to overcome this drawback (25,26).

In conclusion, this study found that all the units in service at the local dental institution had satisfactory output for incremental placement of dental resin composites, which is in line with the expectation at an educational institution. Most units were also capable of curing bulk-fill restorations. However, it is recommended that the light intensity be checked prior to placing fillings as it will impact whether or not the unit should be used as well as the curing duration.

**Conflict of interest**

The authors declare no conflicts of interest.

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