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Battery Levels of a Light Emitting Diode Unit Affects the Properties of Various Flowable Composites

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Abstract

Background: The battery levels may affect the light intensity of light-emitting diode (LED) curing units which can, indeed, directly influence the various properties of composite resins that are polymerized by light activation. Thus, this study aimed to evaluate the effect of battery levels of a cordless LED unit on the various properties of composite resins polymerized by light activation.

Methods: Firstly, the light intensity of the cordless LED unit (Elipar Deep Cure, 3M ESPE) was individually checked and 88 composite discs with the dimensions of 8 × 4 mm were prepared from 2 universal (Estelite Palfique [Tokuyama]; Nova Compo HF [Imicryl Dental]) and 2 bulk-fill composites (Tetric N-Ceram Bulk [Ivoclar Vivadent]; Beautifil-Bulk Flowable [Shofu]). The polymerization process was obtained at different battery levels: high level (HL, 100%), and low level (LL, 10%). The parameters evaluated included the degree of conversion (DC), color, and top/bottom microhardness scores. Data were statistically analyzed, with significance set at $P < .05$.

Results: The composite materials tested in this study exhibited significantly different scores across the parameters evaluated ($P < .05$). However, aside from the DC, the changes in color and the top/bottom microhardness scores were only numerically significant. The LL battery level for all tested composites demonstrated a significantly lower DC compared to the HL samples ($P < .05$).

Conclusion: The varying battery levels of the cordless LED curing unit affect the DC of the tested composites. Therefore, it is essential to routinely check the battery levels of LED units to ensure adequate light intensity during the polymerization process.

Keywords: Battery level, degree of conversion, depth of cure, flowable composites, light intensity

INTRODUCTION

In the 1980s, resin composites became standard materials for dental restorations.[1] Since then, there has been a continual advancement in the development of novel resin-based composite materials, each featuring unique chemical formulations. These innovations have emerged in response to the needs of both clinicians and patients, as well as to address failures observed in existing materials over time. As a result, various groups of materials have been introduced to the category of resin-based dental materials.

The development of bulk-fill composites may be counted as the latest advancements of resin-based materials, which benefit clinicians significantly. These materials can be

What is already known on this topic?

- *Light-emitting diode (LED) curing units are widely used in clinical practice for the polymerization of resin-based composites. The irradiance (light intensity) of cordless LED units may decrease as the battery level drops, potentially compromising polymerization.*
- *Inadequate polymerization can negatively affect the mechanical and physical properties of resin-based composites—such as microhardness and color stability, which may lead to reduced clinical performance and restoration longevity.*

What this study adds on this topic?

- *Although low battery levels in the cordless LED curing unit did not affect the microhardness and color stability of resin composites, they significantly reduced the degree of conversion (DC) in all tested materials, except for Tetric N-Ceram Bulk Fill. The Tetric N-Ceram Bulk Fill group exhibited the highest depth of cure among all groups. This may be attributed to the specialized photoinitiator system and higher light transmittance, which enable better performance under low battery conditions.*
- *Color stability (ΔE_{00} values) was not significantly influenced by battery level, suggesting that visual outcomes might not reflect underlying deficiencies in polymerization.*
- *Battery levels of LED curing units significantly affect light intensity. Therefore, routine monitoring of battery status is essential in clinical practice to ensure sufficient polymerization and achieve durable, long-lasting resin composite restorations.*

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layered up to 4-5 mm in cavities, allowing clinicians to save time and effort during procedures. This improvement is primarily due to changes in the monomer composition, including partially aromatic urethane dimethacrylate and highly branched methacrylates, which enable the polymerization of bulk-fill composites in thicker layers.[2] However, challenges such as light attenuation may still impede adequate polymerization of these improved bulk-fill composites in deeper layers.[2]

Another recent innovation in dental materials is giomers, which can be considered resin composites with ion-releasing capabilities. A unique feature of these composite resins is that only the outer part of the surface pre-reacted glass-ionomer particles, known as (S-PRG) fillers, interacts with polyacrylic acid, while the core remains intact.[3] This ion-releasing mechanism allows the material to maintain its mechanical properties while also providing therapeutic effects.[3] A flowable version of giomers has also been introduced; however, regardless of viscosity differences, all giomer materials must be adequately polymerized to ensure they achieve their intended properties.

The polymerization process in composite resins is initiated by light curing, with radiant exposure being one of the most crucial parameters.[1] Radiant exposure can be defined as the combination of irradiance and its duration delivered by light-curing units (LCUs).[1] It is believed that radiant exposure is proportionally related to the polymerization of resin-based materials. When radiant exposure increases, more photons reach the photoinitiators in the composite resin, activating them and allowing them to interact with amines, which ultimately leads to the formation of carbon double bonds (C=C) in the monomer.[1,4] However, studies have shown that the irradiance from LCUs can be affected by the battery charge. When light-emitting diode (LED) curing units discharge, their irradiance decreases, weakening the structural properties of composite resins.[5,6] Consequently, the properties may be compromised if the curing process is inadequate. Given that the oral environment is dynamic and subject to significant forces, thermal fluctuations, and functional cycles, insufficient polymerization may lead to a reduction in the longevity of restorations. Therefore, it is essential to evaluate some of the structural properties of commonly applied resin composites under both high- and low-battery conditions.

One of the most important factors affecting the longevity of composites is the degree of conversion (DC), which is significantly influenced by irradiance. This, in turn, affects the final properties of resin composites.[5,7] Additionally, microhardness measurements provide insights into the depth of cure of resin composites. Moreover, bottom-to-top microhardness measurements indicate the extent of conversion at the deeper surfaces of the materials.[8]

It is also noteworthy that the microhardness and DC levels of resin-based materials can be adversely affected by colorants present in the oral environment. Numerous studies have evaluated various LCUs,[5,9,10] making it pertinent to investigate the DC, microhardness, depth of cure, and color values of current resin composites polymerized with high- or low-power settings.

Therefore, the aim of this study was to evaluate how high- and low- battery levels of a LED curing unit affect the physical (color) and mechanical properties (DC and microhardness) of various resin-based composites. The tested null hypothesis was that different battery levels do not influence the relevant properties of the resin-based composites.

MATERIAL AND METHODS

The methodology of the present study is designed without any human or human-related subjects and based solely in in vitro conditions. Therefore, no ethical approval or consent was necessarily obtained.

Light Intensity Measurement

A fully charged LED LCU was involved in the current study (Table 1). The light intensity was measured with a LED radiometer (Kerr, Orange, CA, USA). The light guide was positioned over the radiometer sensor, and the light intensity was recorded in mW/cm^2. To simulate the clinical procedures, the LCU was used for 20 seconds repeatedly until the battery was completely discharged, and the light intensity was obtained after every 10 activations. The maximum number of these cycles of 20 seconds with a full battery (100%) was determined. According to that data, the number of cycles regarding 10% battery levels was set.[5]

Sample Preparation

A total of 88 disc-shaped samples (n=11) of a conventional microhybrid composite resin (Palfique Estelite; Tokuyama Dental, Tokuyama, Japan) and 3 flowable composites of a giomer (Beautifil Bulk Flowable; Shofu, Kyoto, Japan), a bulk-fill (Tetric N-Flow Bulk Fill; Ivoclar Vivadent, Liechtenstein) and a nanohybrid (Nova Compo HF Flow; Imicryl, Konya, Türkiye) with the shade of A2, were obtained by using a cylindrical mold (8 mm × 4 mm). Samples were covered with a transparent Mylar strip and a glass slide on the top. After the removal of the excess material, the tip of the LCU covered the surface of the samples completely at a degree of 90°. Except for the bulk-fill group, all samples were applied to the mold in 2 consecutive layers. Bulk-fill group was applied in only 1 layer. Then, each sample was then light-cured with the LCU fully charged (100% battery level) for 20 seconds and stored in the stove for 24 hours at 37°C. The LCU was then used until the battery level decreased by 10%, and the samples of the low battery group were obtained. All samples were stored in distilled water at 37 ± 1°C for 24 hours for post-polymerization. The top surfaces of the samples were polished with flexible aluminum oxide discs (Sof-Lex; 3M ESPE, St. Paul, MN, USA) under running water for 15 seconds

Table 1. Materials and Equipments Used in the Study

Material	Type	Brand	Content
Palfique Estelite (PE)	Microhybrid	Tokuyama Corp., Tokuyama, Japan	BisGMA, TEGDMA 50-100 nm spherical silica-zirconia filler and prepolimerized silica-zirconia (82% by weight)
Beautifil Bulk Flowable (BB)	Bulkfill giomer	Shofu, Kyoto, Japan	BisGMA, BisMPEPP, TMGDMA FAlSi glass (73% by weight)
Tetric N-Flow Bulk Fill (TN)	Nanohybrid bulkfill flowable	Ivoclar Vivadent, Liehtenstein	BisGMA, UDMA, TEGDMA. Barium glass, ytterbium trifluoride, mixed oxid, silicone dioxid (68.2% by weight)
Nova Compo HF Flow (NC)	Nanohybrid flowable	Imicryl, Konya, Türkiye	Bis-GMA, TEGDMA, and hydrophobic aromatic dimethacrylate, UDMA, Bis-MEP, silanated barium glass, ytterbium, silanated higly dispersed silicon dioxide, zirconia, prepolymer (68% by weight)
Elipar Deep Cure	LED light curing unit (10 mm tip)	3M ESPE, St. Paul, MN, USA	–

Bis-GMA, 2, 2-bis [4-(2-hydroxy-3-methacryloxy propoxy) phenylene] propane; bis-MEP, Bis[2-(methacryloyloxy)ethyl] phosphate; BisMPEPP, 2,2-bis(4-methacryloxy poly-ethoxyphenyl)propane; TEGDMA, triethyleneglycol dimethacrylate, UDMA, urethanedimethacrylate.

for each step. Afterward, the polished surfaces were marked with a water-resistant pen. Polishing was performed by the same clinician to eliminate operator-dependent variables and Sof-Lex discs were renewed after the third use. Then, all of the samples were numbered and kept in artificial saliva at 37 ± 1°C for post-polymerization of 24 hours which is also the beginning of the testing.

EVALUATIONS OF THE PROPERTIES OF THE COMPOSITES

Hardness Ratio

The Vickers hardness scores (VHN) were obtained using a hardness tester (Innovatest, Manual Impressions XT Hardness Testing Instrument, Software Version 1.07, Maastricht, the Netherlands), with a load of 300 g and dwell time of 15 seconds, on the top and bottom surfaces of the samples. Three consecutive measurements were obtained with each indentation spaced 100 µm apart from the previous measurement. Following the calculation of the mean VHN scores, the hardness ratio (hardness of the bottom surface/hardness of the top surface) of the samples was determined.[11]

Degree of Conversion

The DC of the samples was accessed in a Fourier transform infrared spectroscopy unit (FT/IR 4700 Jasco, Easton, USA) in attenuated reflectance mode. Spectra were acquired between 1500 and 1750 cm^{-1} with a resolution of 1 cm^{-1}, an exposure time of 10 seconds, and 10 accumulations. The number of remaining converted and unconverted carbon double bonds was calculated by comparing the percentage of aliphatic C=C (vinyl) (1637 cm^{-1}) and aromatic C=C absorption (1608 cm^{01}) between cured and uncured samples. Degree of conversion of each composite was calculated by comparing the area and amplitude of particular peaks derived from the uncured and cured samples. Then, the DC was calculated by the following equation:[12]

$$DC\% = 1 - \frac{[Abs(aliphatic)/Abs(aromatic)]polymer}{[Abs(aliphatic)/Abs(aromatic)]monomer}$$

Color Measurements

Color measurements of the samples were performed against a white background using spectrophotometry (Vita EasyShade V) according to CIEDE2000. The contact guide of the device was positioned on the center of the surfaces of the samples of groups cured with 2 different battery levels. Three consecutive readings from separate points were obtained for each sample and then the scores were averaged. All data from the coordinates were then transferred to the CIEDE2000 formula which was calculated as (ΔE00).[13]

"ΔL," "ΔC," and "ΔH" are the differences in lightness, chroma, and hue, respectively. "RT" terms for the interaction between chroma and hue in the blue region. "SL," "SC," and "SH" are weighting functions that arrange the total color difference in the location of the color difference pair in "L" coordinates. The parametric factors (k_L, k_C, and k_H) were all set to 1.0 in the present study.

Statistical Analysis

Data were analyzed in the Statistical Package for Social Sciences version 23.0 software (IBM Corp.; Armonk, NY, USA). The suitability of the data for normal distribution was examined with Shapiro–Wilk tests. Tukey HSD test was used to compare normally distributed microhardness values according to material, battery, and surface. For the comparison of abnormally distributed conversion values according to material and battery, the 2-way Robust test was used and multiple comparisons were examined with the Bonferroni test. Color differences were analyzed with the Kruskal–Wallis test in which the data was abnormally distributed among groups as well. The significance level was set at $P < .05$.

RESULTS

To identify the effects of different battery levels of the LED on flowable resin composites, scores and comparisons of hardness ratio, DC, and change of color (ΔE_{00}) are given in Tables 3-5. Multivariate Robust test showed that there are statistically significant differences in the microhardness of the surfaces ($P < .001$), interactions among microhardness scores of materials, and both of the battery levels ($P = .002$) and surfaces (top and bottom) ($P < .001$). However, there is no significant interaction between the battery levels and microhardness levels of surfaces ($P = .756$). The interaction of all the variables regarding microhardness levels is shown in Table 2.

Table 2. Comparison of Microhardness Values According to Material, Battery Level and Sample's Surfaces

	Sum of Square	Mean Square	*P*
Material	234.130	78.040	.023
Battery level	8.820	8.820	.543
Surfaces	3508.780	3508.780	<.001
Material × battery level	357.570	119.190	.002
Material × surfaces	546.110	182.040	<.001
Battery level × surfaces	2.310	2.310	.756
Material × battery level × surfaces	634.360	211.450	<.001

The obtained VHN scores and hardness ratio of the tested groups are given in Table 3.

According to the obtained results, battery levels did not have a significant effect on the microhardness scores of the tested composites ($P = .543$). However, there is a significant difference among the microhardness scores of the groups regarding the top and bottom surfaces ($P < .001$). There are no significant differences among the top surfaces of the tested composites cured with 100% battery level ($P > .05$). Multiple comparisons determined that the bottom microhardness ratios of the groups Tetric-N Flow Bulkfil (TN) and Beautifil Bulk Flowable (BB) are significantly higher than the other groups. The depth of cure of the TN group is significantly the highest among all ($P < .05$).

Comparing the groups cured with 10% battery, the Nova Compo HF Flow (NC) group shows the highest microhardness scores without any significant difference. Palfique Estelite (PE) group shows the lowest top surface microhardness values which are significantly different from NC and TN groups. Tetric-N Flow Bulkfil group also has significantly the highest microhardness score of the bottom surface, and there are no significant differences among other groups ($P > .05$). There is no significant difference among the depth of cure ratios of PE and TN groups. Nova Compo HF Flow had significantly the lowest hardness ratio among all.

According to the Robust test, there are significant differences among the DC levels of tested materials ($P < .001$) as well as the interaction between materials and battery levels ($P < .001$). Besides, battery level did not significantly affect the DC level of tested materials ($P = .762$). The obtained DC scores of the tested groups are shown in Table 4.

Since there was not a normal distribution, significance was evaluated by the "median" scores of the groups according to the Bonferroni test. Regarding the groups cured with 100%, TN and BB had significantly higher DC ratios and NC and PE ($P < .001$). Besides, there are no significant differences among the DC ratios of BB and PE groups. NC group shows the lowest DC ratio among all without any significant difference in the PE group.

Regarding the groups cured with 10%, there are no significant differences among the PE, BB, and NC groups ($P > .05$). Tetric-N Flow Bulkfil group shows the highest DC ratio among all without any significant difference in the BB group.

The results for the change of color (ΔE_{00}) scores of the tested groups are given in Table 5.

Since there was not a normal distribution, significance was evaluated by "median" scores of the groups according to the Kruskal-Wallis test. There are no significant differences among the ΔE_{00} scores of the resin composites cured either with 100% or 10% battery levels ($P = .187$).

DISCUSSION

Due to the findings of the present study, it is determined that the battery level of the LED curing unit affects several

Table 3. Significancy and Standard Deviation Among Vickers Hardness Scores (VHN) and Hardness Ratio of Tested Groups

		Materials			
Battery Level	Measurement	Palfique Estelite (PE)	Beautifil Bulk Flowable (BB)	Nova Compo HF Flow (NC)	Tetric-N Flow Bulkfill (TN)
100%	Top surface	$54.2 \pm 3.7^{A,B}$	57.0 ± 3.5^{A}	$54.8 \pm 4.4^{A,B}$	$54.8 \pm 4.3^{A,B}$
	Bottom surface	$43.4 \pm 5.2^{E,H}$	46.5 ± 2.0^{C}	45.6 ± 6.8^{D}	$48.7 \pm 1.5^{B,C}$
	Depth of cure ratios	$80\%^{f}$	$81.6\%^{f}$	$83.2\%^{f}$	$88.9\%^{g}$
10%	Top surface	$51.7 \pm 5.4^{A,B,C,D}$	$53.7 \pm 5.5^{A,B,C}$	57.6 ± 3.6^{A}	56.8 ± 4.2^{A}
	Bottom surface	$43.0 \pm 7.0^{E,H}$	$41.3 \pm 7.2^{E,H}$	38.4 ± 6.3^{H}	$47.8 \pm 2.1^{B,C}$
	Depth of cure ratios	$83.2\%^{f}$	$76.9\%^{i}$	$66.7\%^{j}$	$84.1\%^{f}$

Different uppercase letters show significancy among surfaces ($P < .05$). Different lowercase letters show significancy among hardness ratios ($P < .05$).

Table 4. Mean with Standard Deviation Values Among Degree of Conversion of Tested Groups

Materials	Battery Level			
	100%		10%	
	Mean ± SD	Median (min.-max.)	Mean ± SD	Median (min.-max.)
Palfique Estelite (PE)	58.6 ± 2.9	60.1 (53.4-60.2)^{A,C}	57.3 ± 4.2	57.0 (51.3-62.2)^{A,C}
Beautifil Bulk Flowable (BB)	67.3 ± 2.7	68.3 (63.8-69.9)^{A,B}	64.7 ± 6.1	67.8 (56.2-69.9)^{A,B,C}
Nova Compo HF Flow (NC)	49.0 ± 2.5	50.2 (45.7-51.4)^{C}	48.6 ± 4.3	51.0 (42.4-52.4)^{C}
Tetric-N Flow Bulkfil (TN)	72.4 ± 1.9	72.4 (70.0-75.2)^{B}	73.8 ± 0.9	73.8 (72.7-74.7)^{B}

Different uppercase letters show significancy among groups ($P < .05$).
min., minimum; max., maximum.

mechanical properties, such as microhardness, depth of cure, and DC in various resin-based composites. The only physical property tested that showed no significant change between high and low battery levels of the LCU was color difference (ΔE_{00}). Therefore, the null hypothesis is partially accepted. This outcome may be attributed to the voltage of the LCU, which decreased as the battery level was lowered, resulting in reduced light intensity from the device.

It is important to note that the materials tested are typically designed for use in both anterior and posterior regions. The differences in structure among the tested material groups may have contributed to the significant variations observed in mechanical properties. Factors related to light curing or polymerization include the type of monomer, the amount of the resin matrix, the type of fillers used, and the interactions between these components.[1] The polymerization process involves photoinitiator systems in the resin matrix that react with tertiary amines and other monomers to generate free radicals.[14]

Some of the primary monomers found in commercial resin composites are known to be more reactive. For instance, BisEMA has longer and more flexible molecules, and it has been reported to achieve a higher conversion ratio when combined with BisGMA.[15] However, this was not demonstrated in the current study. The only resin composite containing various types of methacrylates (NC group) did not show significantly higher DC values or depth of cure ratios. In fact, the NC group exhibited lower DC values than the recommended threshold of at least 55% for both tested battery levels.[16] Additionally, current literature supports the partial replacement of BisGMA with UDMA, which offers greater flexibility, and TEGDMA, which has higher mobility and a lower molecular weight.[17] This replacement aims to mitigate the disadvantages associated with low monomer mobility and crosslinking, which can lead to lower DC at low battery levels. However, in the current study, the battery level significantly impacted DC scores only based on the material used.

Table 5 Mean with Standard Deviation Values and Median with Min. and Max. Values of ΔE_{00} Scores of Tested Groups

Materials	ΔE_{00} Scores		P
	Mean ± SD	Median (min.-max.)	
Palfique Estelite (PE)	1.46 ± 0.52	1.55 (0.89-2.52)^{A}	
Beautifil Bulk Flowable (BB)	2.07 ± 1.62	1.2 (0.3-4.26)^{A}	
Nova Compo HF Flow (NC)	2.2 ± 1.2	2.08 (0.83-4.44)^{A}	
Tetric-N Flow Bulkfil (TN)	2.87 ± 1.67	2.28 (0.82-5.09)^{A}	
			.187

Same uppercase letters show there is no significancy among groups ($P > .05$).
min., minimum; max., maximum.

In the current study, 3 of the 4 tested resin composites were found to be flowable, incorporating TEGDMA as the viscosity-diluent monomer. Due to its higher mobility and lower molecular weight, TEGDMA is assumed to enhance the monomer conversion of C=C double bonds. The flowable resin composites exhibited varied outcomes, primarily depending on their material composition. Both flowable resin composite groups, TN and BB, demonstrated superior DC scores compared to the packable composite group, PE, with a significant difference noted between them. These findings may be attributed to the structural differences during polymerization in the TN and BB groups, which may also be related to the light transmission features of the materials. Consequently, the viscosity and the structures based solely on monomers do not effectively enhance the DC.

The depth of cure does not refer to the quantity of material cured by light radiation; rather, it represents the outcome measured by the microhardness ratio of the surfaces. However, no consistent results were observed regarding the depth of cure (the bottom/top microhardness ratio), as significant material-dependent differences were evident. Although there was no significant interaction between battery levels and surface microhardness levels, the microhardness ratios of the top and bottom surfaces were notably influenced by the low battery level. This outcome may be linked to the light transmission capabilities of the various tested structures in the study. The only bulk-fill composite included in the methodology is recognized for its more translucent structure, which facilitates higher light transmission.[18] Moreover, it contains a distinct photoinitiator, Ivocerin, which has the ability to absorb more light in the spectrum of 400-450 nm. Unlike camphorquinone/amine-based photoinitiation systems found in the other tested materials, the germanium-based Ivocerin generates at least two radicals for the photoinitiation of the polymerization process.[12]

This difference could lead to more efficient photoinitiation, thereby resulting in significantly higher microhardness scores and depth of cure values in high-battery groups of the bulk-fill composite.

It is evident that the depth of cure ratios were significantly reduced, with the exception of the conventional packable composite group, PE. The PE group did not show any significant changes, likely due to its highest filler content and the spherical shape of its fillers, which is unique among the tested composites. Many studies[17,19,20] concluded that the depth of cure results for resin composites are primarily dependent on the material used. Moreover, the filler ratio can alter the filler-matrix interface, affecting light scattering within the composite structure.[20] As a result, the spherical form of the fillers may have influenced light transmission through the matrix, leading to improved depth of cure results. However, only the BB and NC groups cured at low battery levels exhibited a curing depth lower than the acceptable threshold of a 0.8 bottom-to-top microhardness ratio.[20] While the combination of reduced light emission from the low battery levels and material differences may primarily explain these subpar results, there could be additional factors affecting some of the tested groups. The samples were prepared in steel molds with metallic surfaces that reflect light, suggesting the tested composites might achieve higher depth of cure ratios in an oral environment.[21]

Furthermore, giomer-based composites, such as Beautifil bulk and flowable resin composites, utilize softer S-PRG fillers compared to the zirconia or silica fillers found in the other tested materials.[21] This difference may contribute to the significantly lower depth of cure values observed in the low-battery level groups. It is also important to note that all samples were stored in artificial saliva to simulate the oral environment. According to recent findings,[22] the lower filler ratio and the presence of TEGDMA in the organic matrix could have increased the water sorption of the tested NC composite under these storage conditions.

On the other hand, color measurements of the groups were incorporated into the methodology to evaluate whether lower voltage levels could affect the monomer conversion or microhardness values, potentially causing changes in color due to inadequate curing of the organic matrix. However, battery levels did not significantly impact either the DC or the color changes (ΔE_{00} scores) of the groups (P=.762 and P=.187, respectively). The observed differences were attributed to the structures of the tested resin-based materials. Additionally, DC[5] and the depth of cure[23] were linked to color alterations resulting from inadequate curing. To the authors' knowledge, this is the first study to evaluate color changes during curing with different battery levels using CIEDE2000 formula. Nevertheless, there are limitations not introduced by the in vitro conditions. Measurements were taken immediately after post-polymerization, so significant differences may have occurred if the immersion in artificial saliva had been extended. This assumption applies to the other tested parameters as well, as unreacted monomers may have been released and influenced the scores.

The current study found that while the DC values and color changes were not influenced by battery level, the microhardness at the bottom of the specimens decreased significantly. It appears that the battery level affects monomer conversion, likely due to the direct impact of light emission; however, the light transmission to the lower areas was inadequate, particularly in the giomer and conventional flow composite groups. Consequently, significant changes in properties related to battery levels were observed, which can be attributed to the structural differences among the tested materials. Clinicians should ensure that LED curing units are fully charged to prevent potential issues in daily practice. Further laboratory research is needed with different light-activated materials to assess how battery levels affect various properties of these materials.

Ethics Committee Approval: The methodology of the present study is designed without any human or human-related subjects and based solely in *in vitro* conditions. Therefore, no ethical approval was necessarily obtained.

Informed Consent: The methodology of the present study is designed without any human or human-related subjects and based solely in *in vitro* conditions. Therefore, no informed consent was necessarily obtained.

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