ORIGINAL ARTICLE

A measurement of irradiance of light-curing units in dental offices in three Croatian cities

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ABSTRACT

Aim To determine irradiance of light-curing units (LCUs) in dental offices in three Croatian cities and to compare irradiance values with the age and model of LCUs.

Methods Private and public dental offices in three most prominent cities in Croatia (Rijeka, Split and Zagreb) were included in this study. In total, 195 LCUs were tested, using radiometer Ivoclar Bluephase Meter 2 for irradiance (mW/cm^2). The minimum acceptable value was set at 400 mW/cm^2. The age, model and difference between declared and measured irradiance of the LCUs were also determined. Of the total of 195 LCUs, 190 (98%) were LED (light-emitting diode) and 5 (2%) were QTH (quartz-tungsten – halogen).

Results The mean age of tested LCUs was 4.43±3.4 years; the oldest was in Rijeka, 5.2±3.8 years. The overall mean irradiance for all three cities was 806.4 mW/cm^2 (p=0.0004). Of all LCUs, 11.3% were considered clinically unacceptable with irradiance of less than 400 mW/cm^2. Of all tested LCUs 42% (p=0.0005) had a 30% lower value of irradiance than the manufacturer of the LCU declared. In 73% tested LCUs, there was a matching between measured and declared irradiance. The age and model of LCUs had the most significant impact on irradiance.

Conclusion The most commonly used LCU included in dental offices was LED. Mean irradiance was good enough to secure adequate polymerization of resin-based materials. Irradiance decreases with usage time of LCU.

Key words: composite dental resin, dental curing lights, polymerisation

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Original submission:
01 December 2020;
Revised submission:
12 February 2021;
Accepted:
10 March 2021
doi: 10.17392/1323-21

Med Glas (Zenica) 2021; 18(2):505-509

INTRODUCTION

Light-activated resin-based composites (RBC) are the most commonly used restorative materials because of their easy handling, excellent aesthetics and good physical and mechanical properties (1). They are used in everyday clinical practice not only as restorative materials but also as liners or as luting agents for cementation of inlays, onlays, crowns, veneers and orthodontic brackets (2). An adequate polymerization of RBCs is essential for the ultimate success of restorations (3). The quality of the energy delivered to RBC restorations can be affected by many factors such as the exposure duration of light from light-curing units (LCUs), intensity of the light output, wavelength range, the distance between the surface of the restoration and the curing tip, operators technique, beam profile, internal/external diameter, time of exposure (3,4).

Incomplete polymerization produces adverse biological effects, increasing water absorption, composite solubility and reduced hardness, which clinically results in discolouration, low resistance to wear, marginal breakdown, cytotoxicity and increased microleakage (5), irreversible pulpal damage and allergic reaction (6).

There are four types of LCUs used by dentists to polymerize RBCs: quartz-tungsten – halogen (QTH), light-emitting diode (LED), Plasma Arc (PAC) and Argon-Lasers units (7). QTH and LED are the most commonly used types of LCUs in dental offices. QTH produces blue light in the 400-500 nm region, and the intensity ranges between 400 and 1600 mW/ cm^2. Some limitations of QTH LCUs are producing a broad-spectrum light energy, including the infrared radiation range, which is responsible for excessive heat generation and short service life (bulb, reflector or filter degradation) (8). LED polymerization units (third-generation) produce blue light between 450 and 470 nm and delivering no light below 420 nm (monowave) and polywave that produce two or more distinct emission bands from 440 to 470 nm and another below 420 nm. Newer high power LED LCUs light intensity approach or go above 3000 mW/ cm^2 (9). PAC light sources provide light intensity more than 2000 mW/ cm^2 and very rapid polymerization, but studies showed inadequate polymerization resulting with microleaking of RBCs (10). Argon ion lasers are quite useful in polymerizing RBCs, but small light size (spot size) prolongs the curing cycle of RBCs. In order to enhance the clinical success of composite resin restorations, dental manufacturers have focused on the development of new LCUs (11).

An appropriate intensity of light with the maximum absorption wavelength of photoinitiators is the main factor in the polymerization of RBCs (12). According to Lopes et al. (13), two decades ago, irradiance of 300 mW/cm 2 is low and should be compensated by curing time of 60 s for a 2-mm increment. With new curing units, usually 1000 mW/cm^2, we would not suggest this curing time because of the possibility of burning soft tissue and pulp.

The reduction of light intensity of the LCUs can reduce the success rate of the restorative treatment by reducing the degree of conversion of composites (14) with abovementioned consequences.

As the LCUs usage time, the irradiance diminishes due to deterioration of the components (7) leading to the reduction of LCUs effectiveness. There are many models of LCUs in the dental market, and each manufacturer in datasheets provided by the manufacturer states maximum irradiance for their device. Every model of LCUs has different characteristics and limitations, and that is why we wanted to determine the relationship between the model of LCU and irradiance. As to our knowledge a similar study was conducted ten years ago but only in Zagreb (15).

The aim of this study was to assess irradiance of LCUs used in the dental offices in Split, Rijeka and Zagreb, as well as the differences between the manufacturer declared and measured irradiance and the relationship between the LCSs' age and irradiance were assessed.

MATERIALS AND METHODS

Materials and study design

A list of public and private dental offices and clinics in selected three cities was obtained from the Croatian Dental Chamber registration. A total of 65 dental offices in the cities of Rijeka, Split and Zagreb (Croatia) were randomly selected. A total of 195 LCUs in 65 dental offices were tested for their irradiance in the period between April and August 2019. After explaining the methodology

and the principle of the study, an informed consent was obtained from doctors.

Methods

Radiometer Ivoclar Bluephase Meter 2 (Ivoclar Vivadent, Schaan, Principality of Liechtenstein) was used for evaluation of irradiance of LCUs measuring the LCUs light intensity of the wavelength between 385 nm and 515 nm and it was used solely for the round-peak devices of the light conductor. The same person conducted the reading procedure in Rijeka, Split and Zagreb (for each city there was one person, in total three persons). All investigators were trained in taking sample readings by the same experts. The tip of each LCU was cleaned with an alcohol swab and visually inspected to ensure that no debris was present. This was followed by placing the tip of the LCU in direct contact with the sensor of the radiometer.

Three measurements were performed on each device (at the beginning, in the middle and at the end of the curing process), and the average was calculated. The standard program and 20 s curing time was used. Minimally required irradiance was 400 mW/cm^2 (16).

The type of LCU, their usage time and declared values from the manufacturer of the LCU were also recorded. Declared values were found in unit instructions online.

Statistical analysis

The frequency tables were used for presentation of each categorical variable. The presence/absence of a statistically significant difference between the three cities was determined using the Kruskal-Wallis ANOVA test. For continuous variables, the basic statistical parameters were calculated, and the statistical significance of the difference was tested using the variance analysis and the Newman-Keuls test. The $p<0.05$ was considered statistically significant.

RESULTS

In total, 195 LCUs were tested. Five of them were QTH and 190 were LED LCUs (Table 1).

The overall mean usage time of the tested LCUs was 4.43±3.4 years (Figure 1). The oldest LCUs were found in Rijeka (5.2±3.8 years) then in Split (4.1±3.4) and Zagreb (4.1±2.9) (p=0.1668). The mean irradiance of tested LCUs' values was lowest in Rijeka (713.3 mW/cm^2) then in Split (818.8 mW/cm^2) and Zagreb (880.8 mW/cm^2) (p=0.0406).

Table 1. Distribution of light curing units (LCU) in dental offices in three cities in Croatia

City	No (%)	
	LED	QTH
Rijeka	59 (30.25)	3 (1.53)
Split	66 (33.84)	2 (1.02)
Zagreb	65 (33.33)	0
Total	190 (97.45)	5 (2.55)

LED, light - emitting diode; QTH, quartz - tungsten – halogen;

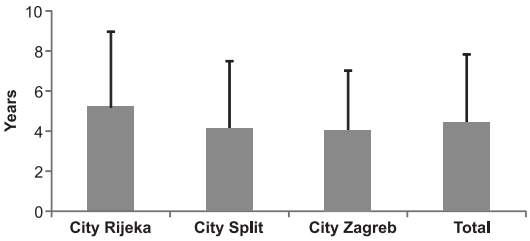

Figure 1. Usage time of the measured light- curing units (LCUs) in three different cities and in total expressed in years

The overall mean irradiance for all three cities was 806.4 mW/cm^2. Of 195 LCUs, 21 (11.3%) were considered clinically unacceptable with irradiance of less than 400 mW/cm^2. A high number of LCUs had the 30% lower value of irradiance than the manufacturer of the LCU declared (Table 2).

Table 2. Mean intensity and intensity 30% lower than declared of the tested light curing units (LCUs)

Intensity	City			Total	p
	Split	Rijeka	Zagreb		
Mean (mW/cm^2)	818.3	718.3	880.8	806.4	0.0402*
30% lower than declared (%)	39.7	50.8	36.9	42.21	0.0005*

*statistically significant

Declared irradiance of LCUs ranged from 500 – 3200 mW/cm^2 with a mean value of 1200 mW/cm^2 in all three cities. Measured irradiance ranged from 0 – 2050 mW/cm^2 with mean value of 875.6 mW/cm^2. The ratio between declared and measured irradiance indicated a statistically significant difference (p=0.0002) in values between three cities. The lowest overlap of measured and declared irradiance was in Rijeka, than in Split, and highest in Zagreb (Figure 2). As for the model of LCUs, the highest irradiance between

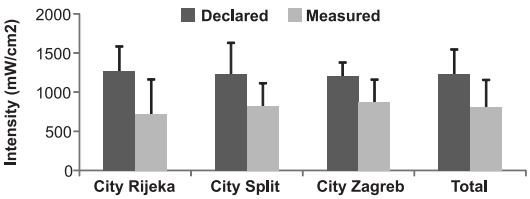

Figure 2. Difference between declared and measured irradiance of tested light – curing units LCUs

Table 3. Dependence of mean measured intensity on selected predictor variables

Variable	Total		Rijeka		Split		Zagreb	
	β	p	β	p	β	p	β	p
Model of LCU	0.16	0.0131*	0	0.9682	0.03	0.7888	0.16	0.2269
LED/ QTH	0.11	0.1206	0.31	0.0444*	0.2	0.1652	-	-
Usage time of LCU	0.38	0.0000*	0.46	0.0001*	0.61	0.0000*	0.14	0.2805

*statistical significance; LCU, light - curing unit; LED, light - emitting diode; QTH, quartz-tungsten – halogen; β, beta coefficient of the individual contribution of a single variable to the overall;

all measured LCUs of 2050 mW/cm^2 had Mini LED Ortho 2 (Acteon, Mont Laurel, NY), than 1000 mW/cm^2 on Elipar Freelight 2 (3M ESPE, Germany). However, the largest match between the measured and declared irradiance values of 99% was shown by the LCU Bluephase style and 95% by the Woodpecker LED.B.

Usage time of the LCUs seems to have the most significant impact on irradiance (p=0.0000), especially in Rijeka (p=0.0001). Also, the type of tested LCU had a statistically significant impact on irradiance in total (p=0.0131) and again in Rijeka (p=0.0001) and Split (0.0000) (Table 3).

DISCUSSION

Light-activated RBCs are the available and esthetic solution for dental restorative treatments. Inadequate handling or use of improper equipment such are LCUs can result in unesthetic restorations, secondary caries and pulpal irritation (17). Our results showed that the most commonly used LCUs were LEDs (97.43%), which present a high percentage if we compare it with the results from recent literature. Similar results with 88.5% LED LCUs were reported by Alquira et al. (18). LED LCUs were least represented in Rijeka (30.25%), Split and Zagreb had similar ones (33.84% and 33.33% respectively). This difference could have resulted from the small sample number since in tested dental offices in Rijeka, a very high number of LED LCUs was in use.

Mean irradiance in this study was 806.4 mW/cm^2, which is much higher than in the study of Al Shaafi (4), and similar to the results reported by Alquira (18). Only five LCUs had irradiance higher than 1000 mW/cm^2. Similar results were reported by Al Shaafi et al. (19) in their study. The lowest values were recorded in Rijeka, where mean irradiance was acceptable but the lowest of all three tested cities. Perhaps the frequency of using LCUs in Rijeka is higher than in the other two cities. Also, in one-quarter of the tested LCUs, the irradiance was less than 400 mW/cm^2 and in half of them 30% lower than the manufacturer of LCU declared. These results are in accordance with another study (20), where 27.4% of LCUs without minimally required irradiance were reported. Matosevic et al. (15) reported that 44% of tested LCUs had irradiance lower than 400 mW/cm^2. Results from Split and Zagreb were similar and in accordance with the results of an Iranian study (12). In a Brasilian study, six out of 22 LCUs delivered inadequate irradiance in the posterior region (7).

Every manufacturer of the LCU declares maximum irradiance in the manufacturer provided datasheets. In this study, we wanted to assess if that declared intensity was in accordance with the measured one. Declared irradiance of tested LCUs models varied from 800 to 3000 mW/cm^2, which is quite a range of values. A large number of models of LCUs with different characteristics and maximum irradiance are available in the market which, as the results of this study show, had an impact on measured irradiance. Similar results were reported by Omidi et al. (12). A comprehensive study conducted by the University of Mainz in dental practices in the Rhine-Main area in 2005 also showed that many curing lights do not achieve the specified light irradiance stated by the supplier. In extreme cases, they did not even achieve half of the stimulating power (21).

Our results showed matching between measured and declared irradiance in 73% of LCUs in total. The results in Rijeka showed matching of 55.3%, and in Zagreb, it was 75.1%.

The effect of the LCUs usage time on irradiance was also tested. The mean usage time was four years, and LCUs in Rijeka were a bit older than average (5.2 years). These results follow results of a few studies (14,22). Our results suggest that the age of the LCUs had the most significant influence on irradiance considering all other tested parameters (the type of the LCU and model). Other studies reported similar conclusions (14,22). However, Javaheri and Ashreghi (20) found no significant

correlation between clinical age and light intensity. Two possible reasons for the difference in the results of different studies could be the use of different models of LCUs in different studies and different levels of device awareness by participating dentists. Testing and regular servicing are critical for light-curing units to ensure adequate irradiance. LCUs should be tested, and their components should be replaced regularly (4).

In conclusion, the results of this study showed mostly LED LCUs in dental offices. The light intensity of the tested curing units was lower than expected, but still, most of them have satisfactory irradiance that enables adequate and quality polymerization of light-activated resin-based composite. The age and model of LCUs have significant impact on irradiation and thus have impact on the quality and durability of resin-based composite fillings.

ACKNOWLEDGEMENTS

The authors would like to thank professor Ivana Brekalo-Pršo for help in organizing the collection of data on light-curing units in Rijeka.

FUNDING

No specific funding was received for this study.

TRANSPARENCY DECLARATION

Competing interest**:** None to declare.

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