

# Efficiency of Radiant Power of Different Light-Curing Unit Brands With Varying Ages and Tip Conditions in Private and Governmental Dental Centers

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**AIM:** Insufficient awareness among clinicians regarding the performance of light-curing devices may lead to inadequate polymerization, which can ultimately compromise the long-term success of dental restorations. This study aimed to examine the radiant power of different light-curing unit (LCU) brands by using three types of radiometers in terms of clinic and LCU types, age, tip diameter, and LCU tip condition in the Aseer region.

**METHODS:** LCUs were assembled from selected dental centers. LCU brands and data, including clinical dental age (<1, 1–3, and >3 years), nozzle state (intact, damaged, and presence of debris), and tip diameters (6–7, 8–9, and 10 mm), were recorded. The radiant power was categorized into  $\leq 1000$ , 1000–1200, and  $> 1200$  mW/cm<sup>2</sup>, which were labeled as adequate, sufficient, and adequate and sufficient, respectively, and recorded with three brands of digital radiometers (Woodpecker, Ivoclar, and Rogin). Analysis of Variance (ANOVA) and *t*-test were performed to determine the difference between and within groups, with a significance value of  $< 0.05$ .

**RESULTS:** Among 132 LCUs surveyed and assessed, a significant difference in the radiant power of LCUs was observed between governmental and private dental clinics, particularly with the Ivoclar radiometer ( $p < 0.05$ ). No significant differences in radiant power values were detected between the radiometers and the assessed LCUs' nozzle. Older LCUs demonstrated higher radiant power in the  $\leq 1000$  mW/cm<sup>2</sup> category when measured with the Ivoclar radiometer. Differences in radiant power were noted on the basis of tip diameter and the presence of remaining bond and composite materials ( $p < 0.05$ ).

**CONCLUSIONS:** The assessed LCU brands recorded marginally sufficient radiant power values in governmental and private dental clinics. The Rogin radiometer consistently demonstrated increased radiant power values across LCU brands and intact tip conditions. Differences in radiant power were noted in terms of tip diameter and the remaining bond and composite materials.

**Keywords:** light cure units; radiant power; private dental clinic; governmental dental clinic; tip condition

## Introduction

Resin composite materials are the most common choice for direct restorations [1], and they have gained popularity owing to improvements in material properties [2]. These materials undergo curing via addition polymerization activated by visible light [3]. Incomplete polymerization can cause

fractures, reduced bonding strength, sensitivity, and color changes [4]. The performance of resin composites is influenced by the quality of light-curing units (LCUs) [5]. Effective radiant exitance enhances the performance and longevity of resin composites.

The radiant power of LCUs measures light intensity for curing resin-based composites, expressed in mW/cm<sup>2</sup>. Effective polymerization in dental restorations requires adequate power, categorized as inadequate ( $< 400$  mW/cm<sup>2</sup>), marginal (400–850 mW/cm<sup>2</sup>), and sufficient ( $> 850$  mW/cm<sup>2</sup>) [6]. Current restorative resins need at least 400 mW/cm<sup>2</sup> for 20 s as curing time at a thickness of 2 mm or less for optimal properties [7]. LCUs use various light sources, including plasma arc, quartz tungsten halogen, argon-ion laser, and light-emitting diode (LED), with LED units favored for their efficiency and long lifespan [7].

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Introduced in the 1990s, LED technology has established itself as the standard for dental curing lights. Modern units offer radiant exitance between 1000 and 2400 mW/cm<sup>2</sup>, making them reliable for polymerization [8]. Most of the used LCUs are LED curing units [6].

Dental radiometers are specialized devices designed to measure the radiant exitance of LCUs. These tools convert light into electrical energy, typically using silicon photodiodes that transform light into electrical current. The productivity from the curing light is then displayed on an analog or digital meter [9]. Dental radiometers are employed to measure the radiant exitance at the curing units' nozzles in mW/cm<sup>2</sup> to ensure accurate radiant exitance. Regular monitoring of LCUs is essential to track any changes in radiant exitance over the period, providing optimal light curing [10].

Previous studies have indicated that dental radiometers struggle to accurately measure light output from dental LCUs. Price *et al.* [11] found that the form and category of curing light significantly affect radiometer accuracy, with notable variability in irradiance readings between different brands and even among samples of the same brand. Shimokawa *et al.* [9] reported that measurements can be influenced by the actual tip width, light beam shape, and emission spectrum of the LCUs.

Other studies have evaluated the effectiveness and radiant exitance of different LCUs in dental centers worldwide, considering factors like age, nozzle condition, and maintenance. In Jordan, many units have radiant exitance below 300 mW/cm<sup>2</sup>, and small changes in tip diameter can significantly affect irradiance, leading to different power outputs despite similar irradiance levels [12]. In Bulgaria, a correlation was found between the duration of practice and radiant power, with many units producing less than the necessary 400 mW/cm<sup>2</sup>, rendering them impractical [4]. A study in Qazvin, Iran showed that LED units have significantly higher average light intensities (over 300 mW/cm<sup>2</sup>) than those below this threshold. The age of LCUs negatively affects light intensity, with older devices showing decreased output [13].

Studies have shown that the effectiveness of LCUs differs between governmental and private dental centers because of factors like age and maintenance. In governmental clinics, most LED units provide adequate radiant power for curing resin-based composites, but performance declines with age. Damaged or unclean tips significantly reduce light intensity output, risking restoration failure [6]. In private clinics, notable variability was observed in light intensity among 95 LCUs; although many were acceptable, some displayed significant reductions that weakened cured resins [13]. Regular maintenance, including replacing aging components, can boost light intensity output by up to 322.7%. Some dental practitioners' lack of awareness about LCU performance can lead to inadequate curing, compromising restoration longevity and effectiveness [13].

No previous study has investigated the efficiency of radiant power of different light curing brands with different age and tip conditions used in private and governmental dental centers in the Aseer region, south of Saudi Arabia (SA). The current study examined the radiant power of LCUs by using three brands of radiometers. This evaluation considered several factors, including the type of clinic, LCU type, age, tip condition, tip diameter, and the presence of residual bonding material or composite on the LCU tips in the Aseer region. The null hypothesis proposed no significant differences in the recorded radiant power among the three radiometer brands, regardless of the LCU type, age, tip condition, tip diameter, presence of residual bonding or composite material, or clinic type.

## Materials and Methods

### Study Design and Sample Calculation

A cross-sectional descriptive study was conducted using a non-probability sampling method. The collected LCUs from a mix of governmental and private dental clinics at Aseer, SA, were assessed for radiant power values. The sample size was calculated using the G\*Power software program (version 3.1.9.2, Heinrich Heine University Düsseldorf, Düsseldorf, Germany) with the following inputs: two-tailed significance level, type I error ( $\alpha$ -error) of 5%, study power ( $\beta$ -error) of 95% and effect size of 0.5. Thus, a total of 120 LCUs were required for the study. This number was increased by 25% for the possibility of attrition. Therefore, the final required sample size was 132 LCUs. Ethics exempted by the institutional ethics committee.

### Selection Criteria of the Assessed Devices

This study included dental centers that agreed to participate. Functional LED LCUs available in eight dental centers—six private and two governmental—were assessed during the study period, which occurred between July and August 2024. Inactive or nonfunctional LCUs undergoing maintenance were omitted from this cross-sectional study.

### Radiometer Adjusting

Three radiometers were utilized in this study: the Woodpecker LM-1 (Woodpecker, Changsha, China), the Ivoclar Bluephase Meter II (Ivoclar Vivadent, Schaan, Liechtenstein), and the Rogin TQ8 (Rogin Dental, Guangzhou, China). The Woodpecker LM-1 and the Ivoclar Bluephase Meter II were powered on by introducing and adjusting their respective batteries, whereas the Rogin TQ8 was powered on by plugging it into an electrical outlet. The Woodpecker LM-1 was activated by pressing the power button on the device's side. By contrast, the Ivoclar and Rogin radiometers were equipped with sensors that automatically provided readings when exposed to light of the LCU. Notably, the Ivoclar radiometer required adjustments on the basis of the tip diameter of the LCU being measured. Accordingly, the

**Table 1. Details of the radiometers and LCU devices.**

| Device     | Brand             | Manufacturer                                                         |
|------------|-------------------|----------------------------------------------------------------------|
| Radiometer | Woodpecker        | Woodpecker LM-1 (Woodpecker, Changsha, China)                        |
|            | Ivoclar Vivadent  | Ivoclar Bluephase Meter II (Ivoclar Vivadent, Schaan, Liechtenstein) |
|            | Rogin             | Rogin TQ8 (Rogin Dental, Guangzhou, China)                           |
| LCUs       | Acteon Mini LED   | (Acteon Mini LED, Acteon, Merignac, France)                          |
|            | 3M                | (3M, St. Paul, MN, USA)                                              |
|            | Woodpecker        | (Woodpecker, Changsha, China)                                        |
|            | Ivoclar Vivadent  | (Ivoclar Vivadent, Schaan, Liechtenstein)                            |
|            | Ortholux Luminous | (Ortholux Luminous, St. Paul, MN, USA)                               |
|            | Eighteeth         | (Eighteeth, Nanjing, China)                                          |

LCU, light-curing unit; LED, light-emitting diode.

radiometer's tip diameter setting was adjusted to match the measured LCUs.

#### *Radiant Power Measurement*

The LCUs of the agreed centers were collected, and the curing mode was selected from a list of available curing programs, opting for an average constant setting with the highest light output. The curing time was set to 20 s by using the time adjustment button to ensure capturing the full light intensity output, preparing the LCU for use. The radiometers were placed on a flat surface to begin the measurement. The LCU tips were positioned at a 0 mm distance directly over the center of the detector window. Care was taken to ensure the tip remained in contact with the detector surface at a 90° angle.

Radiant power was then recorded in mW/cm<sup>2</sup>, with instant readings displayed. The luminous power was presented as a digital number on the display for the Woodpecker and Ivoclar radiometers. The Rogin radiometer, however, indicated readings by using a red marker at one of the preset numbers (1000, 1200, 1600, or 2000). Each reading was repeated three times, and the average was recorded as the mean reading. A single researcher collected all data to eliminate errors caused by inter-operator variability. All measurements adhered strictly to the manufacturer's instructions, including the power switch, mode selection button, time adjustment button, and the proper switching on and off of the devices. Radiometers were checked periodically against the light sources to ensure consistency and equipped with new batteries after every 20 measurements (20 × 3 for each LCU).

#### *Assessed Parameter*

The assessed and measured parameters in this study included the type of clinic, categorized as governmental or private, and the type of LCU, which included Acteon Mini LED, 3M, Woodpecker, Ivoclar Vivadent, Ortholux Luminous, and Eighteeth models. The clinical age of the LCUs was documented in three categories: <1, between 1 and 3, and >3 years. The condition of the LCU tip was evaluated and classified as either damaged or intact. The presence of residual bonding material or composite on the

LCU tips was visually assessed using a magnification lens (×10) and recorded as either present or absent. Finally, the LCU tip diameters were measured and categorized into three size ranges: 6–7, 8–9, and 10 mm. All parameters were classified in accordance with previous studies, with some modifications [4,6,9,12–14]. Each reading on the assessed LCU brands and their radiant power values recorded by the three radiometers (Woodpecker, Ivoclar, and Rogin) was repeated three times. Subsequently, the average was recorded as the mean reading used in the statistical part. Table 1 shows the details of the radiometers and LCUs.

#### *Data Collection*

The recorded radiant power values were characterized into three groups of reading and classified as “adequate intensity that can be compensated even by increasing the light curing time”, “sufficient intensity at which extra curing was needed”, and “adequate and sufficient intensity where further curing time was not necessary” and represented as ≤1000, between 1000 and 1200, and >1200 mW/cm<sup>2</sup>, respectively [4,6,9,12–14]. For the LCUs, the abovementioned data were recorded for each brand, which are usually utilized throughout day-to-day practice in the surveyed and nominated dental centers and used by dental professionals for composite resin curing.

#### *Statistical Analysis*

Statistical Package for Social Science (SPSS) version 26.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The Shapiro-Wilk test was used to assess the normality of continuous variables, and the results showed no significant deviation from a normal distribution ( $p \geq 0.05$ ). However, the mean and standard deviation were calculated to describe radiant power values (mW/cm<sup>2</sup>). Frequency and percentage were used to describe categorical variables. Independent *t*-test was used to compare the mean of radiant power values and determine the significant difference between two groups. One-way Analysis of Variance (ANOVA) was used to compare the mean radiant power values and test the significance difference between three or more groups. Statistical significance was set at  $p < 0.05$ .

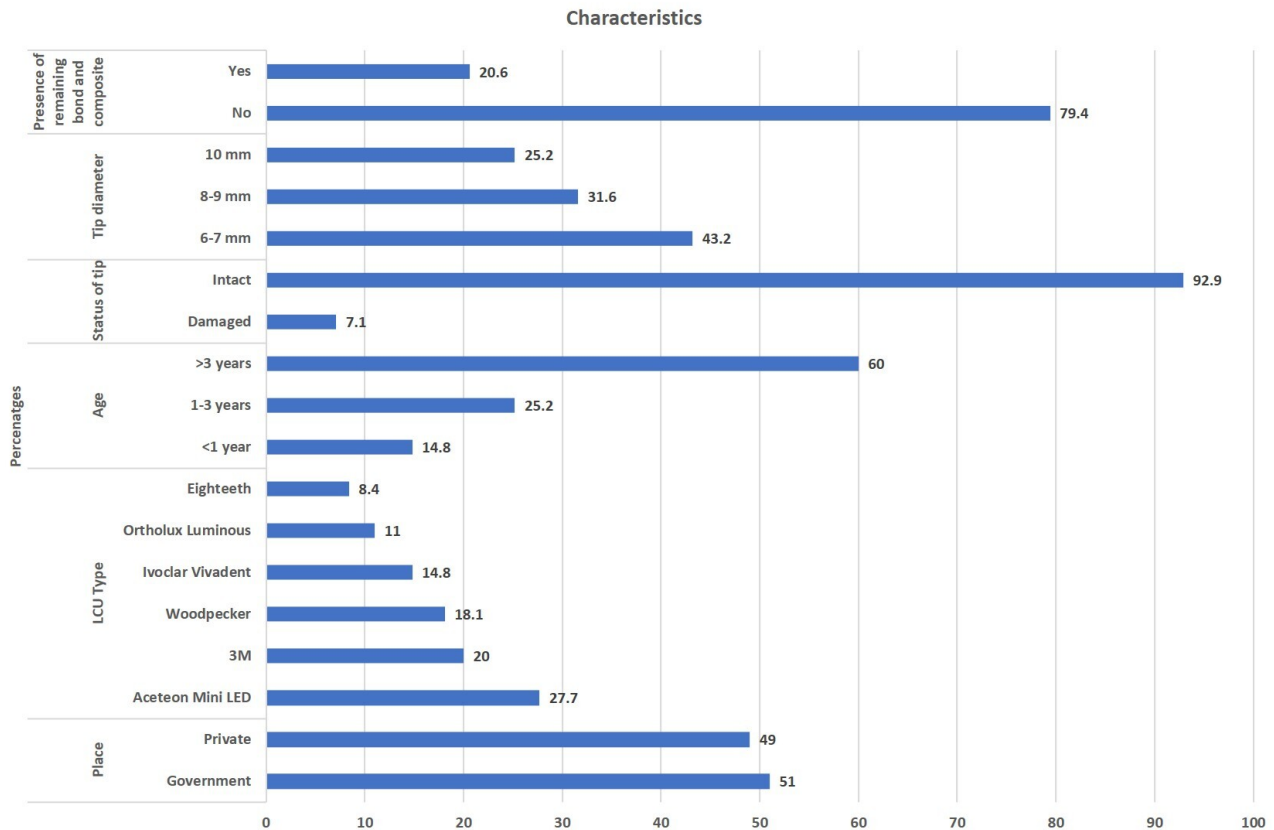


Fig. 1. Distribution of LCUs by clinic, type, age, status of tip, tip diameter, and presence of remaining bond and composite.

## Results

### Devices' Characteristics

Details of the radiometer and LCU used in this study are summarized in Table 1. A total of 132 LCUs were tested in this study, where governmental dental centers (51.0%) were slightly higher than private centers. Acetoon Mini LED was the most common type of LCU (27.7%), followed by 3M (20.0%) and Woodpecker (18.1%). The common LCUs were used for over 3 years (60.0%), with intact tips (92.9%). The most common tip diameter of LCUs was 6–7 mm (43.2%), and the majority of LCUs (79.4%) did not have residual bonding material or composite on the tip (Fig. 1).

The LCU brand used by most governmental dental clinics was Acetoon Mini LED (100.0%), followed by Woodpecker, 3M, and Ortholux Luminous (57.1%, 41.9%, and 41.2%, respectively). By contrast, the LCU brands used by most private dental clinics were Ivoclar Vivadent and Eighteenth (100.0%), followed by Ortholux Luminous, 3M, and Woodpecker (58.8%, 58.1%, and 42.9%, respectively). Ivoclar Vivadent LCU was the most common brand aged less than 1 year old (78.3%), whereas Eighteenth was the most common LCU brand aged 1–3 years (76.9%). Acetoon Mini LED was the most common LCU brand over 3 years old (100.0%), as shown in Fig. 2.

The Ivoclar Vivadent and Eighteenth LCU types had intact tips (100.0%), followed by 3M, Acetoon Mini LED, and Woodpecker (96.8%, 93.0%, and 92.9%, respectively). In terms of the highest proportion of LCU brands with a large tip diameter, Ivoclar Vivadent had 10 mm at 100.0%, Eighteenth had 8–9 mm at 92.3%, and Woodpecker had the most minor tip diameter (6–7 mm) at 89.3%. The most common LCU brand that have remaining bond or composite was Ivoclar Vivadent (78.3%), followed by Eighteenth (76.9%, Fig. 2).

The mean  $\pm$  SD of the radiant power values ( $\text{mW}/\text{cm}^2$ ) of 3M and Ivoclar Vivadent LCUs, as measured by different radiometers, indicated that Woodpecker exhibited the highest values ( $1319.2 \pm 143.4$  and  $1504.0 \pm 150.1$ ) among Ivoclar ( $1172.2 \pm 103.1$  and  $1216.3 \pm 63.9$ ) and Rogin ( $1129.0 \pm 97.3$  and  $1200.0 \pm 0.0$ ). The mean  $\pm$  SD of the radiant power of Eighteenth LCUs measured by Rogin was the highest ( $1282.1 \pm 361.2$ ) among those measured by Woodpecker ( $1195.5 \pm 368.5$ ) and Ivoclar ( $934.4 \pm 847.4$ ), as shown in Fig. 3.

The mean  $\pm$  SD of the radiant power values of Ortholux Luminous LCUs measured by Woodpecker was the highest ( $1257.8 \pm 304.0$ ) among those measured by Ivoclar ( $1177.5 \pm 351.2$ ) and Rogin ( $1145.1 \pm 85.7$ ). The mean  $\pm$  SD of the radiant power values of Acetoon Mini LED and Woodpecker LCUs measured by Ivoclar was the highest ( $1660.8$

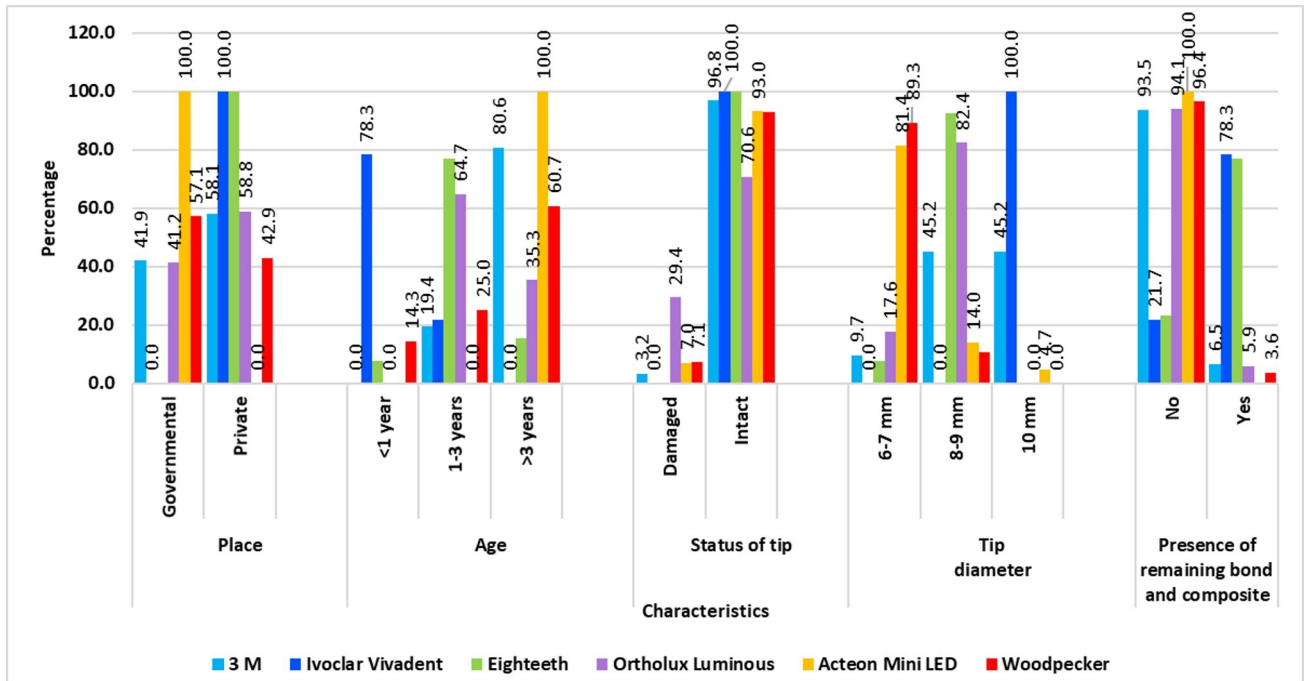


Fig. 2. Distribution of LCU types according to clinic type, age, status of tip, tip diameter, and presence of remaining bond and composite.

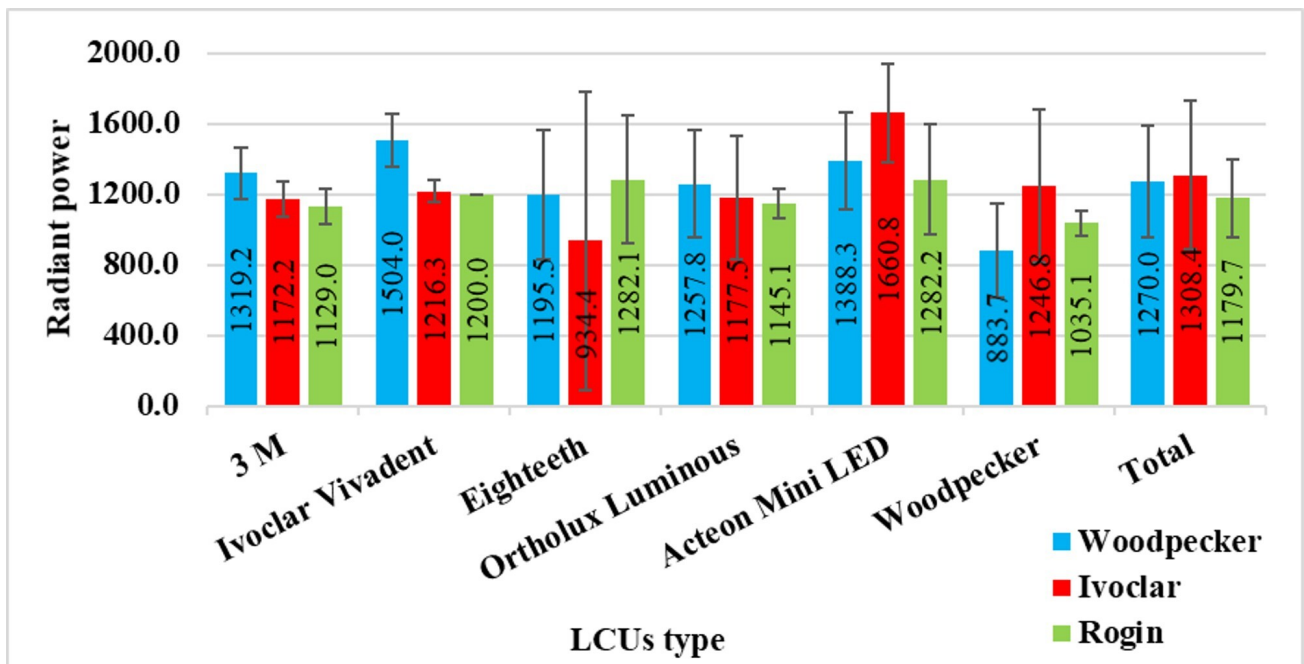


Fig. 3. Mean  $\pm$  SD of radiant power values ( $\text{mW}/\text{cm}^2$ ) by type of LCUs and radiometer brands.

$\pm 279.5$  and  $1246.8 \pm 429.7$ ) among those measured by Woodpecker ( $1388.3 \pm 277.7$  and  $883.7 \pm 266.3$ ) and Rogin ( $1282.2 \pm 314.3$  and  $1035.1 \pm 70.0$ ), as shown in Fig. 3. Regarding the radiant power category of  $\leq 1000 \text{ mW}/\text{cm}^2$ , the mean  $\pm$  SD of the radiant power values measured by Ivoclar in governmental clinics was significantly higher ( $936.67 \pm 53.61$ ) than that in private dental clinics ( $621.00 \pm 168.27$ ,  $p < 0.0001$ ). A value of  $315.67$  was the mean

difference between governmental and private dental clinics. However, no statistically significant differences were found in the radiant power values measured by Woodpecker ( $p = 0.603$ ) and Rogin among different surveyed dental clinics (Table 2).



**Table 2. Comparison of radiant power values (mW/cm<sup>2</sup>) between and within clinic type and radiometer brands.**

| Radiant power                | Radiometer brand            | Governmental |                    | Private |                    | <i>t</i> | <i>p</i> value <sup>a</sup> |
|------------------------------|-----------------------------|--------------|--------------------|---------|--------------------|----------|-----------------------------|
|                              |                             | N            | mean (± SD)        | N       | mean (± SD)        |          |                             |
| ≤1000 mW/cm <sup>2</sup>     | Woodpecker                  | 18           | 788.89 (± 138.47)  | 19      | 820.18 (± 216.85)  | -0.53    | 0.603                       |
|                              | Ivoclar                     | 7            | 936.67 (± 53.61)   | 20      | 621.00 (± 168.27)  | 7.38     | <0.001*                     |
|                              | Rogin                       | 32           | 1000.00 (± 0.00)   | 21      | 1000.00 (± 0.00)   | NC       | NC                          |
|                              | F                           |              | 40.46              |         | 30.29              |          |                             |
|                              | <i>p</i> value <sup>b</sup> |              | <0.001             |         | <0.001             |          |                             |
| 1001–1200 mW/cm <sup>2</sup> | Woodpecker                  | 11           | 1132.55 (± 75.88)  | 6       | 1146.89 (± 60.53)  | -0.39    | 0.677                       |
|                              | Ivoclar                     | 10           | 1117.00 (± 37.83)  | 28      | 1137.00 (± 64.74)  | -1.18    | 0.245                       |
|                              | Rogin                       | 39           | 1194.44 (± 18.06)  | 50      | 1193.33 (± 20.20)  | 0.273    | 0.785                       |
|                              | F                           |              | 22.98              |         | 16.08              |          |                             |
|                              | <i>p</i> value <sup>b</sup> |              | <0.001*            |         | <0.001*            |          |                             |
| >1200 mW/cm <sup>2</sup>     | Woodpecker                  | 50           | 1448.17 (± 161.46) | 51      | 1476.92 (± 138.33) | -0.96    | 0.339                       |
|                              | Ivoclar                     | 62           | 1623.44 (± 247.18) | 28      | 1434.05 (± 429.62) | 2.17     | 0.036*                      |
|                              | Rogin                       | 8            | 1883 (± 218.94)    | 5       | 1706.67 (± 146.06) | 1.74     | 0.109                       |
|                              | F                           |              | 18.66              |         | 2.12               |          |                             |
|                              | <i>p</i> value <sup>b</sup> |              | <0.001*            |         | 0.127              |          |                             |

<sup>a</sup> Independent *t* test; <sup>b</sup> one-way Analysis of Variance (ANOVA); \* significant at *p* < 0.05; NC, not calculated.

**Table 3. Comparison of radiant power values (mW/cm<sup>2</sup>) between and within LCU age and radiometer brands.**

| Radiant power                | Radiometer brand            | <1 year |                    | 1–3 years |                    | >3 years |                    | F     | <i>p</i> value <sup>a</sup> |
|------------------------------|-----------------------------|---------|--------------------|-----------|--------------------|----------|--------------------|-------|-----------------------------|
|                              |                             | N       | mean (± SD)        | N         | mean (± SD)        | N        | mean (± SD)        |       |                             |
| ≤1000 mW/cm <sup>2</sup>     | Woodpecker                  | 4       | 931.25 (± 65.40)   | 16        | 789.06 (± 226.81)  | 17       | 790.20 (± 142.62)  | 1.09  | 0.346                       |
|                              | Ivoclar                     | 1       | 880.00 (NC)        | 19        | 606.67 (± 159.55)  | 7        | 938.57 (± 54.12)   | 15.03 | 0.001*                      |
|                              | Rogin                       | 3       | 1000.00 (± 0.00)   | 15        | 1000.00 (± 0.00)   | 35       | 1000.00 (± 0.00)   | NC    | NC                          |
|                              | F                           |         | 2.69               |           | 24.79              |          | 41.13              |       |                             |
|                              | <i>p</i> value <sup>a</sup> |         | 0.161              |           | <0.001             |          | <0.001             |       |                             |
| 1001–1200 mW/cm <sup>2</sup> | Woodpecker                  | 3       | 1192.56 (± 1.54)   | 1         | 1100.00 (NC)       | 13       | 1127.82 (± 73.59)  | 1.26  | 0.313                       |
|                              | Ivoclar                     | 10      | 1150.67 (± 59.79)  | 11        | 1114.70 (± 77.53)  | 17       | 1132.16 (± 43.32)  | 0.97  | 0.389                       |
|                              | Rogin                       | 20      | 1193.33 (± 20.52)  | 21        | 1187.30 (± 26.82)  | 48       | 1196.88 (± 13.60)  | 1.86  | 0.162                       |
|                              | F                           |         | 4.71               |           | 8.42               |          | 29.66              |       |                             |
|                              | <i>p</i> value <sup>a</sup> |         | 0.017              |           | 0.001              |          | <0.001             |       |                             |
| >1200 mW/cm <sup>2</sup>     | Woodpecker                  | 16      | 1518.23 (± 130.39) | 22        | 1454.55 (± 113.82) | 63       | 1451.42 (± 164.08) | 1.31  | 0.274                       |
|                              | Ivoclar                     | 12      | 1278.89 (± 110.41) | 9         | 1409.26 (± 297.78) | 69       | 1634.44 (± 321.43) | 8.47  | <0.001*                     |
|                              | Rogin                       | 0       | NC                 | 3         | 1600.00 (± 0.00)   | 10       | 1880.00 (± 193.22) | 5.92  | 0.033*                      |
|                              | F                           |         | 26.24              |           | 1.29               |          | 16.41              |       |                             |
|                              | <i>p</i> value <sup>a</sup> |         | <0.001*            |           | 0.289              |          | <0.001*            |       |                             |

<sup>a</sup> One-way ANOVA; \* significant at *p* < 0.05.

**Table 4. Comparison of radiant power values (mW/cm<sup>2</sup>) between and within LCU type and radiometer brands.**

| Radiant power                | Radiometer brand     | 3 M |                   | Ivoclar Vivadent |                    | Eighteenth |                    | Ortholux Luminous |                    | Acteon Mini LED |                    | Woodpecker |                    | F     | p value <sup>a</sup> |
|------------------------------|----------------------|-----|-------------------|------------------|--------------------|------------|--------------------|-------------------|--------------------|-----------------|--------------------|------------|--------------------|-------|----------------------|
|                              |                      | N   | mean (± SD)       | N                | mean (± SD)        | N          | mean (± SD)        | N                 | mean (± SD)        | N               | mean (± SD)        | N          | mean (± SD)        |       |                      |
| ≤1000 mW/cm <sup>2</sup>     | Woodpecker           | 0   | NC                | 0                | NC                 | 8          | 930.21 (± 36.71)   | 3                 | 666.67 (± 217.94)  | 5               | 831.67 (± 181.08)  | 21         | 770.63 (± 191.66)  | 2.39  | 0.086                |
|                              | Ivoclar              | 2   | 918.33 (± 54.21)  | 0                | NC                 | 10         | 538.33 (± 104.82)  | 5                 | 704.00 (± 134.85)  | 2               | 863.33 (± 0.00)    | 8          | 813.75 (± 234.18)  | 5.05  | 0.005*               |
|                              | Rogin                | 11  | 1000.00 (± 0.00)  | 0                | NC                 | 7          | 1000.00 (± 0.00)   | 4                 | 1000.00 (± 0.00)   | 9               | 1000.00 (± 0.00)   | 22         | 1000.00 (± 0.00)   | NC    | NC                   |
|                              | F                    |     | 42.24             |                  |                    |            | 111.60             |                   | 6.94               |                 | 5.02               |            | 12.92              |       |                      |
|                              | p value <sup>a</sup> |     | <0.0001*          |                  | NC                 |            | <0.001*            |                   | 0.015*             |                 | 0.024*             |            | <0.001*            |       |                      |
| 1001–1200 mW/cm <sup>2</sup> | Woodpecker           | 8   | 1124.58 (± 70.71) | 2                | 1191.67 (± 0.00)   | 0          | NC                 | 0                 | NC                 | 4               | 1160.00 (± 67.80)  | 3          | 1106.44 (± 88.85)  | 0.81  | 0.509                |
|                              | Ivoclar              | 15  | 1127.56 (± 55.23) | 10               | 1174.17 (± 26.14)  | 1          | 1183.33 (NA)       | 2                 | 1183.33 (± 0.00)   | 3               | 1135.56 (± 21.17)  | 7          | 1057.62 (± 49.32)  | 6.44  | <0.001*              |
|                              | Rogin                | 20  | 1200.00 (± 0.00)  | 23               | 1200.00 (± 0.00)   | 1          | 1133.33 (NA)       | 13                | 1189.74 (± 25.04)  | 26              | 1194.87 (± 18.12)  | 6          | 1163.89 (± 34.02)  | 8.42  | <0.001*              |
|                              | F                    |     | 14.87             |                  | 12.09              |            | NC                 |                   | 0.12               |                 | 8.10               |            | 6.55               |       |                      |
|                              | p value <sup>a</sup> |     | <0.0001*          |                  | 0.0001*            |            | NC                 |                   | 0.731              |                 | 0.002*             |            | 0.011*             |       |                      |
| >1200 mW/cm <sup>2</sup>     | Woodpecker           | 23  | 1386.87 (± 88.85) | 21               | 1533.73 (± 118.77) | 5          | 1620.00 (± 197.70) | 14                | 1384.52 (± 92.33)  | 34              | 1497.06 (± 168.15) | 4          | 1310.42 (± 78.87)  | 6.58  | <0.001*              |
|                              | Ivoclar              | 14  | 1256.19 (± 34.83) | 13               | 1248.72 (± 66.03)  | 2          | 2790.00 (± 0.00)   | 10                | 1413.00 (± 158.23) | 38              | 1744.21 (± 157.37) | 13         | 1615.13 (± 298.85) | 52.43 | <0.001*              |
|                              | Rogin                | 0   | NC                | 0                | NC                 | 5          | 1706.67 (± 146.06) | 0                 | NC                 | 8               | 1883.33 (± 218.94) | 0          | NC                 | 2.51  | 0.141                |
|                              | F                    |     | 27.45             |                  | 62.40              |            | 39.74              |                   | 0.31               |                 | 27.61              |            | 3.90               |       |                      |
|                              | p value <sup>a</sup> |     | <0.001*           |                  | <0.001*            |            | <0.001*            |                   | 0.584              |                 | <0.001*            |            | 0.067              |       |                      |

<sup>a</sup> One-way ANOVA; \* significant at  $p < 0.05$ . NA, not applicable.

**Table 5. Comparison of radiant power values (mW/cm<sup>2</sup>) between and within LCU's status of tip and radiometer brands.**

| Radiant power                | Radiometer brand            | Damaged |                   | Intact |                    | <i>t</i> | <i>p</i> value <sup>a</sup> |
|------------------------------|-----------------------------|---------|-------------------|--------|--------------------|----------|-----------------------------|
|                              |                             | N       | mean (± SD)       | N      | mean (± SD)        |          |                             |
| ≤1000 mW/cm <sup>2</sup>     | Woodpecker                  | 8       | 768.75 (± 244.17) | 29     | 814.94 (± 163.94)  | -0.50    | 0.626                       |
|                              | Ivoclar                     | 3       | 685.00 (± 232.05) | 24     | 705.00 (± 204.64)  | -0.13    | 0.901                       |
|                              | Rogin                       | 8       | 1000.00 (± 0.00)  | 45     | 1000.00 (± 0.00)   | NC       | NC                          |
|                              | F                           |         | 4.78              |        | 41.59              |          |                             |
|                              | <i>p</i> value <sup>b</sup> |         | 0.024             |        | <0.001             |          |                             |
| 1001–1200 mW/cm <sup>2</sup> | Woodpecker                  | 0       | NC                | 17     | 1137.61 (± 69.24)  | NC       | NC                          |
|                              | Ivoclar                     | 4       | 1116.67 (± 81.65) | 34     | 1133.77 (± 57.22)  | -0.40    | 0.708                       |
|                              | Rogin                       | 3       | 1155.56 (± 38.49) | 86     | 1195.16 (± 17.12)  | -1.77    | 0.216                       |
|                              | F                           |         | 0.56              |        | 37.00              |          |                             |
|                              | <i>p</i> value <sup>b</sup> |         | 0.486             |        | <0.001             |          |                             |
| >1200 mW/cm <sup>2</sup>     | Woodpecker                  | 3       | 1291.67 (± 57.74) | 98     | 1467.92 (± 149.15) | -4.81    | 0.018*                      |
|                              | Ivoclar                     | 4       | 1508.33 (± 293.9) | 86     | 1567.13 (± 327.76) | -0.39    | 0.719                       |
|                              | Rogin                       | 0       | NC                | 13     | 1815.38 (± 207.55) | NC       | NC                          |
|                              | F                           |         | 1.52              |        | 12.74              |          |                             |
|                              | <i>p</i> value <sup>b</sup> |         | 0.272             |        | <0.001*            |          |                             |

<sup>a</sup> Independent *t* test; <sup>b</sup> one-way ANOVA; \* significant at *p* < 0.05.

Concerning the radiant power category of 1001–1200 mW/cm<sup>2</sup>, no statistically significant differences were observed in the radiant power values for any radiometers between governmental and private clinics (all *p* > 0.05). For the category of >1200 mW/cm<sup>2</sup>, the mean ± SD of the radiant power values measured by Ivoclar in governmental dental clinics was significantly higher (1623.44 ± 247.18) than that in private dental clinics (1434.05 ± 429.62, *p* = 0.0363), with a mean difference of 189.39. However, no statistically significant differences were observed in the radiant power values measured by Woodpecker and Rogin between governmental and private dental clinics (*p* = 0.339 and = 0.109, respectively, Table 2).

For the ≤1000 mW/cm<sup>2</sup> category, the mean of the radiant power values measured by Ivoclar in age >3 years was significantly higher (938.57) than that in age <1 year (880.00) and 1–3 years (606.67), with *p* = 0.001. However, no statistically significant differences were found in the radiant power values measured by Woodpecker and Rogin between age groups (*p* > 0.05, Table 3). Concerning the radiant power category of 1001–1200 mW/cm<sup>2</sup>, no statistically significant differences were observed in the radiant power values for any radiometers between age groups (all *p* > 0.05). For the >1200 mW/cm<sup>2</sup> category, statistically significant differences were found in the radiant power values measured by Ivoclar and Rogin between age groups (*p* < 0.001 and = 0.033, respectively). In terms of age groups, Rogin had significantly increased radiant power values in age <1 year for the 1001–1200 mW/cm<sup>2</sup> category (*p* = 0.017), in age 1–3 years for the ≤1000 and 1001–1200 mW/cm<sup>2</sup> categories (*p* < 0.001 and < 0.001, respectively), and in age >3 years for all categories (all *p* < 0.001, Table 3).

For the ≤1000 mW/cm<sup>2</sup> category, the radiant power value of 3M measured by Ivoclar was significantly higher than

those of the other LCU brands (*p* = 0.005). For the 1001–1200 mW/cm<sup>2</sup> category, the radiant power values of Eighteeth and Ortholux Luminous measured by Ivoclar were significantly higher than those of the other LCU brands (*p* < 0.001). Similarly, the radiant power values of 3M and Ivoclar Vivadent measured by Rogin were significantly higher than those of the other LCU brands (*p* < 0.001, Table 4).

For the >1200 mW/cm<sup>2</sup> category, the radiant power values of Eighteeth measured by Woodpecker and Ivoclar were significantly higher than those of the other LCU brands (*p* < 0.001). Among LCU types, Rogin exhibited significantly increased radiant power values of 3M, Eighteeth, Ortholux Luminous, Acteon Mini LED, and Woodpecker for the ≤1000 mW/cm<sup>2</sup> category (*p* < 0.0001, < 0.001, = 0.015, = 0.024, and < 0.001, respectively); 3M, Ivoclar Vivadent, Acteon Mini LED, and Woodpecker for the 1001–1200 mW/cm<sup>2</sup> categories (*p* < 0.0001, = 0.0001, = 0.002, and = 0.011, respectively); and 3M, Ivoclar Vivadent, Eighteeth, and Acteon Mini LED for the >1200 mW/cm<sup>2</sup> category (all *p* < 0.001, Table 4).

A significant difference was found between damaged and intact tips only for Woodpecker in the >1200 mW/cm<sup>2</sup> category, with intact tips showing high radiant value (Table 5). Concerning the status of the tip, Rogin had significantly high radiant power values of LCUs with an intact tip for all radiant power categories (all *p* < 0.001).

Statistically significant differences were observed in the radiant power values of tip diameters between Woodpecker and Ivoclar for the ≤1000 (*p* = 0.005 and = 0.003, respectively) and >1200 mW/cm<sup>2</sup> categories (*p* = 0.021 and < 0.001, respectively, Table 6). Statistically significant differences were also found in the radiant power values of tip diameters between Ivoclar and Rogin for the 1001–



**Table 6. Comparison of radiant power values (mW/cm<sup>2</sup>) between and within LCU tip diameter and radiometer brand.**

| Radiant power                | Radiometer brand     | 6–7 mm |                    | 8–9 mm |                    | 10 mm |                    | F     | p value <sup>a</sup> |
|------------------------------|----------------------|--------|--------------------|--------|--------------------|-------|--------------------|-------|----------------------|
|                              |                      | N      | mean (± SD)        | N      | mean (± SD)        | N     | mean (± SD)        |       |                      |
| ≤1000 mW/cm <sup>2</sup>     | Woodpecker           | 26     | 752.88 (± 192.14)  | 11     | 928.03 (± 46.29)   | 0     | NC                 | 8.78  | 0.005*               |
|                              | Ivoclar              | 11     | 810.91 (± 209.44)  | 14     | 587.14 (± 130.55)  | 2     | 918.33 (± 54.21)   | 7.39  | 0.003*               |
|                              | Rogin                | 32     | 1000.00 (± 0.00)   | 19     | 1000.00 (± 0.00)   | 2     | 1000.00 (± 0.00)   | NC    | NC                   |
|                              | F                    |        | 22.60              |        | 123.32             |       | 4.53               |       |                      |
|                              | p value <sup>a</sup> |        | <0.001*            |        | <0.001*            |       | 0.167              |       |                      |
| 1001–1200 mW/cm <sup>2</sup> | Woodpecker           | 7      | 1116.95 (± 78.11)  | 6      | 1147.89 (± 76.24)  | 4     | 1158.33 (± 43.57)  | 0.52  | 0.603                |
|                              | Ivoclar              | 8      | 1090.42 (± 59.40)  | 12     | 1121.67 (± 47.85)  | 18    | 1157.31 (± 55.60)  | 4.55  | 0.017*               |
|                              | Rogin                | 32     | 1189.06 (± 24.54)  | 22     | 1190.91 (± 23.42)  | 35    | 1200.00 (± 0.00)   | 3.20  | 0.046*               |
|                              | F                    |        | 21.62              |        | 10.96              |       | 11.31              |       |                      |
|                              | p value <sup>a</sup> |        | <0.001*            |        | <0.001*            |       | 0.001*             |       |                      |
| >1200 mW/cm <sup>2</sup>     | Woodpecker           | 34     | 1428.68 (± 123.16) | 32     | 1437.18 (± 175.54) | 35    | 1519.05 (± 135.89) | 4.03  | 0.021*               |
|                              | Ivoclar              | 48     | 1713.13 (± 276.51) | 23     | 1464.93 (± 350.85) | 19    | 1309.65 (± 179.24) | 15.95 | <0.001*              |
|                              | Rogin                | 3      | 1644.44 (± 203.67) | 8      | 1833.33 (± 198.41) | 2     | 2000.00 (± 0.00)   | 2.21  | 0.160                |
|                              | F                    |        | 15.87              |        | 7.95               |       | 24.89              |       |                      |
|                              | p value <sup>a</sup> |        | <0.001*            |        | <0.001*            |       | <0.001*            |       |                      |

<sup>a</sup> One-way ANOVA; \* significant at  $p < 0.05$ .

1200 mW/cm<sup>2</sup> category ( $p = 0.017$  and  $= 0.046$ , respectively). Rogin had significantly increased radiant power values of LCUs within tip diameter categories for all radiant power categories (all  $p < 0.001$ ), except within 10 mm for ≤1000 mW/cm<sup>2</sup> ( $p = 0.167$ ), and within 6–7 mm for >1200 mW/cm<sup>2</sup>, Ivoclar had significantly increased radiant power values of LCUs ( $p < 0.001$ ).

Statistically significant differences were observed in the radiant power values between the presence and absence of remaining bond and composite for Woodpecker and Ivoclar under the ≤1000 mW/cm<sup>2</sup> category ( $p = 0.004$  and  $= 0.013$ , respectively), for Woodpecker under the 1001–1200 mW/cm<sup>2</sup> category ( $p = 0.004$ ), and for Ivoclar and Rogin under the >1200 mW/cm<sup>2</sup> category ( $p < 0.001$  and  $< 0.001$ , respectively). Within tip diameters, Rogin had significantly increased radiant power values of LCUs in the presence of remaining bond and composite for all radiant power categories (all  $p < 0.05$ , Table 7).

## Discussion

Poor curing outcomes are caused by several negative factors that can ultimately lead to composite filling failure. Consequently, an ineffective LCU may be a vital causative issue in the definitive failure of permanent restoration [15]. Given the absence of a uniform light curing procedure and practice followed by respondent general dental practitioners in SA, focusing on essential issues about light curing radiant power could progress their knowledge and clinical skills on light-curing resin composites [16]. In addition, low radiant power (below 1000 mW/cm<sup>2</sup>) value as considered in this study, may negatively affect the related dental procedures which end by sub-optimal restoration quality, increased risk of restoration failure, or any other clinically significant outcomes.

The current study assessed and evaluated the LCUs in terms of the radiant power exitance of three brands of radiometers, with consideration on the type of clinic, LCU brand, age of LCUs, statues and diameter of LCU tips, and presence of remaining bond and composite on the top of the LCU prop in Aseer region.

The total radiant power values of six selected brands in governmental and private clinics measured by Woodpecker, Ivoclar, and Rogin were 1270, 1308, and 1179 mW/cm<sup>2</sup>, respectively. By contrast, Hasan *et al.* [6] reported that 21.9%, 52.4%, and 25.6% of LCUs in governmental clinics have outputs below 400, between 400 and 850, and above 850 mW/cm<sup>2</sup>, respectively. Nassar *et al.* [15] found most LCUs in undergraduate areas produced below 600 mW/cm<sup>2</sup>, with many between 900 and 1200 mW/cm<sup>2</sup>. A study in Riyadh showed varied outputs across units. Differences in results across studies are due to measurement techniques, LCU conditions, environmental factors, and usage patterns. Proper maintenance and usage significantly affect LCU performance [17].

Different studies were performed to evaluate the effectiveness and radiant exitance values of different LCUs used in dental clinics and their relation to the type of clinic [15,18,19]. The current study results rejected the first part of the null hypothesis because Ivoclar demonstrated significantly higher radiometer readings in governmental clinics than in private clinics for the ≤1001 and >1200 mW/cm<sup>2</sup> categories. Among different brands, 3M showed significantly higher radiant power in the ≤1000 mW/cm<sup>2</sup> category, whereas Eighteenth and Ortholux Luminous stood out in the 1001–1200 mW/cm<sup>2</sup> range. Eighteenth performed notably well in the >1200 mW/cm<sup>2</sup> category. These findings aligned with those of previous research, indicating variability in LCU performance across different brands [19,20].

**Table 7. Comparison of radiant power values (mW/cm<sup>2</sup>) between and within radiometer type and LCU tip condition.**

| Radiant power                | Radiometer brand            | Yes |                    | No |                    | <i>t</i> | <i>p</i> value <sup>a</sup> |
|------------------------------|-----------------------------|-----|--------------------|----|--------------------|----------|-----------------------------|
|                              |                             | N   | mean (± SD)        | N  | mean (± SD)        |          |                             |
| ≤1000 mW/cm <sup>2</sup>     | Woodpecker                  | 8   | 911.46 (± 68.85)   | 29 | 775.57 (± 192.03)  | 3.14     | 0.004*                      |
|                              | Ivoclar                     | 10  | 585.00 (± 162.39)  | 17 | 772.16 (± 195.89)  | -2.67    | 0.013*                      |
|                              | Rogin                       | 7   | 1000.00 (± 0.00)   | 46 | 1000.00 (± 0.00)   | NC       | NC                          |
|                              | F                           |     | 34.19              |    | 31.66              |          |                             |
|                              | <i>p</i> value <sup>b</sup> |     | <0.001*            |    | <0.001*            |          |                             |
| 1001–1200 mW/cm <sup>2</sup> | Woodpecker                  | 3   | 1192.56 (± 1.54)   | 14 | 1125.83 (± 71.09)  | 3.50     | 0.004*                      |
|                              | Ivoclar                     | 10  | 1148.00 (± 65.13)  | 28 | 1126.25 (± 56.90)  | 0.94     | 0.365                       |
|                              | Rogin                       | 22  | 1193.93 (± 19.62)  | 67 | 1193.93 (± 19.20)  | 0.03     | 0.974                       |
|                              | F                           |     | 5.177              |    | 35.30              |          |                             |
|                              | <i>p</i> value <sup>b</sup> |     | 0.011*             |    | <0.001*            |          |                             |
| >1200 mW/cm <sup>2</sup>     | Woodpecker                  | 21  | 1497.22 (± 123.78) | 80 | 1453.62 (± 155.77) | 1.35     | 0.183                       |
|                              | Ivoclar                     | 12  | 1278.88 (± 110.41) | 78 | 1608.00 (± 325.12) | -6.76    | <0.001*                     |
|                              | Rogin                       | 3   | 1600.00 (± 0.00)   | 10 | 1880.00 (± 193.22) | -4.58    | 0.001*                      |
|                              | F                           |     | 17.05              |    | 16.66              |          |                             |
|                              | <i>p</i> value <sup>b</sup> |     | <0.001*            |    | <0.001*            |          |                             |

<sup>a</sup> Independent *t*-test; <sup>b</sup> one-way ANOVA; \* significant at *p* < 0.05.

Rogin consistently recorded high values for several brands, particularly 3M, Ivoclar Vivadent, and Acteon Mini LED, with all results exhibiting strong statistical significance (*p* < 0.0001), leading to the rejection of the second part of the null hypothesis. Overall, the Rogin radiometer demonstrates high performance across all categories. This may be attributed to its advantages, including a radiant power output ranging from 0 to 1200 within the first 5 seconds, followed by stabilization at its maximum value. It also ensures a uniform and direct spectrum, improved penetrability, and reduced radiant power loss.

This finding aligned with that of Shimokawa *et al.* [9], who noted that different radiometers showed a variation in mean irradiance for the same LCU of up to 479 mW/cm<sup>2</sup>. Price *et al.* [10] reported considerable discrepancies in results among the three radiometer samples from the same brand, complicating the establishment of a definitive ranking for accuracy. Among the radiometers tested by Maucoski *et al.* [21], only the Bluephase Meter II accurately measured the irradiance for 11 of the 12 LCU brands evaluated. Variations in measurements across different radiometers are attributed to radiometer construction, including filters and detectors, affecting performance and calibration. Each radiometer has a specific dynamic range and responsiveness, affecting performance under different light intensities [9].

An inverse relationship exists between the clinical age of LCUs and their light intensity; older devices produce less light [4]. The results of the present study showed that the mean radiant power for LCUs older than 3 years was significantly higher than that of units less than 1 year and those aged 1–3 years in the ≤1000 and >1200 mW/cm<sup>2</sup> categories. This result contradicted the null hypothesis, which suggested no significant differences in light intensity

among the various age groups, this may relate to proper and regular maintenance. Conversely, Hasan *et al.* [6] found higher radiant exitance in LCUs less than 1 year old than those over 5 years (*p* = 0.001). Omid *et al.* [13] confirmed that older units produce lower output, and Georgiev *et al.* [22] noted that 77.5% of LED LCUs used for 10 years fell below the threshold of 400 mW/cm<sup>2</sup>, with degradation varying by model.

Frequent use of LCUs causes damage and contamination of LCUs, significantly lowering light output and overall performance [18,23]. The present study found significant differences between damaged and intact tips for Woodpecker in the >1200 mW/cm<sup>2</sup> category, with intact tips showing high values. Rogin indicated high radiant power for intact tips (all *p* < 0.0001). Hasan *et al.* [6] noted that tip condition significantly affects radiant exitance. Altaie *et al.* [18] reported that 16% of tips were contaminated and 26% were damaged, reducing irradiance output by 62% and 50%, respectively. Conversely, other study did not observe any statistically significant differences, which may be attributed to the age of the LCUs and the thickness of the composite materials used [24].

LCUs typically have tip diameters between 6 and 10 mm, affecting curing efficiency, especially for extensive restorations. A small tip diameter may inadequately cover resin composites, leading to insufficient polymerization. Modern LCUs are utilized for various clinical applications, with many manufacturers offering additional light guide tips in multiple diameters and shapes [25,26]. The present study showed that the diameter of the light guide tip significantly affected the radiant power of LCUs, with 10 mm tips producing higher radiant power than other diameters across all three categories (Table 5). Cardoso *et al.* (2022) [27] found that the type of LCU and its tip diameter significantly af-

fect the degree of conversion of bulk-fill resin composites. Lehmann *et al.* (2024) [28] concluded that light irradiance values at distances of 0 and 2 are around 1000 mW/cm<sup>2</sup>, using a photometer, Bluephase Meter II, and LED LCUs with 8 mm-tip diameter (Woodpecker LED.H, Guilin Woodpecker Medical Instrument Co., Guilin, China). Comparable values were documented in the current study for similar LCU brands.

The results showed that LCUs with intact tips comprised 92.9%, and most LCUs (79.4%) did not have a remaining bond or composite on the tip. However, different results were obtained by Nassar *et al.* [15], who showed that only 23.5% of the units had clean tips. Altaie *et al.* [18] found that the condition of the light curing guides was poor, with only 48% identified to be in good condition. Hasan *et al.* [6] recently found that most LCUs did not have adhesion of composite resin (66.4%), whereas 33.6% of the LCUs had residual fractures. A study conducted in Brazil detected that 90% of the light sources measured at a dental university in Goiânia had breakages and cracks, residual resin composite on the transmitter nozzle, and an adhesive agent on the tip. Regarding the power strength or radiant of the light source, 55% showed a general practitioner lower than 300 mW/cm<sup>2</sup> [29].

In this study, radiant exitance was measured using three brands of digital radiometers: Woodpecker, Rogin, and Ivoclar. These devices are intended for use with LED LCUs, as previously utilized by researchers [18,30] who measured each LCU with the Blue Phase II (BPII) digital radiometer (Ivoclar Vivadent, Amherst, NY), as well as by Georgiev *et al.* (2020) [22] and Hasan *et al.* (2024) [6], who measured Light Intensity Output (LIO) by using a digital radiometer (Woodpecker, China).

Dental radiometers are systems and instruments utilized to assess radiant exitance at their tip in mW/cm<sup>2</sup>, emitted by LCUs that change light into an electronic current, which is calculated via a numerical screen [25,31]. A previous study designated 400–850 mW/cm<sup>2</sup> radiant power range as the borderline intensity [6]. Other studies considered adequate intensities above 850 mW/cm<sup>2</sup> [17,19]. However, the present study categorized radiant power values into three groups: adequate intensity denoted by ≤1000 mW/cm<sup>2</sup>, sufficient intensity between 1000 and 1200 mW/cm<sup>2</sup>, and proper intensity represented by >1200 mW/cm<sup>2</sup>.

The study had several limitations. It focused on LCUs from one city only and did not assess how damage or build-up affects their intensity, leaving the effect of cleaning curing tips uncertain. Additionally, the radiometers used provide relative irradiance measures only and do not account for wavelength, active diameter, or light modes, reflecting maximum output only. Although employing three types of radiometers (Woodpecker, Ivoclar, and Rogin) enhanced reliability, the study lacked details on their calibration and validation, which could have been crucial for accurate readings. Lastly, the clinical age of the LCUs was based on the

reported age, but varying usage and maintenance practices across clinics could affect their actual performance.

Future research should compare the performance of various LCU brands and models under standardized conditions, conduct longitudinal studies to assess durability, and investigate the influence of factors (such as operator technique, ambient light, and environmental conditions) on LCU performance. Additionally, studies could focus on the efficacy of LCUs for specific dental applications to improve understanding of their performance in varied contexts. The imbalance in the government and private clinics (2:6) and the uneven distribution of LCU brands may reflect the characteristics of the specific region and the selected brands, limiting the generalizability of the findings to a broader clinical context. Future studies could benefit from a more diverse and balanced sample to enhance the generalizability of the results.

## Conclusions

Within the selected and examined LCU in this region, the following conclusions can be withdrawn; this study revealed significant differences in the radiant power of LCUs between governmental and private dental clinics, particularly with the Ivoclar radiometer, which showed high mean values in governmental clinics for the ≤1000 and >1200 mW/cm<sup>2</sup> categories.

The Woodpecker and Rogin radiometers did not differ significantly between the clinic types. Old LCUs (>3 years) demonstrated high radiant power in the ≤1000 mW/cm<sup>2</sup> category when measured with the Ivoclar radiometer.

The Rogin radiometer consistently demonstrated increased values across different LCU brands and conditions, especially with intact tips. Differences in radiant power were noted on the basis of tip diameter and the presence of remaining bond and composite materials.

## Availability of Data and Materials

The data analyzed are available from the corresponding authors upon reasonable request.

## Author Contributions

Concept and design: GSA, WHA, SAA. Data collection and/or processing: NNA, NAA, FHA, MAA. Data analysis and/or interpretation: MMA, AAA, VM. Literature review: MMA, VM. Manuscript writing: GSA, VM. Supervision: FHA, MAA, AAA. All authors have been involved in revising it critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

## Ethics Approval and Consent to Participate

Ethics exempted by the King Khalid University College of Dentistry Institutional Review Board.

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## Conflict of Interest

The authors declare no conflict of interest.

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