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ORIGINAL ARTICLE

Effects of different infection control methods on the intensity output of LED Light-Curing Units ☆

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Abstract *Objective:* To evaluate the effect of two different infection control techniques on the irradiance value output of LED curing units.

Methods: Two different infection control techniques were involved in this investigation: (1) autoclaving and (2) disinfectant with a clear barrier. A high-power LED (Elipar S10, 3 M, Neuss, Germany) was used as the curing unit. Light irradiance values (mW/cm^2) of each light tip were measured by a calibrated spectral device (PS-MARC [Patient Simulator-Managing Accurate Resin Curing] BlueLight Analytic Inc., Halifax, Nova Scotia, Canada). For each group, 5 new curing tips were involved and a total of 25 cycles were performed. For the autoclave group, each of the 5 curing tips was sterilized with an autoclave cycle (15 min). In the second group, the 5 tested tips were wiped with a disinfectant solution (MinutenSpray, APMD GmbH, Munich, Germany) and then covered with a clear commercial disposable barrier (Disposa-Shield, Dentsply, USA). The statistical analysis involved using the *t*-test and the Tukey test.

Results: Analysis of the data showed reductions of irradiance values in both groups compared with the baseline values. The group with autoclaved curing tips had a lower value compared with the disinfectant/barrier tips group. There were statistically significant differences between the tested groups ($P < 0.05$).

Conclusion: The quality of the tested LCU was reduced when either of the above infection control techniques was used. Clinicians are recommended to monitor their LCU by applying the same infection control methods on light tips when testing its irradiance value.

1. Introduction

Resin-based composites (RBC) are presently the most popular restorative material used in dental practices, due to the increased demand for esthetics along with improvements in both their physical and mechanical properties [10,12,17].

RBCs are classified based on their polymerization mode, either auto-polymerized (chemically activated) or light-polymerized (light-activated) [7,8]. However, more light-

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activated RBCs are used in dental clinics because of more color stability and the fact that working time for light curing (polymerizing) can be controlled when needed [11,16].

Light-cured resins are activated by different LCU systems, including the quartz–tungsten–halogen (QTH) and light-emitting diode (LED) systems. LED units currently dominate the clinical market. They are considered superior to QTH because of longer-lasting bulbs with fewer maintenance concerns, and because they produce higher-power intensity, thus reducing polymerization time [2,10,11].

For an RBC to be considered appropriately polymerized, it should receive sufficient irradiance value in terms of efficient exposure curing time (energy density), along with proper wavelength range (from 385 to 515 nm, depending on the photoinitiator activated) [20,25]. However, there are many factors affecting the delivery of this needed energy. These factors could be related to the material being cured, such as the shade of the resin, filler type in the composite, thickness of the resin increment, or photoinitiators used in the cured resin, and that explains why energy density could range between 6 and 36 J/cm^2. Other factors—such as the quality of the substrate through which the light is curing (i.e., through enamel, dentin, or a barrier covering the LCU curing tip), the distance between the LCU tip and the cured increment, or the use of different LCU systems—will also affect the RBC polymerization process [18].

There is a significant potential for cross-infection in dental offices due to the existence of saliva and blood in the field of treatment [1]. Guidelines from both the American Dental Association (ADA) and the Centers for Disease Control and Prevention (CDC) have addressed the prevention of any possible infections transmitted by either direct or indirect contact with a variety of potentially infectious body fluids. Instruments and equipments used in dentistry are subject to different infection control protocols, depending on their level of contact with body fluids. In the CDC guidelines, LCUs are in the 'semi-critical' category, because they are used within the oral cavity and have the potential for saliva or blood contamination but are not designed to penetrate vital tissues [3]. Different infection control techniques are available that meet the CDC-recommended standards. These include the sterilization of curing tips (either heat or cold), the use of disposable barriers, or the use of a single-use plastic curing tip. However, despite the technique used, proper light output from light-curing tips should be delivered.

The literature reports result from studies that evaluated different infection control techniques and their effects on light output. Dugan and Hartleb found that LCU curing tips "revealed a structural breakdown of the surfaces of the glass rods in fiber-optic light guide" when they investigated the reason for irregularly cured resins [4]. Intensity output reduction of more than 50% was caused by the use of Cidex 7 (glutaraldehyde disinfectant agent). Nelson and others also examined the effect of glutaraldehyde on light transmission of curing tips and recommended that cold sterilization be avoided, due to its 49% reduction in light intensity [15].

The effect of autoclaving light-curing tips was also evaluated. Kofford and colleagues found a 7% lower light intensity when tips were packed with distilled water and autoclaved for 30 cycles. [9] Another study showed a reduction of 50% with only 3–4 cycles of autoclaving, but tips were packed in tap water [24].

Many studies investigated the effect of using disposable barriers to cover the curing tips [13,26]. The reduction ranged from 1.6% when a cellophane wrap was used and up to 70.5% when latex gloves were used, all covering the curing tips.

The aim of this study was to evaluate the effect of two different infection control techniques on irradiance value output from LED curing units.

1.1. Methods

Two different infection control techniques were involved in this investigation:

1. Autoclaving.
2. Disinfectant with a clear barrier.

A high-power LED (Elipar S10, 3 M, Neuss, Germany) was used as the curing unit. The manufacturer of this curing unit advocates that their curing tips are autoclavable and recommends to either autoclave them or disinfect them to avoid any cross infection between patients [5].

The light irradiance value (mW/cm^2) for each light tip was measured with a new calibrated spectral device (PS-MARC [Patient Simulator-Managing Accurate Resin Curing], Blue Light Analytic Inc., Halifax, Nova Scotia, Canada). This device captures the emitted light by its sensors (located either in anterior or posterior teeth of a manikin head), which are connected to a calibrated spectral radiometer, and then these data are directed to a computer where the MARC software will analyze and provide multiple results, including the tested emitted light irradiance values [23].

The MARC bench device was used to hold the curing-light unit in a fixed position relative to the PS-MARC anterior sensor every time light intensity was measured.

For measurement of irradiance values, the light-curing tip was positioned and fixed directly at a right angle to the center of the 3.9-mm anterior sensor of the PS-MARC device. Fixed-duration intervals of 20 s were recorded for each curing tip. Each reading had 5 repeats, and the mean average was calculated.

For each group, 5 new curing tips were involved in this investigation. All 10 tips used in this study had 5 repeated measurements recorded at the baseline and used as a control group. For the autoclave group, each of the 5 curing tips was packed in a pouch saturated in distilled water and sterilized with an autoclave cycle (20 min duration in 121 °C). In total, 25 sterilization cycles were performed. After every 5 cycles, the irradiance values were measured, and 5 repeats were recorded for each curing tip.

In the second group, the 5 tested tips were wiped with a disinfectant solution composed mainly of ethanol (25%), isopropanol (35%), and of Chlorinehexidine (10%) (MinutenSpray, APMD GmbH, Munich, Germany), and then covered with a clear commercial disposable barrier (Disposa-Shield, Dentsply, USA). This technique was repeated 25 times, and, as for the autoclave group, the irradiance values were measured after every 5 cycles, and 5 repeats were recorded for each curing tip involved.

For each group tested, every 5 cycles represented one phase for data collection. That is, cycles 1–5 represented phase 1, cycles 6–10 represented phase 2, and so on until phase 5, where

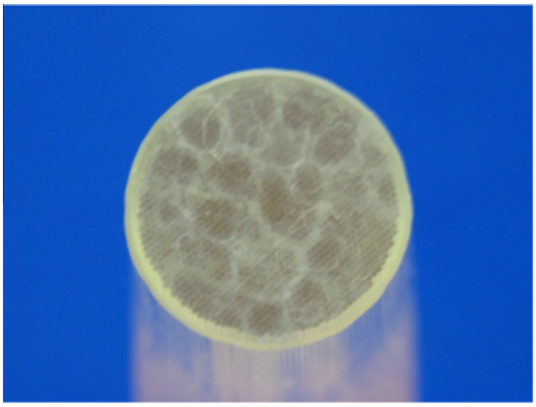

Figure 1 Light-curing tip after treatment with autoclave.

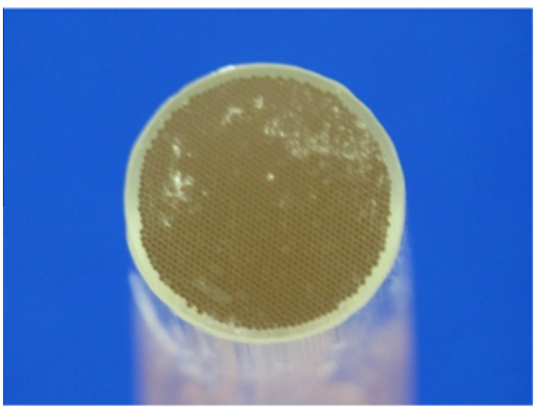

Figure 2 Light-curing tip after treatment with disinfectant/barrier.

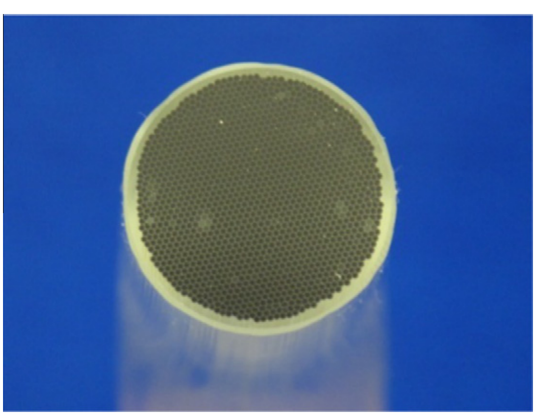

Figure 3 Light-curing control tip as received from the manufacturer.

we concluded the 25 tested cycles for each curing tip. At the end of the investigation, a 1:1 ratio image of the light curing tip surface was captured with a microlens camera for each tested group to document the clearness of the tip surface of each group and compare it to a control image captured prior

Table 1 Mean irradiance values after 25 cycles for autoclave and disinfectant/barrier groups with their control groups.

Infection control techniques	Mean irradiance values ± SD (mW/cm^2)	
	Groups	Values
Autoclave	Control	1828 ± 36.4
	Autoclave	1534 ± 74
Disinfectant/barrier	Control	1837 ± 19.4
	Disinfectant/barrier	1609 ± 114

Table 2 Comparison of mean differences in irradiance values between groups (independent t test, where $P < 0.05$).

	Difference in irradiance values (mW/cm^2)	P-value
Control vs. autoclave	294	0.000
Control vs. disinfectant/Barrier	228	0.000
Autoclave vs. disinfectant/barrier	75	0.030

Table 3 Effect of number of cycles of autoclaving of curing tips on irradiance values.

No. of cycles	Mean irradiance values ± SD (mW/cm^2)	Reduction% compared with control
5 cycles	1788 ± 68	2.2
10 cycles	1730 ± 56(a)	5.2
15 cycles	1738 ± 72(a)	4.9
20 cycles	1679 ± 64	8.2
25 cycles	1534 ± 74	16.1

[Letters in parentheses = homogeneous subsets. All other values were statically significant. (Tukey HSD, $\alpha = 0.05$)]

to investigation. (Figs. 1–3) Statistical analysis involved the t test and the Tukey test, with significance set at $\alpha = 0.05$.

2. Results

Mean irradiance values after 25 cycles for the autoclaved and disinfectant/barrier tips, with their control groups, are shown in Table 1. Analysis of the data shows reductions of irradiance values in both groups compared with baseline (control) values. The autoclave curing tip group had a lower value compared with the group with disinfectant/barrier tips. There were statistically significant differences between the tested groups ($P < 0.05$) (Table 2).

In the autoclaved group, by the end of the 25 cycles, irradiance values had lost 16.1% of their baseline value. There was no significant difference in reduction between 2nd and 3rd cycles. However, the reduction percentage between 1st and 2nd (2.2–5.2), 3rd and 4th (4.9–8.2), and 4th and 5th cycles (8.2–16.1) almost doubled (Table 3).

In contrast, disinfectant/barrier tips lost 12.4% of power after 25 infection control cycles. Although this was minimal, the more counts (cycles) the tips were swabbed with disinfectant between cycles, the more their power output

Table 4 Effect of number of cycles of disinfectant/barrier curing tips on irradiance values.

No. of cycles	Mean irradiance values ± SD (mW/cm^2)	Reduction% compared with control
5 cycles	1714 ± 85.5	6.6
10 cycles	1679 ± 109	8.6
15 cycles	1651 ± 101[(a)]	10.1
20 cycles	1637 ± 103[(a)]	11.0
25 cycles	1609 ± 114	12.4

[Letters in parentheses = homogeneous subsets. All other values were statically significant. (Tukey HSD, α = 0.05)]

was reduced. There was a marked percentage of reduction between the 1st and 5th cycles, from 6.6 to 12.4% (Table 4).

3. Discussion

Infection control guidelines are highly detailed, including rules for instrument sterilization with surface and equipment disinfecting [3]. Both the CDC and ADA stress to the dental team that all patients should be treated as if they could be infectious [3]. In reference to LCU, the use of a disposable barrier at their curing tips has been advocated for consideration as an acceptable, cost-effective, easy-to-use infection control technique [6,13,26,27]. The use of heat sterilization autoclaving technique for light curing tips, although not as popular as the disposable barrier, is still considered a safe technique and is used in many dental clinics [3,24].

This study was designed to evaluate the effect of two different infection control techniques on high-power LED curing tips and their output (irradiance) value. In general, both techniques investigated showed reduction in their irradiance values in comparison to the control group.

The autoclave technique was found to affect the light curing tips and reduce its irradiance values (which dropped 16.1%), and was statistically significant when compared with the control group ($P < 0.05$). The major cause for such reduction relates to the increasing build-up of mineral residue on the curing tips (Fig. 1). In the literature, Rueggeberg and co-workers found a reduction of up to 50% after only 4 cycles [24]. However, their study used autoclaved tips packed in tap water compared with the distilled water in our study. Another study used distilled water and reported a reduction of only 7% after 30 cycles, compared with our 16.1% reduction [9]. Two main factors could account for these differences. The curing tip used in this study was related to high-power LED units compared with the QTH curing tips used in the previous study. Their manufacturing material and specifications could have affected the outcome. This claim is also supported by McAndrew and his colleagues, who concluded that different LCU tips respond differently to infection control measurements [13]. In this study, a digital spectrometer was used to analyze light output, and light-curing tips were fixed in the same location every time we recorded our measurements. The earlier study used an analog radiometer, which has been reported in the literature as not being very reliable [22]. Also, regarding the radiometer sensor, it was not clearly documented whether the tested tips were located in the same position as the control tips. We now know that irradiance values will differ for the same curing tip if angulations or distance is changed, either horizontally or vertically [19,21]. For the other technique investigated, the use of a disposable barrier showed a reduction of 12.4% after the tip was swabbed (with a disinfectant solution) 25 times. A major reason for this high reduction percentage could be related to the effect of disinfectant solution on the structure quality of the curing tip used (Fig. 2) [4,14,15]. Most studies in the literature testing the effect of a disposable barrier on curing tips did not consider swabbing the tips, although dental practices are urged to disinfect all surfaces subject to possible contamination with blood or saliva between patients [3]. This could explain why our results showed a higher reduction percentage when compared with others [6,13,26,27]. The other factor affecting such reduction is the thickness and quality of the covering barrier used. The range of reduction in curing with a commercially used disposable barrier fell between 2.4 and 6.1%. Although analysis of our data shows a larger percentage reduction compared with others, this technique is still considered to provide a significantly better light output when compared with the autoclave technique.

It is important for clinicians to consider the effects of different infection control techniques on the final irradiance value outcome from their LCUs. Even with minimal reduction, compared with our findings, clinicians should know that their clinical outcome could be compromised. Constant checking of LCU output readings, and compensation for such reduction with increased exposure times, may help to avoid compromised clinical quality.

4. Conclusion

Within the limitations of this study,

1. With an S10 high-power LED, both infection control techniques tested in this study significantly reduced irradiance values, with the lowest reduction shown by the autoclave group ($P > 0.05$).
2. Increasing the number of disinfectant cycles on the curing tips had a negative effect on the LCU irradiance values.
3. Clinicians are strongly recommended to monitor their LCUs by testing the irradiance values, applying the same infection control conditions (i.e., if disposable barriers are used, curing tips should be covered with the barrier used), to control the quality of their clinical restorative dentistry.

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