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EVALUATION OF BATTERY LEVEL AND DISTANCE OF LED LIGHT CURING ON THE MICROHARDNESS OF BULK FILL COMPOSITE RESIN

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ABSTRACT

Objectives: to analyze the influence of the battery level and the distance from the light source have of a light-curing device on the microhardness of a bulk-fill composite resin. **Material and Methods:** the battery level of a Radii-Cal LED light curing device (SDI) was standardized (100% and 50%) using a radiometer. The distance from the light source to the composite resin was standardized with an acrylic matrix (0mm, 2mm, and 8mm). Thirty samples (4mm x 6mm) were made with the Filtek One Bulk Fill (3M/ESPE), divided into six groups (n = 5) based on two battery levels and the three distances from light source. They were subjected to the Vickers microhardness test, performing three superficial and three basal analyses. To perform comparisons between the groups, the F-test (ANOVA) and Tukey's multiple comparison was used with 5% of error margin. **Results:** The microhardness averages decreased when the light-curing distance was increased for each battery charge level. When analyzing the reduction in battery charge, it was found that some groups had significantly higher averages when photopolymerized at 100% charge. **Conclusions:** In view of the limitations of the present study, these results can negatively influence the clinical performance of bulk fill composites resins.

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INTRODUCTION

The properties of composite resins can be influenced by light activation, depending mainly on the performance of the curing unit (Silva, Poskus, Guimarães, 2008). Adequate photopolymerization depends on a series of factors such as the photoactivation technique, time, distance, intensity of light emitted, amount of guidance and well-defined protocols for the maintenance of photopolymerizers (Fatemeh *et al*., 2016; Furuse *et al*., 2016, Pereira *et al.*, 2016; Davidson, Gee, 2000), and, as more recently discussed, the battery levels of the photopolymerizers (Silva, Poskus, Guimarães, 2008; Aguirar *et al*., 2008). For many years, restorative materials have been polymerized by halogen light devices. However, these devices are no longer used due to their low luminous intensity and the fact that their lamps generate heat (Poggio *et al*., 2012).

Thus, LED photopolymerizers were introduced in the dental market, becoming the gold standard for photopolymerizing dental materials activated by light and revolutionizing the process of photopolymerizing oral biomaterials (Mouhat *et al*., 2017; Price *et al*., 2011). Clinically, composites face different tensions and can be subjected to high-stress situations. Concerns have been raised, however, regarding restoration fractures and wear (Ferracane, 2011). For the composite resin to have good physical and mechanical properties, there needs to be an optimal degree of conversion of the monomers into polymers (Tongtaksin *et al.*, 2017). The quality of the process of photopolymerizing composite resins can be evaluated using various tests, the most common being the microhardness test. This test has been used to predict the wear resistance of a material, its abrasion capacity, or the likelihood that it will be worn out by opposite dental structures (Pereira *et al*., 2016;

Espíndola-Castro *et al.*, 2020). Changes in microhardness can reflect the state of the setting reaction and the degree of polymerization of materials, the surface microhardness test thus being one of the indirect indicators of the degree of polymerization (Tarle *et al.*, 2015; Garousho *et al.,* 2016). Therefore, the aim of this study was to analyze the influence of battery level and light-curing distance of the light emitted by a light curing device on and the microhardness of bul fill composite resin. The null hypotheses tested are: (1) there is no influence on the battery level of the photopolymerizer on the microhardness of the bulk fill composite resin. (2) there is no influence of the distance from the light source on the microhardness of the bulk fill composite resin.

MATERIALS AND METHODS

This study was developed at the Multi-User Materials Research Laboratory of the Dental School, Universidade de Pernambuco. Initially, the battery level of a LED light curing (Radii-Cal LED, SDI, Victoria, Australia) was standardized. For this, the batteries were fully discharged and connected immediately afterward to an electrical power source to obtain their full charge (100% of the battery level), totaling three hours of charging, according to the manufacturer's instructions. The number of 25-second cycles during which the device was able to perform in continuous mode until it was fully discharged was then counted. One half of the value obtained represented the number of cycles where the device performed at a 50% load. An average total of 322 cycles with 100% battery level was obtained, resulting in, consequently, 161 cycles with 50% battery level.

The distance from the light source to the resin was standardized by an acrylic matrix with pre-established distances (D1: 0 mm, D2: 2 mm, and D3: 8 mm). Subsequently, the intensity of light emitted at each battery level was analyzed (100% and 50%) and the distance from the light source to the resin (0 mm, 2 mm, and 8 mm) was measured using a radiometer (Hilux, LedMax, SDI, Victoria, Australia) (Table 1). Thirty samples (five samples for each analysis) were made using Filtek ™ One Bulk Fill composite resin (3M-ESPE, Minnesota, USA) (Table 1) and selected from the same batch, in the A3 color. The samples were prepared using the single-increment technique in a metallic matrix composed of two threadable parts (Figures 1A and 1B), with a central hole of 6 mm in diameter and 4 mm in depth and surrounding walls of approximately 90º to facilitate the removal of the samples after light curing.[5] A polyester strip was positioned over the cavity and a 20 mm thick glass plate (Figures 1C and 1D) was placed on top of it, applying light pressure for 15 seconds to obtain a flat and uniform material surface. Afterward, the glass plate was removed and a 0.13 mm thick glass coverslip was placed on the polyester strip to standardize the light-curing distances (Figure 1E). Each sample from groups G1 to G6 was light-cured using the Radii-Cal LED light curing device (SDI) for the duration recommended by the manufacturer (25 s) (Figures 1E, 1F, and 1G). Subsequently, the samples were removed from the matrix (Figures 1H and 1I) and immersed in distilled water in a previously identified black plastic container. After 48 hours, each sample was subjected to the Vickers microhardness test, in the superficial and base regions. Six Vickers microhardness measurements were made on each of the samples, three on the superficial portion (facing the tip of the apparatus) and three on the base portion, using an Insize ISHV - D120 microdurometer (INSIZE - Loganville, Georgia, USA) (Figure 2A). The indentations were carried out with a load of 300 gf (Figure 2B). Associated with a time of 15 seconds, this load was sufficient for the tip of the diamond to penetrate the resin sample and promote a visible impression (Figure 2C). The Vickers microhardness calculation for each sample was obtained from the average of the three indentations performed on each tested surface. The data were expressed using the mean, standard deviation (mean ± SD). To perform comparisons between the groups, the F-test (ANOVA),

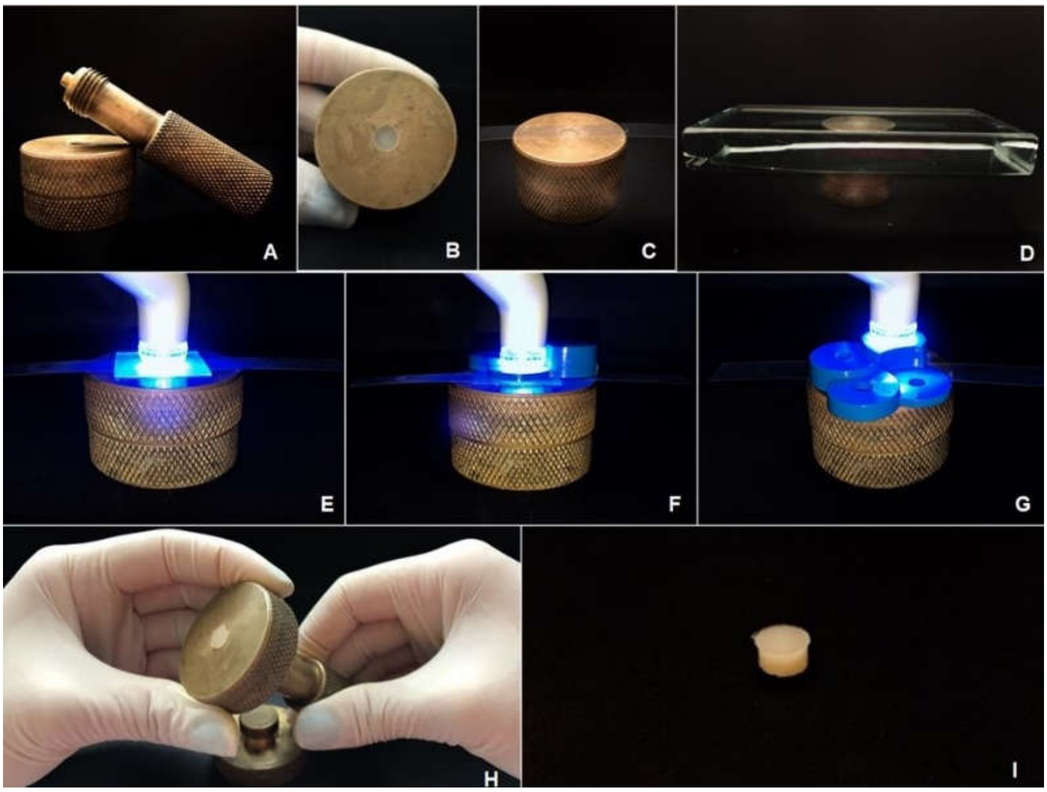

Figure 1.

Tukey's multiple comparison test, and the size test were used for significant differences, equal variances, and unequal variances, respectively. The F-test (ANOVA) was chosen because the normality of the data in each group was verified. The normality was verified using the Shapiro-Wilk test and Levene's F-test was performed to assess the equality of variances. The margin of error used in the statistical tests was 5%. The data were entered into an Excel spreadsheet and IBM SPSS Statistics version 23 was used to obtain the statistical calculations.

RESULTS

Table 2 shows the results of the superficial and base Vickers microhardness measurements in groups G1 to G6 (distances: 0 mm, 2 mm, and 8 mm and percentages of battery charge: 100% and 50%). This table highlights that, among the analyses carried out in the superficial portion, the lowest average occurred in group G6 (44.24), followed by group G3 (50.29). The highest mean (60.02) occurred in group G1 and the referred statistic ranged from 55.73 to 59.21 in the other three groups. Regarding the analyses in the base portion, the averages were considered null in groups G3 and G6, as the samples were not polymerized. In group G5 the average was 13.33, in group G2 it was 21.60, and it ranged from 32.45 to 38.78 in groups G1 and G4, being higher when the battery was at full load (100%). Significant differences were recorded between the groups for the surface and depth variables. Except between groups G1 (60.09), G2 (57.09), and G4 (59.68), a significant difference was found in the analysis of the surface portion, using the multiple comparison test. In the study of the base portion, significance was found among all pairs, except for groups G3 and G6, which had null results. The variability expressed by the variation coefficient was reduced as soon as the referred measures were less than 1/3 of the corresponding averages.

DISCUSSION

The first null hypothesis was rejected since there was a statistically significant influence on the battery level (50% and 100%) on the surface microhardness of the bulk fill composite resin between groups G2 and G5 and between groups G3 and G6 (Table 2). The second null hypothesis was also rejected since there was a statistically significant difference between the groups with different distances from the light source (0mm, 2mm and 8mm). In the assessment of surface microhardness with 100% battery, there was a significant difference between groups G1 and G2 when compared to group G3. With 50% battery, there was a statistical difference between the three different distances (G4, G5 and G6). For a proper polymerization of composite resins to occur, a certain degree of conversion of the resin monomers into polymer

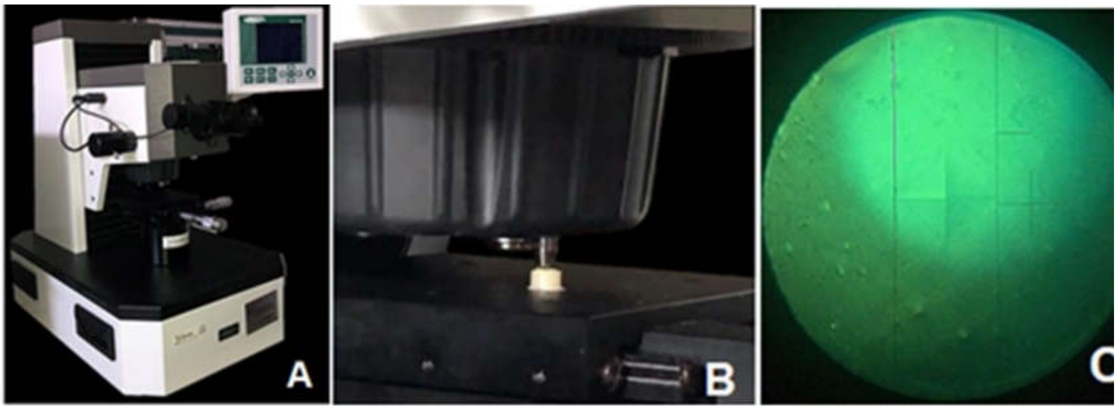

Figure 2.

Table 1. Division of groups according to battery level and distance from the light source

GROUPS	BATTERY LEVEL	DISTANCE	INTENSITY (mW/cm²)
G1	100%	0 mm	~1500
G2	100%	2 mm	~460
G3	100%	8 mm	~140
G4	50%	0 mm	~1100
G5	50%	2 mm	~340
G6	50%	8 mm	~70

Table 2. Surface and depth variables statistics according to distance and battery charge. Different superscript letters means statistical difference

	SURFACE	BASE
GROUP	AVERAGE ± DP	AVERAGE ± DP
G1: 0 mm + 100% Battery	60.02 ± 2.04^{A}	38.78 ± 1.78^{A}
G2: 2 mm + 100% Battery	57.13 ± 1.70^{A}	21.60 ± 3.28^{B}
G3: 8 mm + 100% Battery	50.29 ± 3.84^{B}	0.00 ± 0.00^{C}
G4: 0 mm + 50% Battery	59.21 ± 2.38^{A}	32.45 ± 2.32^{D}
G5: 2 mm + 50% Battery	55.73 ± 2.65^{C}	13.33 ± 0.96^{B}
G6: 8 mm + 50% Battery	44.24 ± 2.31^{D}	0.00 ± 0.00^{C}
p-value	$P^{(1)}<0.001$	$P^{(2)}<0.001$

(1) Through the F-test (ANOVA) by Tukey's multiple comparison.
(2) Through the F-test (ANOVA) by Tamhane's multiple comparison.

chains is necessary (Araújo *et al.*, 2008). The Vickers microhardness test is a reliable instrument and is commonly used as a method to assess the quality of resin polymerization (Tongtaksin *et al.,* 2017). The clinical longevity of direct composite resin restorations is essentially related to the photopolymerization protocol. From this perspective, light intensity, wavelength, distance from the photopolymerizer, and exposure time influence the conversion of monomers to polymers (Besegato *et al.*, 2019). Most resins use camphorquinone, which has a maximum absorption peak at 468 nm, as an initiator. To have an adequate degree of conversion, the range of the photoactivation system must be set to maximum sensitivity to camphorquinone (Caldas *et al.,* 2003). The Radii-Cal (SDI) photopolymerizer produces a strong blue light in waves that vary between 440 - 480 nm, which are the required limits for products containing camphorquinone, such as the Filtek ™ One Bulk Fill (3M ESPE) composite resin used in this study. Changes in light pattern, such as insufficient light intensity, can reduce some of the properties of the resin, such as microhardness and resistance. This is the reason why intensities above 400 mW/cm², with a time of 20 s, are recommended to photoactivate 2 mm increments of a conventional resin (Davidson, Gee, 2000; Sobrinho*et al.,* 2000). For the bulk-fill resin used in the present study, 4 mm increments are recommended.

According to Table 1, intensity values greater than 400 mW/cm² were obtained in groups G1, G4, and G2 (1500 mW/cm², 1100 mW/cm², and 460 mW/cm², respectively) during photopolymerization, thus reaching irradiance values within the ideal photopolymerization range. However, this did not happen in groups G5, G3, and G6 (340 mW/cm², 140 mW/cm², and 70 mW/cm², respectively), which showed values below 400 mW/cm², which indicates that the battery level and the distance from the wireless LED unit can affect the light intensity of the equipment. This can be explained by the fact that the light intensity of the LED unit gradually decreased when the battery charge was reduced and distance from the wireless LED unit was increased (Aguirar *et al.*, 2008). Therefore, the intensity of a LED light-curing unit should be assessed during the life of the battery charge, to ensure that sufficient light intensity is generated (Aguirar *et al.*, 2008; Tongtaksin *et al.*, 2017). A study by Silva, Poskus and Guimarães (2008) also demonstrated that the different polymerization methods can influence hardness, flexural strength and flexural modulus. This reinforces the results obtained in this research paper, presented in Table 2, which show that the microhardness of the samples, in the superficial portion, in group G6, and in the deep portion, in groups G4 and G5, was reduced by the lower light intensity emitted in a 50% battery charge. The samples in these groups had significantly lower microhardness values when compared to groups G3 (superficial portion), G1, and G2 (deep portion), photopolymerized at 100% load. In the present study, the lowest microhardness values were found when the light intensity was below 300 mW/cm². Therefore, it is important for light-curing devices to remain at a constant charge of 100%, or close, so that the light intensity is high and stable, guaranteeing the appropriate polymerization of the composite resin (Tongtaksin *et al.,* 2017; Haenel*et al.*, 2015). According to studies by Erdemir *et al.* (2013), materials with low surface hardness are more susceptible to roughness and this can compromise the fatigue resistance of the material and cause premature restoration failure.

In studies by Aromaa, Lassila, and Vallittu (2017) and Caldas *et al.* (2003) it was found that increasing the distance from the photopolymerization tip to the surface of the composite resin also decreases the light intensity, which affects restoration. This confirms the results of the present research, explained in Table 2, in which the microhardness of the samples in all groups reduced significantly with the increase of the photoactivation distance, both in the superficial and the deep portions. Regarding the polymerization of the deepest portion of the resin composite increment, it was observed in a study by Fowler, Swartz, and Moore (1994) that the microhardness of the superficial portion was superior to that of the deepest region, for all polymerized samples. Similar results were found in this study. As shown in Table 2, all surface microhardness values were higher than the microhardness values observed in the deep portions of the samples. The superficial region is closer than other regions to the photoactivating tip of the device, there is practically no interference with light transmission, which reaches the surface area with the greatest possible intensity. However, for the deep region, the light needs to pass through the entire composite resin body, being partially absorbed or reflected, attenuating the intensity and reducing the effectiveness of photoactivation and, consequently, polymerization in the deeper portions of the material, which corroborates with our results (Kim *et al.,* 2015; Nagi, Moharam, Zaazou, 2015; Colak, Ercan, Hamidi, 2016). Despite being an *in vitro* study, with the associated limitations of a study of this type, the present study showed a statistically significant difference between some of the superficial and deep microhardness values. In this way, complementary tests in this area must be carried out to investigate the light/battery intensity in other LED light curing devices, as the clinical success of a composite resin restoration depends on the mechanical characteristics of the material used, which, when within the limits expected, reduce the need for future replacements of restorations, preserving healthy dental tissue.

Conclusions

- The light intensities emitted by the LED light apparatus decreased with the increase in the light-curing distance, influencing the reduction of the microhardness of the samples.
- The reduction in the level of the light-curing battery influenced microhardness in the following cases: in the superficial portion, in the 8 mm groups with 100% and 50% battery charge and in the deep portion, in the 0 mm and 2 mm groups, at both levels of battery charge.
- The deep portion of the light-cured samples at 8 mm distance (G3 and G6), at 100% and 50% battery charge, remained in plastic form, making it impossible to evaluate microhardness.

Conflicts of interest: The authors declare that they have no conflicts of interest.

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