Original Article

Infection Control Barrier and Curing Time as Factors Affecting the Irradiance of Light-Cure Units

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Abstract

Objective: The objective of the study is to investigate the effect of infection control barrier (ICB) and curing time on irradiance of light cure units (LCUs).

Methods: Irradiance (mW/cm^2) of the LCUs at a government dental school were recorded with and without ICB at 0 (T_0), 10 (T_{10}), and 20 (T_{20}) seconds using a digital radiometer. Data were analyzed using IBM® SPSS® Statistics Version 17 for Windows software for the analysis of variance and Bonferroni methods at 0.05 significance level.

Results: Using ICB resulted in a statistically significant effect on the irradiance mean ($P < 0.01$). A significant difference existed between the four different brands of LCUs at different time intervals, irrespective of the use of ICB. At T_0 and T_{10}, the mean output of Acteon mini-light-emitting diode (LED) was significantly higher than that of either the Kerr Demi Ultra or the Kavo Polylux II. At T_{20}, E-Morlit's mean irradiance was significantly higher than that of Kerr Demi Ultra, which in turn was significantly higher than that of the Kavo PolyLux II. The mean irradiance of the LEDs was significantly higher than that of the halogens irrespective of barrier placement and at all-time points.

Conclusion: The ICB used in this study resulted in a statistically significant reduction in the irradiance output. No significant difference in the irradiance was found at different curing time intervals for the tested units regardless of ICB usage.

Keywords: *Infection control barrier, irradiance, resin composite, resin composite curing time*

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Introduction

With the increase in the use of the resin-composite materials in restorative dental practice, the demand for light cure units (LCUs) has become very high. Many factors can affect the efficiency of polymerization of resin composite materials which can be different among manufacturers, and some can be under the control of the clinician and understanding the influences of these factors is crucial for the long-term success of these restorations.[1] The correct application of the light-curing step is crucial for the success of the resin-composite restorations. The LCUs' irradiance is an important factor for the adequate polymerization of resin composite restorations.[2-5] Adequate curing time is also critical for adequate polymerization and time-management.[4-13] LCUs have to be used in close proximity to the restoration, as the distance is one of the factors affecting the irradiance at the surface of the material and thus optimum curing.[14,15] This makes the contact of the light-curing tip with the mucosa and oral fluids imperative and difficult to avoid without using an appropriate infection control barrier (ICB).[16]

Several infection control methods, such as autoclaving and cold sterilization have been used with LCUs. Autoclaving of the conventional light curing tips leads to the build-up of an opaque scale at the tip end, which has been reported to greatly reduce the light

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intensity (irradiance).[17,18] The use of cold sterilization solutions can also lead to a reduction in the light intensity at the tip irreversibly for specific brands of cold sterilization agents.[17] In addition, the sterilization methods are time and money consuming especially with the increased need for the use of LCUs. Another suggestion was the use of disposable, pre-sterilized light activation probes,[19] which are expensive.

The use of ICBs is one of the most common and cost-effective infection control methods associated with the use of LCUs because of its efficiency and effectiveness. It is also less time consuming and has a lower financial demand compared to other methods. Thus, it is important to determine whether the use of such a barrier will affect the irradiance at the tip of the curing light.

The irradiance and curing times are among the two most important interrelated factors affecting the optimum polymerization of dental resin composites; increasing the irradiance will require less curing time and vice versa.[5,11,20,21] Usually, the intensity of LCUs is measured at the first exposure with the sensor in the radiometer, which is at time 0 (T_0);[22] it is important to know whether the irradiance is changing at different times during the light-curing cycle.[23]

Thus, the objective of this investigation was to evaluate whether the irradiance of the LCUs was affected by the use of a common ICB and whether there will be any change in the irradiance between the first exposure at T_0 and subsequent time points.

Table 1: The brands and number of light cure units

Light-cure unit brand	Number of Units (*n*)
Acteon mini-LED	66
E-Morlit	58
Kerr Demi Ultra	15
Kavo Polylux II	26

LED=Light-emitting diode

Methods

A two-by-three factorial design was adopted for this study with the use of barrier (yes or no) and curing time (0 (T_0), 10 (T_{10}), or 20 (T_{20}) seconds) as variables. The sample size was selected using all-inclusive purposeful sampling where all the LCUs found within a government dental school were included in the study. The study was approved by the restorative department head to be conducted and was exempt from the need for ethical approval, as it does not involve human or animal subjects or their tissues. The study was implemented during July 2016 when all the students were on summer vacation and the clinics were more available to test their LCUs.

For each unit tested, the tip of the curing unit was placed flat on the sensor of a digital radiometer (Bluephase Meter II, Ivoclar Vivadent, Liechtenstein) and the unit was operated, without a plastic barrier for 20 s. The output on the radiometer's screen was recorded in mW/cm^2 immediately after starting the curing cycle, then after 10 s and finally after 20 s. The reading for each unit's time point was taken as the average of three runs. For all tests, one investigator(HN) performed the test while another investigator(FH) recorded the results using a standardized electronic form. The same test was repeated after placing a plastic barrier (Barrier Film Model: HY-6053, Lot Number: 231198, Zhejiang Huiya Medical Products Co., Zhejiang, China).

Data were collected, tabulated, and analyzed using a statistical software (SPSS Ver. 17, IBM, Armonk, New York, United States). Quantitative variables are described using the Mean, standard deviation, the Range (Maximum – Minimum) and 95% confidence. At each time point (0, 10, and 20 s), One-way Analysis of Variance (ANOVA) was used. It tested the equality of the light irradiance means of the various brands, which was then followed by a multiple comparison using the Bonferroni procedure to test the significant difference between any two means. To test the equality of means of light irradiance for the two types at each time point, independent samples *t*-test was applied. Two-way

Table 2: Two Way ANOVA. Tests Between-Subjects Effects. Dependent Variable: Light Intensity mw/cm^2

Source	Type III Sum of Squares	df	Mean Square	*F*	Sig.
Corrected Model	865685.151a	5	173137.030	3.121	0.008
Intercept	672499273.305	1	672499273.305	12121.925	0.000
Time	215802.876	2	107901.438	1.945	0.144
Barrier	597218.492	1	597218.492	10.765	0.001
Time *Barrier	3380.127	2	1690.064	0.030	0.970
Error	44715210.277	806	55477.928		
Total	803527696.000	812			
Corrected Total	45580895.429	811			

ANOVA was used to assess the simultaneous effect of time and brand and their interaction on the light irradiance. Further, it was applied to study the effect of time and type and their interaction on irradiance. The significance level is considered at $P < 0.05$ as significant. Two-tailed distribution is assumed throughout the analysis for all statistical tests.

Results

A total of 165 LCUs were tested in total [Table 1] from four manufacturers: Acteon mini - light-emitting diode (LED) (A-dec Dental UK Ltd., Warwickshire, England), Kerr Demi Ultra ((Kerr Dental, Orange, California, USA), Kavo Polylux II (KaVo Dental GmbH, Bismarckring, Germany, and E-Morlit (Apoza Enterprise Co. Ltd., New Taipei City, Taiwan) The placement of an ICB had a significant effect on the mean irradiance of all the LCUs tested, at every time period tested as revealed by two-way ANOVA. When irradiance was compared with the use of the tested ICB versus without, it was found that there was a statistically significant effect of using the barrier on the mean detected irradiance ($P < 0.01$) [Table 2]. However, even with a barrier, all the LCUs had an output of well over the recommended 300 mW/cm^2.[24,25]

Figure 1 shows the mean output of all LCUs at different time intervals, while Figure 2 illustrates the findings after breaking the LCUs up into groups by brand, time interval, and barrier placement. When comparing the three-time intervals tested during the curing cycle, there was a significant difference found between the four different brands of LCUs, irrespective of whether or not a barrier was used. The Bonferroni multiple comparison processes revealed that at T_0 and T_{10} seconds, the mean output of Acteon mini-LED was significantly higher than that of either the Kerr Demi Ultra or the Kavo Polylux II.

There was no significant difference between the mean light irradiance of the Acteon mini-LED compared with E-Morlit or the Kerr Demi Ultra when compared to the Kavo Polylux II. The Acteon mini-LED only cures for 10 s continuously, so it was not possible to acquire T_{20} for it. At T_{20}, there was a significant difference between the remaining three LCU brands tested according to ANOVA. Bonferroni comparison showed that E-Morlit's mean irradiance was significantly higher than that of the Kerr Demi Ultra, which in turn was significantly higher than that of the Kavo PolyLux II.

When the tested LCUs were grouped into LED and halogen types, the mean irradiance of the LEDs was significantly higher than that of the halogens. This was irrespective of barrier placement and curing time. This is illustrated in Figure 3.

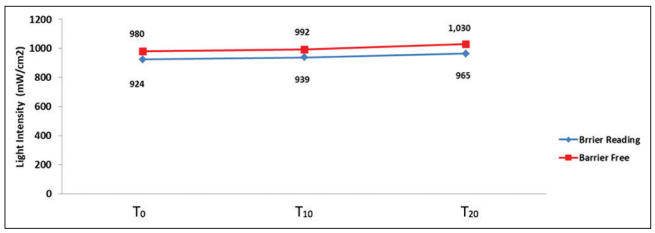

Figure 1: Line graph illustrating the effect of barrier placement on light cure unit irradiance with time

Discussion

Achieving adequate curing is paramount for the long-term success of resin composites. Maintaining sufficient irradiance during curing can be affected by multiple factors including distance from the restoration surface and type of curing unit. The primary objectives of this study were to evaluate whether the irradiance of the LCUs was affected by the use of a common ICB and whether there will be any change in the irradiance between the first exposure at T_0 and subsequent time points. It was found that there was a statistically significant effect of using the barrier on the mean detected irradiance for all the tested LCUs. The irradiance of all LCUs at different curing time intervals was found to have statistically insignificant

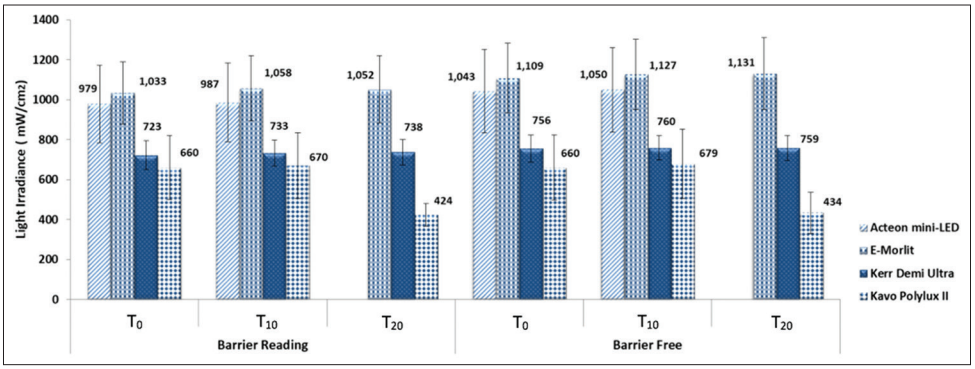

Figure 2: Bar graph showing the mean light irradiance versus brand at different time intervals

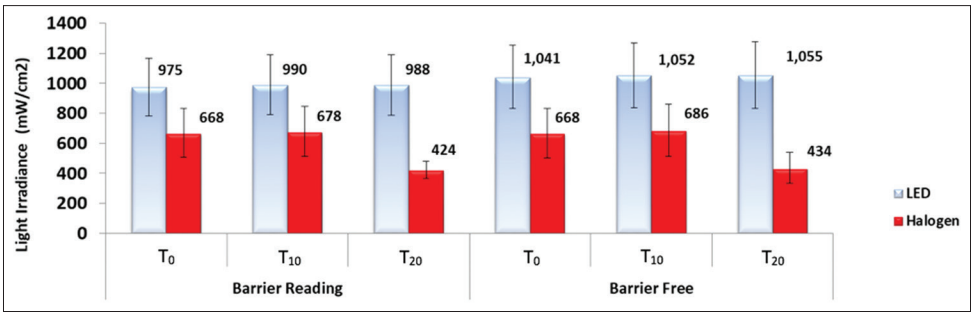

Figure 3: Bar graph showing change of mean light irradiance versus time for light-emitting diode and Halogen light cure units

difference either with or without ICBs. It was also found that irradiance was significantly different between the four different brands of LCUs at the three time-intervals tested during the curing cycle, irrespective of whether or not a barrier was used with the mean irradiance of the LEDs significantly higher than that of the halogens LCUs.

When data were compared regarding irradiance with the use of the tested ICB versus without, it was found that there was a statistically significant effect of using the barrier on the mean detected irradiance. Although the results are statistically significant, the reduction in the irradiance was still producing an output well over 300 mW/cm^2, which is the recommended output for clinical efficiency in curing resin composites for all the tested LCUs.[24] The effect of placing ICB on the clinical efficiency of curing resin composite such as the degree of conversion and microhardness must be tested within the recommended curing time to determine if this reduction will necessitate increasing the curing time over the manufacturers' recommended curing time.[5,20,21,23,26]

It is important to consider that there are different brands of ICBs available and the current study's results only reflect the effect of a specific barrier on irradiance. Other barriers need to be tested to produce more specific recommendation(s) on the effect of using the different ICBs on irradiance. The result on the effect of using the tested ICB on the irradiance of LCUs is in line with another study by Chong *et al*.[27] where they tested the effect of using four different ICBs in the curing-light intensity and Knoop hardness values of the cured resin composites and they found that the intensity values had statistically significant difference with barrier use versus no barrier control; while there was no statistically significant difference in Knoop hardness values between the barrier versus no barrier groups; finding no correlation between the Knoop hardness values and light-intensity output with the different ICBs they concluded that the barriers could be used with no clinically significant effect on the light-intensity and that all groups had an output values well above the recommended 300 mW/cm^2.[27]

In another study, Hodson *et al*.[16] tested the effect of using 2 ICBs on the intensity of curing lights with different levels of light output and on the depth of cure of the resin composite samples compared to the control with no barrier. They found a statistically significant reduction in the light intensity for all the curing units when the ICBs were used; there was no significant reduction in the depth of cure except for the high-output light, which was considered a small decrease in the cure depth and is clinically insignificant.[16] Furthermore, Sword *et al*.[28] tested the effect of six different barrier materials on six different curing lights and found that all barriers had a statistically significant reduction in the irradiance, but this reduction was not clinically significant except with polywave LED curing light when covered with latex-based barrier, so they recommended clinicians to be aware of the possible effect of the use of barriers on the optimal cure of the resin composite restoration.[28] A study by Khode *et al*.[29] tested the effect of using four different disposable barriers on the light intensity against the control group where no barrier was used and found that there was a statistically significant reduction in light intensity with all ICBs, but the hardness ratio was only significantly affecting with using Latex cut glove pieces (LCGP) as an ICB. They recommended the use of disposable ICBs except the LCGP.[29]

Compared to the previous studies, the current study was done on all LCUs used at a governmental dental school (n = 165 units) and from different clinical areas. The study by Chong *et al*. was done using only one LCU, but they used four different ICBs.[27] Sword *et al*.'s study was done using only 6 LCUs different from the brands used in the current study and 6 different ICBs.[28] The study by Hodson *et al*. was done on 3 LCUs that differ in light intensity and using 2 commercially available ICBs.[16]

Regarding the irradiance at different curing time intervals, it was found to be statistically insignificant difference for all LCUs with (0.14 $P > 0.05$) or without ICBs (0.97 $P > 0.05$). This indicates sufficient output irradiance for curing resin composite along the curing

period for the tested units. Rodriguez *et al*.[30] found that the polymerization efficiency is increased with increasing the light-curing time to 40 s when compared to 20 s and also with using lighter shades of bulk-fill resin composites.[30]

A study by Harlow *et al*.[31] suggested that assessment of the irradiance from the LCUs must be reported throughout the entire exposure cycle and that a single irradiance value does not adequately describe the actual output from the LCUs.[31] The same suggestion was also reported by Price *et al*.[22] on his review article about LCUs.[22] A study by Shimokawa *et al*.[32] showed that irradiance is one factor related to the LCUs and affecting the polymerization of the bulk-fill resin composites, tip diameter, emission spectrum, and light beam profile were also measured and they found that the combination of a wide tip and homogeneous light distribution had better polymerization effect on bulk-fill resin composites.[32]

It is important to note that the outcomes of this study are based on using one type of plastic barrier (Barrier Film Model: HY-6053, Lot Number: 231198, Zhejiang Huiya Medical Products Co., Zhejiang, China) which was used at the school. Different ICBs might have different outcome measures based on the material and manufacturers' production differences. This will limit the recommendations of this study to be limited to the type of ICB used. Also, other factors related to the ICB used might have an effect on the irradiance such as the number of layers and adaptation to the LCU tip which were not tested in this study. However, this study was carried on all the available LCUs in a governmental school which represents a large number of units with variable consumption and a well-randomized sample.

More studies are needed to test whether the use of barrier will produce clinically significant reduction in the degree of conversion and microhardness while utilizing the above-mentioned LCUs brands. This would recommend that dentists check the irradiance of their LCUs with the ICB used in their clinical practice and would necessitate increasing the curing time more than the recommended by the manufacturer. Future studies with consistent methodologies using different ICBs and LCUs are needed to produce data applicable to be compiled in a quantitative systematic review to be able to reach a consensus based on a higher level of evidence. Within the limitations of this study and limited data from other studies, the conclusion may be made that placing the ICB used in this study can cause a statistically significant reduction in the irradiance output. However, this effect was not sufficient to reduce it below the recommended clinical irradiance and thus is not clinically significant to affect the efficiency of the output irradiance in curing resin composites. No significant difference in the irradiance was found at different curing time interval for the tested units regardless of the presence or absence of ICB.

It is recommended that the dentist check the irradiance of their LCU with the ICB they use in their clinical practice to check whether the effect on irradiance can affect the time needed/curing of the resin composite restorative material.

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Conflicts of interest

There are no conflicts of interest.

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