Original Article

Effect of the LED lamp charge on the polymerization depth of a Bulk Fill resin

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Efecto de la carga de lámparas LED en la profundidad de polimerización en resinas Bulk Fill

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No conflicts of interest.

Abstract
Introduction. In the field of dentistry, the use of light-curing composite resins has grown to meet this demand. **Objective.** Determine the influence of the battery charge of an LED lamp on the depth of cure of a Bulk Fill resin. **Methodology.** An experimental study in vitro used 105 samples of Bulk Fill composite resin blocks, conformed into three groups. Each group consisted of 35 samples, with the lamp loaded at 100 %, 50 %, and 10 % of its maximum capacity, respectively. A stainless steel matrix was fabricated according to the ISO standard specifications in 20 seconds. The removal of unpolymerized material was performed using the scripting test technique, resulting in polymerized (hardened) resin blocks, which were subsequently measured with a certified and calibrated digital micrometer. **Results.** The battery level significantly influenced the groups ($p < 0.01$), decreasing the polymerization depth as the load level decreased. **Conclusion.** The different battery levels of the wireless LED curing unit did influence the depth of polymerization.

Keywords
Polymerization, Composite Resins, Pressure Drop.

Resumen
Introducción. En el campo de la odontología, el uso de resinas compuestas fotopolimerizables ha crecido para satisfacer esta demanda. **Objetivo.** Determinar la influencia de la carga de la batería de una lámpara LED sobre la profundidad de polimerización de una resina *Bulk Fill*. **Metodología.** Estudio experimental in vitro, se emplearon 105 muestras de bloques de resinas compuestas *Bulk Fill* conformadas en tres grupos, cada grupo estaba formado por 35 muestras en bloques de resina cuando la lámpara está cargada al 100 %, al 50 % y al 10 % respectivamente. Se confeccionó una matriz de acero inoxidable con las especificaciones que exige la norma ISO, por 20 segundos. La remoción del material no polimerizado se empleó la técnica de *scripting test* y obteniendo bloques de resina polimerizadas (endurecidas) las cuales han sido medidas con un micrómetro digital certificado y calibrado. **Resultados.** El nivel de la batería influenció significativamente entre los grupos p <0,01 disminuyendo la profundidad de polimerización a medida que disminuye el nivel de carga. **Conclusión.** Los diferentes niveles de batería de la unidad de curado LED inalámbricas si influyeron en la profundidad de polimerización.

Palabras clave
Polimerización, Resinas Compuestas, Pérdida de Carga.

Introduction

Patients in the field of dentistry have become increasingly interested and demanding long-lasting and esthetic treatment outcomes. Consequently, to meet this demand, the use of light-curing composite resins has increased. A resin composite produces a cure when its dimethacrylate resin monomer units react chemically, which creates a rigid cross-linked polymer network[i]. Because they can be inserted into cavities and light-cured in one step in increments up to 4-5 mm thick, block-filled composite resins were developed to save time and simplify the restorative process.[ii-iv]

Professionals should use curing lights that provide the appropriate wavelengths for each resin composite to achieve an adequate amount of polymerization of the material. Due of their narrower emission spectrum, their output peak being close to the 470 nm camphorquinone absorption peak, and their ability to run on battery-operated, according to some studies, light-emitting diode (LED) photoactivation curing lamps are the best choice.[iii]

LED photoactivation devices that require an electrical connection are less common than those that are cordless. Lithium battery is present in most LED devices used in dentistry, but little is known about how it affects the performance of the material polymerization process. The battery level of some LED units may be affected as the irradiance of the units decreases as it is discharged, which deteriorates the properties of the materials used.[v-vii] The objective of this research is to determine the influence of the loading of the battery of an LED lamp on the polymerization depth of a Bulk Fill resin.

Methodology

This is an experimental *in vitro* study conducted between August and October 2023 at the laboratory's facilities, which specialize in mechanical testing of materials and calibration at HIGH LAB.TECHNOLOGY, File N.º 04661-2023, located in Jr. Nepentas 364 Urb San Silvestre, San Juan de Lurigancho - Lima- Peru.

The data collection was performed after photoactivation to initiate the polymerization of the resins. The scraping test technique, endorsed by the ISO 4049 standard, was used, which involves the removal of polymerized resin with the head of a plastic spatula.[viii-xi] The processing technique performed was necessary for both the scraping test technique and the decimal micrometer (Mitutoyo), which included a calibration certification and a radiometer to verify the required intensity of the LED. Furthermore, the responsible person knew the ISO 4049 standard and the scraping test pattern (The ISO standard for resins mentions that it is the process in which the scraping is performed, which was codified as the depth of cure measurement).[v,xi-xiv] For the preparation of composite resin samples, a cylindrical steel matrix (4 mm x 10 mm) with a fixing ring was used, which was precisely made by a turner, to which an amalgam matrix holder was added with a matrix to make a tight fit. This was done to maintain the exact measurements, precision, and characteristics in all the samples to be elaborated, thereby avoiding variations and obtaining samples with a standardized pattern for each group. The perforation depth of the steel mold is 10 mm (height), and the internal circumference is 4 mm, complying with the ISO 4049 standard, in which the Beautifil - Bulk resin (manufactured by the Japanese company Shofu) was introduced in sufficient quantity to complete the matrix (4.5 g in "Universal" shade). The glass plate was placed on the base of the steel mold, and on top of the steel mold, the acetate matrix covered the resin cylinder. The polymerization process, was carried out using a Woodpecker LED lamp (manufactured by the Chinese company Woodpecker) was used for 20 seconds; the manufacturer's recommendations were followed at a light intensity (1000 mW / cm^2 ~ 2500 mW/ cm^2 power[2]), the P2 (regular) intensity mode was used, with a light emission power of 1200 mW/cm, and the recommended time is 20 seconds for good polymerization. The photopolymerization of 35 samples was carried out with the lamp at a load of 100 %. Then, the discharge was performed with vacuum shots until reaching 50 % of the battery capacity, and then 35 resin samples were photopolymerized again. Next, vacuum shots were performed until reaching 10 % of the battery capacity, and the last 35 resin samples were photopolymerized[xiv-xvi].

With the technique of scraping, the test ISO 4049 standard is used for the polymerization process of the resin blocks. The resin cylinder is then carefully removed. The scraping is performed with a plastic spatula that has a non-sharp edge on the lower part, which was not photopolymerized and softened due to a lack of light penetration. This process was performed by only one person to avoid variations of strength when doing the scraping and also the location of the LED lamp. After obtaining the resin cylinder, a digital measuring micrometer was used to make the appropriate measurements. It was measured three times, at the ends and the center, and the average was taken. To obtain the measured value of the cylinder, the corresponding notes were made on the data collection sheet. This result was divided into three parts, and the results of the depth of cure for each sample were obtained. The 105 resin blocks were distributed in groups of 35 blocks per group. In group 1 (control) were 35 cylinders light cured at 100 % battery charge, in group 2 were 35 cylinders light cured at 50 % battery charge, and in group 3 were 35 cylinders light cured at 10 % battery charge.

The wavelength of electromagnetic radiation that determines the color is of a measure of 400 to 700 nm; it was suggested to use the light of the dental lamps with

blue color for having a wavelength that goes from 400 to 515 nm; this wavelength is necessary for the activation or initiation of the photopolymerization process.[xvii-xx] The power or irradiance of the light coming out of the tip of a LED lamp used was measured with a digital radiometer, which is expressed radiometrically as intensity and its unit of measurement according to the international system is W/m², with units of power over area.[xiv,xix-xxi] The measurement of electromagnetic radiation in all wavelengths of the electromagnetic spectrum was used. Power is defined as the amount of electromagnetic energy emitted by a focus in a unit of time. Its unit of measurement is the joule per second (J/s), also known as the watt (W).[xxii]

The discharge of the battery in the Woodpecker LED lamp was performed to determine the percentage of the lamp's charge. Vacuum discharges were made until completely discharging the shots of the lamp, in which, using the simple rule of 3, the percentage in which the shots were found was determined. The lamp completed 606 cycles of 20 seconds each cycle, being 100 % of the cycles from 606 to 572, 50 % of the cycles from 303 to 268, and finally, 10 % of the cycles from 60 to 25.

Statistical methods

The data obtained from the experiment, duly certified by the laboratory, were analyzed using SPSS version 27 statistical programs, which included measures of central tendency, Shapiro-Wilk normality tests, and inferential analysis using the ANOVA hypothesis test.

Results

Tests were performed on 105 resin blocks, divided into three groups of 35 blocks per group. Group 1 control (100 %), Group 2 (50 %), Group 3 (10 %).

Table 1 shows the polymerization depth value of the Bulk Fill resin when the LED lamp is loaded at 10 %, presenting a mean of 3.890 mm and a standard deviation of 0.174 mm; the minimum value was 3.56 mm, and the maximum value was 4.17 mm. In contrast, when the LED lamp is loaded to 50 %, it obtained a mean and standard deviation of 4.078 ± 0.147 mm. The minimum value was 3.80 mm, and the maximum value was 4.36 mm. In the end, the polymerization depth value of the Bulk Fill resin, when the LED lamp is loaded at 100 %, presented a mean of 4.253 mm and a standard deviation of 0.187 mm. The minimum value was 3.80 mm, and the maximum value was 4.61 mm.

According to the results of the Shapiro-Wilk normality test, the data are normally distributed. Table 2 shows that according to the results of the ANOVA test, there are statistically significant differences ($p < 0.05$) between the three groups studied. It was observed that the battery charge of an LED lamp influences the depth of polymerization of a Bulk Fill resin.

The differences were observed the battery charge of a LED lamp at 10 % and 50 % with a p-value < 0.001, when the battery was charged at 10 % and 100 % with p-value < 0.001, and finally, when comparing the means of battery charge at 50 % and 100 %, showed significant differences were observed with a p-value < 0.001.

Table 1. Measurement of the polymerization depth of Bulk Fill resin according to the percentage of LED lamp load.

Battery charge	Mean	Standard deviation	Minimum depth	Maximum depth
10 %	3.890 mm	0,174	3.56 mm	4.17 mm
50 %	4.078 mm	0,147	3.80 mm	4.36 mm
100 %	4.253 mm	0,187	3.80 mm	4.61 mm

Table 2. Influence of the battery charge of an LED lamp on the depth of polymerization of a Bulk Fill resin.

Battery load	Mean	Standard deviation	p-value
10 %	3.890 mm	0,174	0,000
50 %	4.078 mm	0,147	0,000
100 %	4.253 mm	0,187	0,000

Discussion

The factors involved in the polymerization process are crucial to the success of treatments based on resinous materials, such as composite resin. One of these factors is the percentage of battery power used by LED lamp to proactive the composite resins, allowing for the conversion of monomers to polymers to occur. The final result is a fully polymerized (hardened) resin.[ii]

In a study by Pereira *et al.* (2016) it is shown that the load of an LED battery influences the physical, chemical, and mechanical properties of a composite resin as in the degree of conversion, sorption, and solubility of the resin samples[vi] coinciding with the present study in which the load influenced the depth of polymerization, resin property, affecting the chemical property, where the photoactivation of the composite resins is performed by the conversion of monomers to polymers in its entirety obtained by the light intensity emitted by LED lamps.

The findings regarding the measurement of the polymerization depth showed a statistically significant difference between the control and experimental groups, as the control group E1 (high level) had a battery percentage of 100 %. In contrast, the experimental groups E1 (medium level) were charged at 50 % and E2 (low level) at 10 %. Cardozo (2019) reported that the level of irradiance from LED units altered various properties of the resins; among them, the depth of polymerization was altered, which is consistent with the findings of this research.[x]

The polymerization process can be influenced by the brand and type of lamp used for photoactivation of the resin material. Tongtaksin conducted a study to determine the effectiveness of different high-power LED lamps on the depth of polymerization of Bulk Fill composite resin where the results obtained show that there is a significant difference in the depth of polymerization of Bulk Fill composite resin after being photopolymerized with different types of LED lamps; just as the battery percentage of the LED lamp is a factor that influences the polymerization process, so are the physical protection barriers at the tip of the LED lamps as a preventive measure in the control of cross-infection control.[vii]

Concerning LED lamps, currently generation lamps usually have better technical characteristics than second-generation and first-generation lamps; however, in a study by Horna in 2019, an Elipar LED lamp with a power of 1200 mW of second-generation power of 3M brand, polymerized better in terms of depth in Bulk Fill resins concerning the Valo LED lamp (manufactured by the U.S. company Ultradent Products, Inc.) of 1400mW of power, showing that the power does not influence the depth of polymerization, in contrast to this study, in which it was found to have an influence but about the level of the load.[xxiii]

Dentistry is a profession that is constantly being updated and improved, and even more so in the different dental materials that each time present better characteristics in their uses and duration, so it is recommended to carry out studies and constant updates of materials such as resins and LED lamps, among others, in order to know the limitations that they could present.

Conclusion

The polymerization process can be influenced by the type of lamp used for the photoactivation of the resin material (composite resin) in order to determine the effectiveness of different high-power LED lamps on the depth of polymerization of composite resin Bulk Fill type. The battery percentage of a third-generation LED lamp does influence the depth of cure of a Bulk Fill composite resin. Therefore, as the battery of an LED lamp is discharges, the irradiance level decreases, which is directly proportional to the light intensity emitted from the lamp tip; consequently, the polymerization of the resin will be affected.

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