Balhaddad et al. BMC Oral Health (2025) 25:718
https://doi.org/10.1186/s12903-025-06126-8

BMC Oral Health

RESEARCH

Open Access

Effect of damage or contamination to the tips of 200 light-curing units

Abdulrahman A. Balhaddad[1*], Afnan O. Al-Zain[2], Hassan A. Alyami[3], Husain A. Almakrami[3], Osama A. Alsulaiman[4], Eman H. Ismail[5], Richard B. Price[6] and Ahmed A. Alsulaiman[4]

Abstract

Objective The light-curing unit (LCU) has become a vital piece of dental equipment that must be correctly maintained. This study investigated the impact of contamination and physical damage to the light tip on the power and radiant emittance values from old and new LCUs.

Materials and methods Two investigators assessed 200 LCUs in dental clinics. The extent of contamination and physical damage to the light-curing unit (LCU) tips was recorded using a scale ranging from 0 to 8, where 0 indicates the absence of damage or contamination, and 8 represents severe damage or contamination. Then, the radiant emittance and power values of the LCU tip were measured using a digital radiometer (Bluephase meter II; Ivoclar, Schaan, Liechtenstein). LCUs that were more than five years old were classified as old. Spearman correlation coefficient was used to determine the relationship between the condition of the LCU and radiant emittance/power ($p = 0.05$).

Results There were no significant differences in the percent reduction of the power and radiant emittance from the values reported by the manufacturers, as well as the presence of contamination or physical damage scores between old and relatively new light-curing tips ($p > 0.05$). The mean ± standard deviation percentage reductions in power and radiant emittance from the manufacturer's stated values were 19.2 ± 17.63% and 3.9 ± 16.49%, respectively. Contamination and physical damage had significant positive correlations with the reduction in the power ($r = 0.22070$, $p = 0.0017$ and $r = 0.27422$, $p < 0.0001$, respectively) and the reduction in the radiant emittance ($r = 0.28626$, $p < 0.0001$ and $r = 0.36650$, $p < 0.0001$). Increased contamination and physical damage scores corresponded to greater percent reductions in the power and radiant emittance ($p < 0.05$).

Conclusions Contamination and physical damage to the LCU can negatively impact the light output from LCUs.

Clinical relevance To ensure optimal performance, dentists should regularly monitor the output of their LCUs and examine the devices for any signs of physical damage or contamination.

Keywords Power, Dental radiometer, Composite, Dental curing lights, Damage, Radiant emittance

*Correspondence:
Abdulrahman A. Balhaddad
abalhaddad@iau.edu.sa
[1]Department of Restorative Dental Sciences, College of Dentistry, Imam Abdulrahman Bin Faisal University, P.O.Box 1982, Dammam 31441, Saudi Arabia
[2]Department of Restorative Dentistry, Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia
[3]College of Dentistry, Imam Abdulrahman Bin Faisal University, Dammam 31441, Saudi Arabia
[4]Department of Preventive Dental Sciences, College of Dentistry, Imam Abdulrahman Bin Faisal University, P.O.Box 1982, Dammam 31441, Saudi Arabia
[5]Department of Clinical Dental Sciences, College of Dentistry, Princess Nourah bint Abdulrahman University, Riyadh 11564, Saudi Arabia
[6]Department of Dental Clinical Sciences, Faculty of Dentistry, Dalhousie University, Halifax, NS, Canada

Introduction

The light-curing unit (LCU) has become an essential piece of equipment in Restorative Dentistry, Orthodontics, Pediatric Dentistry, and Prosthodontics. However, several clinical studies have reported that 30–60% of resin-based composite (RBC) restorations will require replacement within 3 to 8 years [1–4]. The most common reasons for these failures are secondary caries and fracture of the restoration [1–4].

Contrary to the traditional view that attributes most resin-based restoration failures and bracket detachment, mainly to the bonding agent, recent evidence highlights the significant role of the operator's technique in determining the longevity of the restoration [5]. Such failures underscore the high technique sensitivity when using RBCs [6, 7]. Errors in how the RBCs are light-cured can affect the clinical outcome [8] and in vitro studies have shown that under-cured RBCs are more prone to fracture, more wear, reduced physical properties [9, 10], and lower bond strength to the tooth [11]. An often-underestimated factor is the reduced efficiency of LCUs when curing resin-based materials, that can be attributed to a low irradiance from the LCU, inconsistent monitoring of LCU output, or due to the fact that the light-guide tip was contaminated or damaged [6, 7, 12].

Unless the RBC is adequately photocured, the physical and mechanical properties of the RBCs will be adversely affected, there will be more degradation at restoration margins, and the bond strength between the tooth and the restoration will be reduced [6, 7, 12]. Additionally, residual unreacted monomers leaching from the RBC can be cytotoxic and can increase the bacterial attachment to the surface of the RBC [13, 14]., Any of these outcomes may adversely affect the clinical longevity of RBC restorations. Thus, it is important to optimize the light curing technique and to deliver sufficient light at the correct wavelengths to adequately photocure the RBC [13, 14].

Several studies have reported that the light output and the curing potential of LCUs used in dental institutes and dental clinics could be improved [15–19]. For instance, one study reported that approximately 27% of LCUs in dental offices failed to deliver sufficient light energy to adequately cure RBCs in their recommended exposure times [15]. Similarly, the radiant emittance delivered from LCUs in private dental clinics in Japan was found to be up to 82.1% lower than that from brand-new LCUs [16]. Research conducted in Saudi Arabia indicated that about 12.4% of light-emitting diode (LED) and 17.3% of quartz-tungsten-halogen (QTH) LCUs, emitted an unsatisfactory radiant emittance [18]. These findings suggest that a considerable number of resin-based composite restoration failures may be attributed to an inadequate light output from the LCU in addition to material or operator technique-related factors when using the LCU [5]. However, for ethical reasons, it is impossible to conduct a clinical study to prove this and dentists must rely on the results of in vitro laboratory studies.

It is already known that contaminated or damaged LCU tips emit less power and lower radiant emittance levels [12, 19, 20]. However, the relationship between the level of contamination or physical damage and the reduction in the power or radiant emittance has not been investigated. Furthermore, it remains unclear how the age of the device might influence its performance if the tip is contaminated or damaged. This study explores the correlation between the percent reduction of the power and radiant emittance values of old and new LCUs. The impact of contamination and physical damage levels on the LCU tips with their radiant emittance (tip irradiance) and power output at 0 mm from the light tip. The first null hypothesis is that there would be no difference in the contamination, physical damage, and power and radiant emittance output between old and new LCU tips. The second null hypothesis is that an increased severity of the contamination or physical damage to the light tip would not be correlated with a greater reduction in the power and radiant emittance values.

Materials and methods

Sample size calculation

Using a power of 80%, 0.05 significance level, and an effect size (0.86) which was calculated based on previously published paper [20], the sample size was determined to be at least 23 samples in each category (G*Power 3.1.9.4 University of Düsseldorf, Germany).

Ethical approval & study design

This study was conducted in both government and private dental clinics in the Eastern Province of Saudi Arabia. The Institutional Review Board at Imam Abdulrahman bin Faisal University (IRB-2023-02-300) approved this study. Two investigators visited twenty-seven government and private dental clinics in the Eastern Province, Dammam and Khobar cities, to examine two-hundred LED LCUs. Verbal consent was taken from the medical director of each clinic after clarifying the rationale and methodology of the study. The LCU's name, type, radiant emittance output value, year of manufacture, and year of purchase were recorded. Based on the median of the estimated purchased date, LCUs that were more than five years old were classified as old. Two dentists were trained and calibrated on how to use a dental radiometer (Bluephase Meter II; Ivoclar, Schaan, Liechtenstein) and how to accurately record the power and radiant of each light-curing unit (LCU) using the digital radiometer. These values were compared to the power and radiant emittance (irradiance) found in the manufacturers' manuals and categorized as "assumed power and radiant emittance".

When the power value was missing in the manual, it was estimated by calculating the surface area (cm^2) of the LCU tip and applying the formula: power (mW) = surface area (cm^2) × radiant emittance (mW/cm^2).

After gathering the information for each LCU, the light tip diameter gauge on the base of the Bluephase Meter II was used to confirm that the light-curing tip had a diameter of 10 mm. Once confirmed, this value was entered into software of the Bluephase Meter II before measuring the radiant emittance measurements of the LCU. Then, the light-curing tip was placed directly on the Bluephase Meter II sensor surface at 0 mm. The LCU was turned on, and the radiometer measured the radiant emittance value (mW/cm^2). The power (mW) value was also recorded by changing the setting on the radiometer software to record only power. The radiant emittance and power values were measured three times for each LCU, and the average was calculated. A radiant emittance that was within ±10% from the manufacturer's stated value was considered acceptable.

The extent of physical damage and contamination with debris or remaining tooth colored filling material was assessed on a score of 0 to 8, as described by Kojic et al. (Fig. 1) [21]. The LCU tip was divided into eight parts. Based on the extent of physical damage or contamination (Fig. 1), a score ranging from 0 to 8 was assigned to the LCU tip, where 0 had no physical damage or contamination, and 8 was where the physical damage or contamination affected all the eight parts of the LCU tip.

Statistical analysis

Descriptive statistics (mean, standard deviation, median, and interquartile range) were used to summarize the data. Normality of the data was assessed using Kolmogorov–Smirnov test and the Shapiro–Wilk test. Because of the skewness of the data, the Mann-Whitney U Test was used to compare the included variables to the condition of the light tip (i.e., old vs. new). Spearman's correlation coefficient was used determine if there was a relationship between the radiant emittance and power ($\alpha = 0.05$).

Results

Table 1 represents a list of the LCUs evaluated in the government and private dental clinics. Table 2 presents the average and standard deviation of the data collected from the analysis of 200 LCU tips found in government and private dental offices, tips. The mean ± standard deviation percentage reductions in power and radiant emittance from the manufacturer's stated values were 19.2 ± 17.63 and 3.9 ± 16.49, respectively. The mean contamination and physical damage scores were 0.97 ± 1.93 and 0.69 ± 1.79, respectively.

Table 3 presents the descriptive statistics for the light-curing tips that were categorized as old and new. The analysis showed that there were more contaminated (43 vs. 19) and damaged (27 vs. 8) tips among the old LCUs compared to the new ones, resulting in a total of 62 contaminated and 35 damaged LCU tips. However, no statistically significant differences were observed between old and new LCU tips in terms of the amount contamination ($p = 0.091$), physical damage ($p = 0.93$), power reduction ($p = 0.059$), and radiant emittance reduction ($p = 0.87$).

The relationship between contamination, physical damage, and the impact on LCU tips is reported in Table 4; Fig. 2. Contamination of LCU tips resulted in a significant positive correlation with a reduction (%) in the power ($r = 0.22070$, $p = 0.0017$) and consequently a reduction in the radiant emittance ($r = 0.28626$, $p < 0.0001$). Similarly, the presence of physical damage had a significant positive correlation with the reduction (%) the power ($r = 0.27422$, $p < 0.0001$) and radiant emittance ($r = 0.36650$, $p < 0.0001$). These findings are illustrated in Fig. 2, where it is evident that higher contamination (Fig. 2A) and physical damage (Fig. 2B) scores corresponded to greater reductions (%) in power and radiant emittance. For instance, when the contamination score was two (Fig. 2A), the reduction in power and radiant emittance was approximately 15–20%. As the contamination score increased to four or six, a more significant reduction was noted, ranging from 20 to 30%. A reduction of about 35–40% was observed when the contamination score reached eight. Similarly, when the damage score was two (Fig. 2B), the reduction in power and radiant emittance was also around 15–20%. This reduction increased to between 20 and 25% at a score of four, 35–40% at a score of six, and ≥40% when the score reached eight.

Discussion

This study evaluated the influence of the age of the LCU, the presence of contamination on the light tip, and damage on the power and radiant emittance values from the LCUs. A radiant emittance that was ±10% from the manufacturer's stated value was considered satisfactory. The first null hypothesis was accepted because the contamination score, damage score, and the reduction (%) in power and radiant emittance values of old and new LCU tips were not significant. However, the second null hypothesis was rejected because higher levels of contamination and physical damage were associated with a greater reduction (%) in the power and radiant emittance values. Therefore, these results indicate that contamination and damage severity are significantly correlated with power and radiant emittance reduction, regardless of the age of the LCUs. The results emphasize the need for clinicians to regularly inspect and maintain their LCU tips for contamination and damage, as these factors

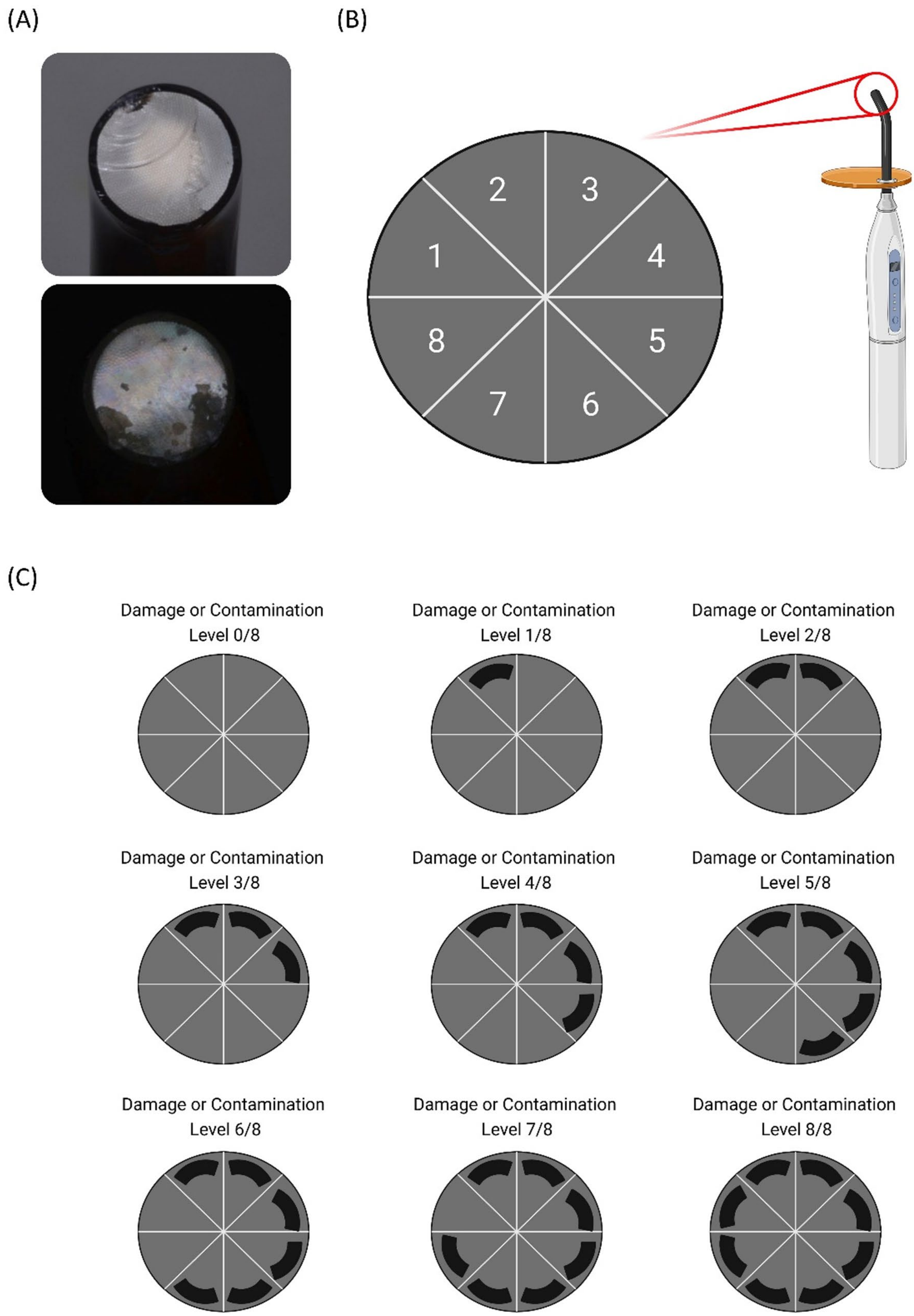

Fig. 1 **(A)** Examples of damaged and contaminated tips. (**B**&**C**) Illustration showing the assessment method with scores ranging from 0 to 8 was assigned to the LCU tip, where 0 had no physical damage or contamination, and 8 was where the physical damage or contamination affected all the eight parts of the LCU tip [21]

Table 1 The brand name, manufacturer and light-curing units number screened in the study

Brand Name	Manufacturer information	N
Satelec Acteon Mini-Led active	Acteon, Merignac, France	91
LED.H	Guilin Woodpecker Medical Instrument Co., LTD., Guilin Guangxi, China	63
Bluephase® PowerCure	Ivoclar vivadent, Schaan, Liechtenstein	9
Eighteeth CuringPen	Changzhou Sifary Medical Technology Co., Ltd, Changzhou City, Jiangsu, China	5
Unitek OrtholouxTM Luminous	3 M, St. Paul, MN, USA	4
Elipar DeepCure-S	St. Paul, MN, USA	3
SmartLite Pro	Dentalsplay Sirona, Milford, DE, USA	3
E-Morlit	APOZA Enterprise Co., Ltd., New Taipei City, Taiwan	3
CL-A Cordless LED Curing Light	Glow Pak International, Lahore, Pakistan	3
MaxCure9	Guilin Woodpecker Medical Instrument Co., LTD., Guilin Guangxi, China	2
i Led Curing Light	Guilin Woodpecker Medical Instrument Co., Guilin, Guangxi, China	2
B-Cure	Guilin Woodpecker Medical Instrument Co., LTD., Guilin Guangxi, China	2
D-2000 LED Curing Light	APOZA Enterprise Co., Ltd., New Taipei City, Taiwan	2
O-Light Curing Light	Guilin Woodpecker Medical Instrument Co., LTD., Guilin, Guangxi, China	1
LED.G	Guilin Woodpecker Medical Instrument Co., LTD., Guilin, Guangxi, China	1
BL-402 Wireless LED Light Curing Unit	Zhaoqing Gaoyao Recende Medical Equipment Co., LTD, Zhaoqing, Guangdong, China	1
BL-404 Wireless LED Light Curing Unit	Zhaoqing Gaoyao Recende Medical Equipment Co., LTD, Zhaoqing, Guangdong, China	1
Demi Plus	Kerr, Brea, CA, USA	1
Layan	Layan Medical Company, Riadh, KSA	1
LITEX 695 LED Curing Light	Dentamerica, City of Industry, CA, USA	1
BA OPTIMA 10 CURING LIGHT	B.A. International Ltd., Northampton, UK	1

Table 2 Descriptive data (mean ± SD), median, and quartile range for the tested light-curing tips ($n = 200$)

Variable	Mean	Standard Deviation	Median	Quartile Range
Calculated Power (mW)*	551.6	112.42	480.81	134.62
Measured Power (mW)	455.6	150.20	443.66	78.33
Power Reduction (%)	19.2	17.63	14.33	26.82
Manufacturer's Radiant Emittance (mW/cm^2)	1275.1	173.30	1250	50
Measured Radiant Emittance (mW/cm^2)	1225.5	290.36	1259	290.83
Radiant Emittance Reduction (%)	3.9	16.49	0	12.24
Contamination Score	0.97	1.93	1	1.00
Damage Score	0.69	1.79	0	0

*When the power value was not reported by the manufacturer, the power was calculated from the irradiance value reported by the manufacturer and measured LCU tip diameter

The measured power and irradiance values were those measured in the study by the dental radiometer

Table 3 Descriptive data (mean ± SD), median, and quartile range for the tested light-curing tips comparing old and new light-curing unit tips (Wilcoxon Two-Sample Test)

Variable		Old tip ($n = 154$)	New tips ($n = 46$)	p-value
Contamination Score ($n = 62$)	*Mean*	0.87	1.30	0.091
	Standard Deviation	1.85	2.19	
	Median	0	0	
	Quartile Range	1.00	2	
Physical Damage Score ($n = 35$)	*Mean*	0.64	0.85	0.93
	Standard Deviation	1.66	2.20	
	Median	0	0	
	Quartile Range	0	0	
Power Reduction (%)	*Mean*	20.5	15.1	0.059
	Standard Deviation	18.07	15.57	
	Median	15.0	13.35	
	Quartile Range	26.34	22.85	
Radiant Emittance Reduction (%)	*Mean*	10.0	7.9	0.87
	Standard Deviation	17.32	13.39	
	Median	0	0	
	Quartile Range	13.52	10.28	

Table 4 Spearman correlation between the light-curing tip ($n = 200$) condition and the percentage reduction in power and radiant emittance

Condition	Power Reduction (%)	Radiant Emittance Reduction (%)
Contamination		
r-value	0.22070	0.28626
p-value	**0.0017**	**< 0.0001**
Physical Damage		
r-value	0.27422	0.36650
p-value	**< 0.0001**	**< 0.0001**

can significantly affect device performance. Adhering to recommended curing protocols is essential for ensuring strong, durable restorations and preventing complications such as fractures [22], brackets and restorations debonding [23, 24], and postoperative sensitivity due to the release of unreacted monomers [25, 26]. Therefore, achieving adequate polymerization and avoiding undercuring of dental resins is crucial to ensure the longevity, functionality, and esthetics of the restoration [27].

Most LCU manufacturers make dental radiometers to monitor the performance of their LCUs [28, 29]. However, in most cases, accurate results can be obtained when measuring the LCUs manufactured by the same brand as the radiometer itself, due to the fact that these

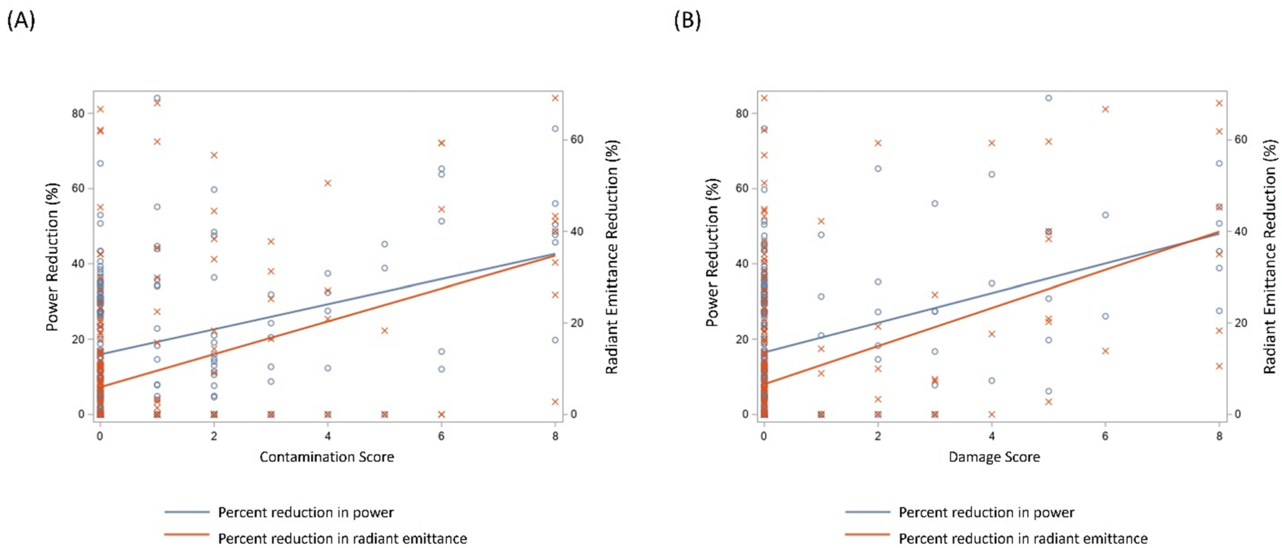

Fig. 2 Correlation between (**A**) contamination and (**B**) severity of physical damage, and the reduction in the power and radiant emittance (%) of the light-curing units (*n* = 200)

radiometers are specifically calibrated to detect a designated range of wavelengths associated with the LCU for which they are engineered [28, 29]. These chairside dental radiometers give a relative measurement sufficient for monitoring the LCU. Furthermore, many dental radiometers exhibit a narrow sensor aperture, which means they do not capture the complete light output generated by such LCUs [30, 31]. This can result in underestimating the radiant emittance value measured [32]. Since the light tip of many LCUs emits non-uniform irradiance across its surface, Various areas with differing irradiance levels or wavelengths can be located across this small aperture. As a result, the irradiance readings captured will fluctuate based on the light tip's location relative to the sensor opening of the aperture, which may cause confusion and incorrect information [30–32]. While laboratory-grade spectrometric devices can measure the radiant emittance and spectral radiant power values more accurately, such as laboratory-grade thermopile, laboratory-grade integrating sphere, and laboratory grade spectrometer such as Managing Accurate Resin Curing (MARC) [20], these devices are more expensive and less practical than chairside dental radiometers. The Bluephase Meter II is a chairside dental radiometer that overcomes many of the limitations of other dental radiometers because it can record the power from up to a 12-mm diameter tip [33, 34]. By entering the tip diameter in whole millimeters, this device can provide a more accurate measurement of the radiant emittance and eliminate the disadvantages of the narrow sensor aperture found in other radiometers [33, 34]. Two studies have reported that among different radiometers, the Bluephase Meter II was the most accurate at measuring power [28, 35] suggesting that the Bluephase Meter II is currently the most reliable available dental radiometer.

Although the Bluephase Meter II may be the most accurate dental radiometer available for the dentist to purchase [35], the radiant emittance reported may be inaccurate due to a limitation of the Bluephase Meter II, which only allows a whole number to be used for the diameter of the light tip [28, 35]. For example, if the tip diameter is 9.5 mm, the device will record the diameter only as 9–10 mm, resulting in a less accurate reading. While this may seem to be a small difference, a 9 mm diameter tip has an area of 63.6 mm^2 and a 10 mm tip has an area of 78.5 mm^2. This is a 23% increase in the area that would result in a 23% difference in the radiant emittance. In addition, the gauge on the bottom of the Bluephase Meter II records the external tip diameter of the LCU light tip. This is fact may accout for errors in reportibg the radiant emittance because the internal tip diameter is the one that should be considered when calculating the radiant emittance of the LCU [28].

The energy (radiant exposure) received by resin-based composite restorations, is affected by the exposure time, distance, irradiance, LCU type, performance of LCUs, tip diameter, ergonomics of the unit, and the light source [36–39]. However, contamination and physical damage of the LCU tip negatively affects the light output and this will likely affect the radiant exposure received by the RBC and the final quality of the restoration. Tip contamination or physical damage was found to significantly reduce the power and radiant emittance values of LCUs. Furthermore, even greater reductions in the radiant emittance and power values were observed as the contamination and physical damage scores increased. These results corroborate other studies that have also shown how contamination and physical damage can decrease the power and radiant emittance values of the LCUs. One study reported an 11.7–13.9% reduction in LCU radiant emittance when the tips were damaged or contaminated, noting a less homogeneous beam profile among the damaged and contaminated tips [20]. Another investigation reported that the LCUs with contaminated tips delivered lower radiant emittance values [19]. Suliman et al. reported an increase in energy output from LCUs when the damaged tip was replaced with a new one [40].

In the present study, the age of the device did not significantly affect the reduction (%) of the power and radiant emittance values from the LCUs, suggesting that frequent use may not necessarily lead to a decline in performance. This finding could be attributed to several factors. First, the technologies and manufacturing quality of these LCUs may have inherent durability and stability, allowing them to uphold steady performance over time. Additionally, consistent maintenance and calibration procedures employed by dental professionals might lessen the effects of aging on the devices. Overall, these factors imply that the durability of the LCUs does not inherently correlate with a decline in their efficacy, highlighting the importance of obtaining LCUs with excellent quality design from major manufacturers.

Cleaning and disinfecting the LCU does not require complex equipment or much time, yet it can have a significant impact on the light output [41–43]. By ensuring a clean tip, the irradiance and radiant exposure delivered by the LCU to the RBC can be increased, reducing the risk of under-cured of light-activated materials, and improving their success rate. However, it is important to use the cleaning solutions approved by the manufacturer of the LCU, as some sterilization solutions can potentially damage the light tip, the lens, or the body of the LCU [41, 43].

Physical damage was found to have a detrimental impact on the light output from the LCUs. Thus, it is strongly recommended that the LCUs be monitored using radiometers and that a record of light output be maintained [12, 44]. While some radiometers do not provide accurate radiant emittance measurements or display numerical values, provided they are always used on the same LCU, they can still determine changes in light output over time [44]. In the past, radiant emittance levels of 400 mW/cm^2 were considered adequate for LCUs in the curing resin-based materials, but exposure times of 40–60 s were common, thus delivering 16 to 24 J/cm^2 [41, 44]. However, since several dental manufacturers now recommend 20 s exposure times, it might be better to consider a minimum radiant emittance value of at least 500–550 mW/cm^2 that would deliver 10 to 11 J/cm^2 [35]. In cases where the radiant emittance falls below the minimum threshold of 500–550 mW/cm^2, it is advised to either repair or replace the LCU. This ensures that light-activated resin receives adequate radiant emittance for proper polymerization.

Before using the LCU on a patient, it is essential for dentists to adhere to the recommended infection control protocols provided by the manufacturer [45]. However, there are conflicting opinions in the literature regarding the use of disposable barriers for infection control. While one study suggested that the barrier can decrease the power output by approximately 5–40% [46, 47], others have indicated that there was no significant negative impact on resin polymerization [48]. A recent investigation highlighted the importance of applying the plastic barriers correctly to minimized the radiant power reduction [46]. It is worth noting that the use of disinfectants to clean light tips can also reduce the efficiency of the reflectors within the tips [43]. Therefore, using autoclavable light tips has been proposed as a gold standard for ensuring optimal cleaning [43], but this can also negatively affect the light output [49]. In conclusion, before using the LCU, and placing a plastic barrier, the LCU guide-tip should be checked to ensure that it is clean, free of contamination and not broken [50]. Keeping a log is also useful to monitor the LCU output and to determine when it falls by 10% from its original value [43]. Dentists should carefully follow the guidelines provided by the manufacturers to disinfect light-curing tips appropriately and monitor their LCU tips for any scratches or physical damage [42, 43]. Light tips or the LCU should be replaced if the light output falls below the manufacturers' tolerances [40].

This study has some limitations. The data were collected from a single region of Saudi Arabia from 200 LCUs and this may restrict the generalizability of the findings. In addition, long-term tracking and monitoring of LCUs at different times could provide more insight into when the output from the LCUs starts to fall. Another limitation is related to the method used to score damage and contamination. Visual inspections can be subjective, as different examiners may interpret signs of damage or contamination otherwise, leading to conflicting evaluations. In addition, some forms of contamination or damage may not be visible to the naked eye, such as microbial contamination or internal damage. Future investigations could include other variables, such as the brand of the LCUs, and the maintenance protocol could be recorded when assessing the impact of physical damage and contamination on LCUs.

Conclusions

Increased contamination and physical damage scores corresponded to greater reductions in the power and radiant emittance of LCUs. However, there was no significant difference in output from old (>5 years) and new LCUs. To ensure optimal performance, dental practitioners should regularly monitor the output of their LCUs and thoroughly examine the devices for any signs of physical damage or contamination.

Acknowledgements
The authors acknowledge the support received from the Imam Abdulrahman bin Faisal University, Dammam, Saudi Arabia.

Author contributions
A.A. Balhaddad, A.O. Al-Zain, and R.B. Price contributed to the design, acquisition, and analysis of the study, drafted the manuscript, and provided critical revisions. H.A. Alyami, and H.A. Almakrami acquired and analyzed the data. O.A Alsulaiman, A.A Alsulaiman, and E.H Ismail contributed to the study's design, acquisition, interpretation of the data, and critically revised the manuscript. All authors gave their final approval and agreed to be accountable for all aspects of the work.

Funding
This research was funded by Princess Nourah bint Abdulrahman University Researchers Supporting Project number (PNURSP2025R350), Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia.

Data availability
The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declarations

Ethical approval and consent to participate
The Institutional Review Board at Imam Abdulrahman bin Faisal University (IRB-2023-02-300) approved this study..

Competing interests
The authors declare no competing interests.

Received: 19 August 2024 / Accepted: 6 May 2025
Published online: 14 May 2025

References

1. Demarco FF, Collares K, Coelho-de-Souza FH, Correa MB, Cenci MS, Moraes RR, et al. Anterior composite restorations: A systematic review on long-term survival and reasons for failure. Dent Mater. 2015;31:1214–24.
2. Alvanforoush N, Palamara J, Wong R, Burrow M. Comparison between published clinical success of direct resin composite restorations in vital posterior teeth in 1995–2005 and 2006–2016 periods. Aust Dent J. 2017;62:132–45.
3. Rasines Alcaraz MG, Veitz-Keenan A, Sahrmann P, Schmidlin PR, Davis D, Iheozor-Ejiofor Z. Direct composite resin fillings versus amalgam fillings for permanent or adult posterior teeth. Cochrane Database Syst Rev. 2014;:CD005620.
4. Moraschini V, Fai CK, Alto RM, Dos Santos GO. Amalgam and resin composite longevity of posterior restorations: A systematic review and meta-analysis. J Dent. 2015;43:1043–50.
5. Demarco FF, Cenci MS, Montagner AF, de Lima VP, Correa MB, Moraes RR, et al. Longevity of composite restorations is definitely not only about materials. Dent Mater. 2023;39:1–12.
6. Leprince JG, Palin WM, Hadis MA, Devaux J, Leloup G. Progress in dimethacrylate-based dental composite technology and curing efficiency. Dent Mater. 2013;29:139–56.
7. Price RBT. Light curing in dentistry. Dent Clin North Am. 2017;61:751–78.
8. Maktabi H, Balhaddad AA, Alkhubaizi Q, Strassler H, Melo MAS. Factors influencing success of radiant exposure in light-curing posterior dental composite in the clinical setting. Am J Dent. 2018;31:320–8.
9. Hasanain FA, Nassar HM. Utilizing light cure units: A concise narrative review. Polym (Basel). 2021;13:1596.
10. Price RB, Ferracane JL, Hickel R, Sullivan B. The light-curing unit: an essential piece of dental equipment. Int Dent J. 2020;70:407–17.
11. Almeida LF, Martins LP, Martins RP. Effects of reducing light-curing time of a high-power LED device on shear bond strength of brackets. J Orofac Orthop. 2018;79:352–8.
12. Rueggeberg FA, Giannini M, Arrais CAG, Price RBT. Light curing in dentistry and clinical implications: a literature review. Braz Oral Res. 2017;31:e61.
13. Maktabi H, Ibrahim M, Alkhubaizi Q, Weir M, Xu H, Strassler H, et al. Underperforming light curing procedures trigger detrimental irradiance-dependent biofilm response on incrementally placed dental composites. J Dent. 2019;88:103110.
14. Maktabi H, Ibrahim MS, Balhaddad AA, Alkhubaizi Q, Garcia IM, Collares FM, et al. Improper light curing of bulkfill composite drives surface changes and increases S. mutans biofilm growth as a pathway for higher risk of recurrent caries around restorations. Dent J (Basel). 2021;9:83.
15. Martin FE. A survey of the efficiency of visible light curing units. J Dent. 1998;26:239–43.
16. Miyazaki M, Hattori T, Ichiishi Y, Kondo M, Onose H, Moore BK. Evaluation of curing units used in private dental offices. Oper Dent. 1998;23:50–4.
17. AlShaafi MM. Evaluation of light-curing units in rural and urban areas. Saudi Dent J. 2012;24:163–7.
18. Alquria T, Al Gady M, Khabeer A, Ali S. Types of polymerisation units and their intensity output in private dental clinics of twin cities in Eastern Province, KSA; a pilot study. J Taibah Univ Med Sci. 2019;14:47–51.
19. Nassar HM, Ajaj R, Hasanain F. Efficiency of light curing units in a government dental school. J Oral Sci. 2018;60:142–6.
20. Balhaddad AA, Garcia I, Collares F, Felix CM, Ganesh N, Alkabashi Q, et al. Assessment of the radiant emittance of damaged/contaminated dental light-curing tips by spectrophotometric methods. Restor Dent Endod. 2020;45:e55.
21. Kojic DD, El-Mowafy O, Price R, El-Badrawy W. Efficacy of light-emitting diode light polymerization units used in private practices in Toronto, Ontario, Canada. J Am Dent Assoc. 2019;150:802–8.
22. Fleming PS, Eliades T, Katsaros C, Pandis N. Curing lights for orthodontic bonding: A systematic review and meta-analysis. Am J Orthod Dentofac Orthop. 2013;143:S92–103.
23. Bragança GF, Vianna AS, Neves FD, Price RB, Soares CJ. Effect of exposure time and moving the curing light on the degree of conversion and Knoop microhardness of light-cured resin cements. Dent Mater. 2020;36:e340–51.
24. Goyal A, Hurkadle J, Magegowda S, Bhatia P. Use of light-curing units in orthodontics. J Investig Clin Dent. 2013;4:137–41.
25. Bin-Jardan LI, Almadani DI, Almutairi LS, Almoabid HA, Alessa MA, Almulhim KS, et al. Inorganic compounds as remineralizing fillers in dental restorative materials: narrative review. Int J Mol Sci. 2023;24:8295.
26. Albeshir EG, Alsahafi R, Albluwi R, Balhaddad AA, Mitwalli H, Oates TW, et al. Low-Shrinkage resin matrices in restorative Dentistry-Narrative review. Mater (Basel). 2022;15:2951.
27. Duruk G, Akküç S, Uğur Y. Evaluation of residual monomer release after polymerization of different restorative materials used in pediatric dentistry. BMC Oral Health. 2022;22:232.
28. Shortall AC, Hadis MA, Palin WM. On the inaccuracies of dental radiometers. PLoS ONE. 2021;16:e0245830.
29. Shimokawa CAK, Turbino ML, Harlow JE, Price HL, Price RB. Light output from six battery operated dental curing lights. Mater Sci Eng C Mater Biol Appl. 2016;69:1036–42.
30. Price RB, Labrie D, Kazmi S, Fahey J, Felix CM. Intra- and inter-brand accuracy of four dental radiometers. Clin Oral Investig. 2012;16:707–17.
31. de Oliveira D, Rocha MG, Correr AB, Ferracane JL, Sinhoreti M. Effect of beam profiles from different light emission tip types of multiwave light-emitting diodes on the curing profile of Resin-based composites. Oper Dent. 2019;44:365–78.
32. Megremis SJ, Ong V, Lukic H, Shepelak H. An Ada laboratory evaluation of light-emitting diode curing units. J Am Dent Assoc. 2014;145:1164–6.
33. Maucoski C, Price RB, Arrais CA, Sullivan B. Power output from 12 brands of contemporary LED light-curing units measured using 2 brands of radiometers. PLoS ONE. 2022;17:e0267359.
34. Shimokawa CAK, Harlow JE, Turbino ML, Price RB. Ability of four dental radiometers to measure the light output from nine curing lights. J Dent. 2016;54:48–55.
35. Maucoski C, Price RB, Arrais CAG. Irradiance from 12 LED light curing units measured using 5 brands of dental radiometers. J Esthetic Restor Dentistry. 2023;35:968–79.

36. Al-Zain AO, Eckert GJ, Platt JA. The influence of distance on radiant exposure and degree of conversion using different Light-Emitting-Diode curing units. Oper Dent. 2019;44:E133–44.
37. Al-Zain AO, Marghalani HY. Influence of Light-curing distances on microflexural strength of two Resin-based composites. Oper Dent. 2020;45:297–305.
38. Al-Zain AO, Eckert GJ, Lukic H, Megremis SJ, Platt JA. Degree of conversion and cross-link density within a resin-matrix composite. J Biomed Mater Res B Appl Biomater. 2018;106:1496–504.
39. Al-Zain AO, Eckert GJ, Lukic H, Megremis S, Platt JA. Polymerization pattern characterization within a resin-based composite cured using different curing units at two distances. Clin Oral Investig. 2019;23:3995–4010.
40. Suliman AA, Abdo AA, Elmasmari HA. Effect of contamination, damage and barriers on the light output of light-Curing units. TODENTJ. 2019;13:196–202.
41. Price RB, Shortall AC, Palin WM. Contemporary issues in light curing. Oper Dent. 2014;39:4–14.
42. Shortall AC, Price RB, MacKenzie L, Burke FJT. Guidelines for the selection, use, and maintenance of LED light-curing units - Part 1. Br Dent J. 2016;221:453–60.
43. Shortall AC, Price RB, MacKenzie L, Burke FJT. Guidelines for the selection, use, and maintenance of LED light-curing units - Part II. Br Dent J. 2016;221:551–4.
44. Price RB, Ferracane JL, Shortall AC. Light-Curing units: A review of what we need to know. J Dent Res. 2015;94:1179–86.
45. Rueggeberg FA. State-of-the-art: dental photocuring–a review. Dent Mater. 2011;27:39–52.
46. Soares CJ, Braga SSL, Ribeiro MTH, Price RB. Effect of infection control barriers on the light output from a multi-peak light curing unit. J Dent. 2020;103:103503.
47. McAndrew R, Lynch CD, Pavli M, Bannon A, Milward P. The effect of disposable infection control barriers and physical damage on the power output of light curing units and light curing tips. Br Dent J. 2011;210:E12.
48. Khode RT, Shenoi PR, Kubde RR, Makade CS, Wadekar KD, Khode PT. Evaluation of effect of different disposable infection control barriers on light intensity of light-curing unit and microhardness of composite - An in vitro study. J Conserv Dent. 2017;20:180–4.
49. Rueggeberg FA, Caughman WF, Comer RW. The effect of autoclaving on energy transmission through light-curing tips. J Am Dent Assoc. 1996;127:1183–7.
50. Platt JA, Price RB. Light curing explored in Halifax. Oper Dent. 2014;39:561–3.

Publisher's note