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ORIGINAL ARTICLE

Dentistry

Impact of Different LED Units, Tip Distance and Time of Light Exposure on Microhardness of Resin-Based Composite for Posterior Teeth

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Abstract

Background: The aim of this in vitro study was to reveal in a time-dependent manner the effect of received irradiance produced by different light-emitting-diode (LED) lamps on the surface microhardness of composite material used in the restoration of posterior teeth.

Methods and Results: A single nanofilled resin composite, Estelite Posterior (Toquyama Dental Corp, Japan) shade PA3, was used to perform this in vitro study. Ninety cylindrical filling samples were made with the help of plastic ring molds and plates to obtain flat surfaces. The mean diameter and height of prepared specimens were 5.5±0.05 mm and 2.5±0.1 mm, respectively. For the polymerization of the composite, two different types of light-curing units (LCU) were selected for this study: Valo X (Ultradent Products, Inc., USA) operated in a "standard" mode, and Bluephase 20i (Ivoclar Vivadent, Liechtenstein) ran in a "high" mode. Photoactivation was done with the light tips fixed parallel to the surface of the filling material and above it at a distance level of 1 mm, 4 mm, and 8 mm. The radiant power (mW) of each LCU was registered in a PL-MW2000 Optical power meter (Beijing Perfectlight Technology Co., Ltd., China).

A total of 18 groups, with five filling samples in each, were formed and processed. Upon the completion of light treatment, by the ISO-4049 protocol, each specimen was immersed in water and stored at 37°C for 24 hours in a lightproof container. After this period, samples were washed and tested for the hardness of top surfaces using a "ПМТ-3" Vickers hardness tester. The means of light intensities of two LCUs in the study were significantly different at 4 mm and 8 mm tip distances in 1.26 and 2 times, respectively. Analysis of hardness values did not reveal significant differences in the light-curing efficacy of two LED lamps. The differences in VHN values were obvious among the 10- and 40-second time exposure groups when the photoactivation was carried out at an 8 mm tip distance.

Conclusion: The effective polymerization of composite restorations with poor accessibility is still a matter of time, not the power of LCU.**(International Journal of Biomedicine. 2024;14(4):700-703.)**

Keywords: light-curing unit • light intensity • resin composite • surface hardness

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Abbreviations

LED, light-emitting-diode; **LCU**, light-curing unit; **VHN**, Vickers hardness number

Introduction

The widespread popularity of tooth-colored restorations in contemporary dentistry is commonly accepted because they meet the needs of patients at the present time. Despite a great variety of materials to efficiently restore teeth for both esthetics and function, resin-based composites are still most in demand. Low invasiveness, high performance, low cost, relative ease of use, and the possibility of repair are among a few perks that make the application of light-activated composites versatile in tooth treatment.[1,2]

However, since the introduction of light-activated filling materials, serious concern has been paid to the quality of a final restoration, which is mainly linked to the degree of resin conversion and the amount of monomer residues in it. It is common knowledge in the dental profession that inadequate polymerization can cause clinical complications, from innoxious discoloration and failure of restoration to severe tooth pain and irreversible pulpitis.[3,4]

Photoinitiation of polymerization depends on the intensity and range of the light flux, which are responsible for activating photosensitizers and subsequently converting a filling material into a hard substance. In addition, the quality of composite restoration may be affected by many other factors, such as duration of illumination and distance between the light source and target area, the shade of resin and its volume to cure, resin temperature, and much more.[5,6]

The absence of appropriate access of a light tip to the tooth area to be restored may play a crucial role even if the resin layer to be illuminated is not more than 2mm thick. In this event, there is a great chance of low depth of cure occurrence and soggy bottom formation in composite restoration. The decrease in light intensity with an increase in distance is in accordance with the inverse square law. This physical phenomenon can be particularly applied to the restoration of Class II lesions where distances up to 10 mm may occur between the cervical cavity margin and the occlusal location of a light source.[7] Also, in the restoration of posterior teeth with a light-cured composite, an excessive loss of energy may happen in the case of a curved light guide design of light-curing unit (LCU) due to the possibility of positioning the light emission window parallel to the occlusal surface to properly illuminate a cavity. In these clinical situations, an ideal solution is to apply an LCU with light-emitting-diode (LED) elements integrated into a flat head whose light is directed by a lens so that a collimated blended beam is obtained at a right angle of incidence relative to the restoration surface.[8] However, many dental practitioners still prefer the classic design of LCU with removable intraoral light guides to meet the best practices of infection control and autoclaving. Thus, they avoid the need for barrier protection, which usually reduces light emission significantly.[9,10]

Therefore, considering the demand for both designs of LED lamps, the aim of this in vitro study was to reveal in a time-dependent manner the effect of received irradiance produced by different LED lamps on the surface microhardness of composite material used in the restoration of posterior teeth.

Materials and Methods

A single nanofilled resin composite, Estelite Posterior (Toquyama Dental Corp, Japan) shade PA3, was used to perform this in vitro study. Ninety cylindrical filling samples were made with the help of plastic ring molds and plates to obtain flat surfaces. The mean diameter and height of prepared specimens were 5.5±0.05 mm and 2.5±0.1mm, respectively. For the polymerization of the composite, two different types of LCU were selected for this study: Valo X (Ultradent Products, Inc., USA) operated in a "standard" mode, and Bluephase 20i (Ivoclar Vivadent, Liechtenstein) ran in a "high" mode. Photoactivation was done with the light tips fixed parallel to the surface of the filling material and above it at a distance level of 1 mm, 4 mm, and 8 mm. The radiant power (mW) of each LCU was registered in a PL-MW2000 Optical power meter (Beijing Perfectlight Technology Co., Ltd., China). The values of irradiance received at the surface were calculated according to the formula: $I = 4P / \pi d^2$, where I – light intensity (W), π = 3,14 and d – light field diameter (cm).

Despite the manufacturer's instruction of a 10-second exposure time for the resin composite of choice and considering the setting characteristics of LCUs, different light cure timings of 2×10 sec and 4×10 sec consecutive cycles were applied in the study. Therefore, 18 groups with five filling samples in each were formed and processed.

Upon the completion of light treatment, by the ISO-4049 protocol, each specimen was immersed in water and stored at 37°C for 24 hours in a lightproof container. After this period, samples were washed and tested for the hardness of top surfaces using a "ПМТ-3" Vickers hardness tester. A 50-gram load was applied for 15sec to make an imprint. There were nine imprints on the top surface of each sample, which were made in a linear and spaced manner across the surface. The diagonals of square indentations were fixed in microns. Measurements were made using a scanning electron microscope (SEM-EVO MA 15, Zeiss, Germany). It was possible to get a clear image from the surface of the filling samples due to their sputtering with gold in a Q150R ES machine (Quorum Technologies, UK). The Vickers hardness number (VHN) was calculated according to the following formula: $VHN = 1.854 \times (F/D^2)$, where F is the applied load (kg) and D is the mean diagonal of the indentation (mm), which yields the VHN units (kg/mm^2).

Statistical analysis was performed using the statistical software package SPSS version 21.0 (SPSS Inc, Armonk, NY: IBM Corp). For descriptive analysis, results are presented as mean±standard deviation (SD). The Mann-Whitney U Test was used to compare the differences between the two independent groups. A probability value of $P<0.05$ was considered statistically significant.

Results and Discussion

The means of light intensities of two LCUs in the study (Table 1) were significantly different at 4 and 8 mm tip distances in 1.26 and 2 times, respectively. Also, both lamps demonstrated a decrease in light intensity as much as the light-curing tip distance from the target area was getting wider. However, regarding the Bluephase 20i, the decrease in surface irradiance values was more pronounced than Valo X.

Table 1.
Light-intensity LCUs at different distances.

LCU	Light curing tip distance (mm)		
	1 mm	4 mm	8 mm
Valo X (mW/cm²)	1276.2 ± 24	922.2 ± 17.5	762 ± 14.4
P-value	>0.05	<0.05	<0.05
BluePhase 20i (mW/cm²)	1236.6 ± 48.6	732.6 ± 28.7	381.6 ± 15

On the other hand, analysis of hardness values did not reveal significant differences in the light-curing efficacy of two LED lamps. However, the differences in VHN values were obvious among the 10- and 40-second time exposure groups (Table 2) when the photoactivation was carried out at an 8mm tip distance (Figure 1).

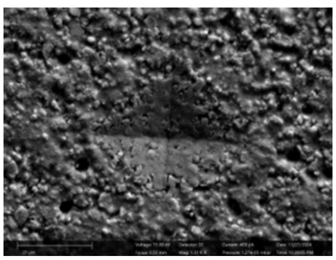

Fig.1a. *Valo X: Tip distance of 8 mm, light exposure of 10 sec.*

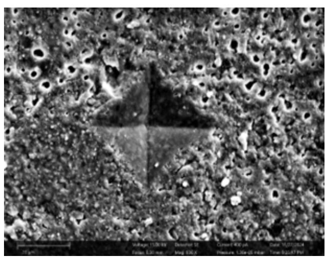

Fig.1b. *Valo X: Tip distance of 8 mm, light exposure of 40 sec.*

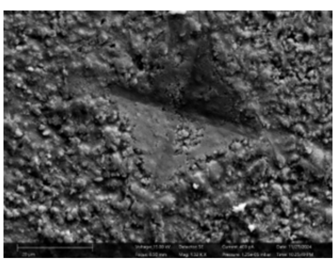

Fig.1c. *BluePhase 20i: Tip distance of 8 mm, light exposure of 10 sec.*

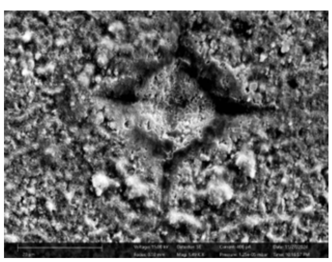

Fig.1d. *BluePhase 20i: Tip distance of 8 mm, light exposure of 40 sec.*

There is a consensus that dental lights must cure resin-based restoratives to the maximum possible degree of conversion to avoid serious postoperative complications in the future. That is why a great emphasis is placed on the amount and quality of curing light for proper activation and polymerization of a composite. Following the study results, the power density output of both LCUs did not drop below the threshold level of 300mW/cm^2, even at an 8mm tip distance. However, as it was shown, the presence of an LED with a higher light intensity could not improve the surface hardness of a final restoration and reduce the amount of time to spend on it. Therefore, the effective polymerization of composite restorations with poor accessibility is still a matter of time, not the power of LCU.

Competing Interests

The authors declare that they have no competing interests.

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Table 2.
Effect of tip distances and various exposure times on surface hardness of resin composite after polymerization with different LCUs.

LCU (VHN)	Tip distance (mm) and light exposure (sec)								
	1 mm			4 mm			8 mm		
	10 sec	20 sec	40 sec	10 sec	20 sec	40 sec	10 sec	20 sec	40 sec
Valo X (kg/mm²)	59.3 ± 4.2	63.6 ± 5.6	66.2 ± 5.2	58.6 ± 4.4	62.9 ± 6.1	65.1 ± 5.4	49.6 ± 3.7	55.1 ± 6.3	62.5 ± 6.5
P-value	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
BluePhase (kg/mm²)	58.8 ± 6.3	62.8 ± 6.7	66.2 ± 8.8	57.7 ± 5.5	63.3 ± 7.1	66.4 ± 6.9	48.4 ± 7.1	54.8 ± 6.2	61.8 ± 5.0

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