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Influence of Battery Level of a Cordless LED Unit on the Properties of a Nanofilled Composite Resin

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Clinical Relevance

Cordless light-curing light-emitting diode units are widely used in dental practice. Clinicians must charge this equipment carefully because of the possible influence of battery voltage/light intensity on the properties of composite resin restorations.

SUMMARY

The properties of composite resins can be influenced by light activation, depending primarily on the performance of the curing unit. The aim of this study was to evaluate how different battery levels of a cordless light-emitting diode (LED) unit influence the properties of a nanofilled composite resin. First, the battery voltage and light intensity of the cordless LED unit were individually checked for all light-curing cycles. Then, composite resin discs were prepared and light-cured at different battery levels: high level (HL, 100%), medium level (ML, 50%), and low level (LL, 10%). The degree of conversion, diametral tensile strength, sorption, and solubility of the specimens were tested. Data were checked for homoscedasticity and submitted to one-way analysis of variance followed by Tukey honestly significant difference and Pearson correlation tests ($p<0.05$). The battery voltage and light intensity varied significantly among the groups ($p<0.001$). The LL group presented a lower degree of conversion than the HL and

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ML groups ($p<0.001$), which shower similar results ($p=0.182$). Lower diametral tensile strength was also verified for the LL group when compared with the HL and ML groups ($p<0.001$), which presented no difference ($p=0.052$). Positive correlation was observed between the light intensity and the parameters studied, with the exception of sorption and solubility ($p<0.001$). The ML and LL groups showed higher sorption than the HL group ($p<0.001$), but no difference was verified between the first two groups ($p=0.535$). No significant differences were found for solubility between the ML and LL groups ($p=0.104$), but the HL group presented lower values ($p<0.001$). The different battery levels of the cordless LED curing unit influenced all the properties of the nanofilled composite resin evaluated.

INTRODUCTION

Since the early 1980s, light-cured composite-based materials have been routinely used for esthetic dental restorations and have been widely used for anterior and posterior applications. The increased popularity of light-activated composites took place because of their suitable biocompatibility, mechanical properties and color stability.[1] Unfortunately, demands of these restorations with regard to *in situ* placement and curing leave significant room for advancements, particularly with respect to polymerization shrinkage and polymerization-induced stress, thermal expansion mismatch, fracture, abrasion and wear resistance, marginal leakage, and toxicity.[1,2]

One of the most important parameters involved in the light-curing of composite resins is the radiant exposure, which is calculated as the product of the irradiance and the time of irradiation provided by the light unit.[3] When more intense light energy is used to activate a composite resin, more photons are able to reach the photoinitiators within the resin, which are activated and raised to the excited state. In this state, the photoinitiator molecule collides with an amine, and a free radical is formed. Then, the latter reacts with the carbon to form a carbon double bond (C=C) of a monomer molecule, and thus polymerization is initiated.[4] Hence, more light energy will commonly result in a higher degree of conversion of monomers into polymers.

In clinical dental practice, light-curing units and their light output intensities can vary significantly, and there may be pronounced differences for newer lights, such as argon ion lasers and light-emitting diodes (LEDs), which are continuously improved to achieve higher irradiation intensities.[5,6] A study that evaluated a series of commercial composite resins found that different energy doses were required to reach appropriate material properties for different irradiation intensities.[7] Additionally, it was shown that the degree of conversion decreased with increased irradiation intensities for equivalent doses.[8] In other studies, the results and correlations observed regarding reciprocity varied depending on the type of material, the curing parameters used, and the degree of conversion achieved during irradiation.[9,10]

The longevity of composite resin restorations is also dependent upon their resistance to degradation in the oral environment.[11] Some properties of composites, such as sorption and solubility, are important parameters that allow the behavior of composite restorations to be predicted. Fluid sorption by composite resins is a diffusion-controlled process that may cause chemical degradation of the material, leading to several problems, such as filler-polymeric matrix debonding and residual monomer release by lixiviation.[12] This process can seriously decrease the mechanical properties of the composite materials and may also reduce the longevity of composite resin restorations.

The solubility of composite resins is directly affected by the amount of leached unreacted monomers and filler particle loss.[13] The sorption and solubility of composite resins depend on the composition of each material, including filler content, size, shape, interparticle spacing, monomer type, degree of conversion, and efficiency of the filler-matrix bonding.[14] The degree of conversion of a resin composite is crucial in determining the mechanical performance of the material and its biocompatibility. The strength, elastic modulus, hardness, and solubility of composite resins have also been shown to directly relate to the degree of conversion.[15]

A lithium-ion battery is the most common power source used by the current cordless LED curing units available, and little is known about the battery's influence on the performance of this class of equipment while discharging. Recently, a professional product review was released by the American Dental Association with some valuable data about several cordless LED units.[16] Since that period, cordless LED curing lights have become increasingly employed in dental practice, and more studies are needed to clarify their working mechanisms and limitations.

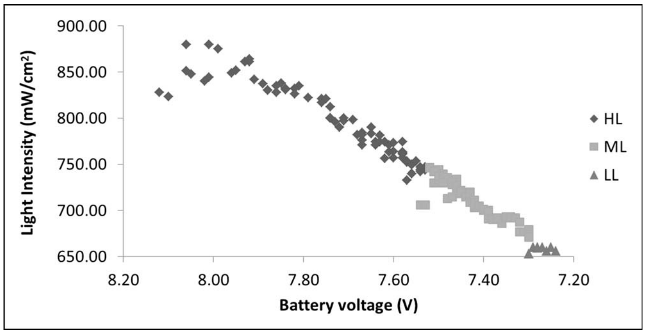

Figure 1. *Graph plotting of the battery voltage (V) and light intensity (mW/cm^2) observed for the cordless LED curing-light unit along the complete discharging (150 cycles of 60 seconds).*

Thus, the aim of this study was to evaluate how different battery levels (100%, 50%, and 10%) of a cordless LED unit affect battery voltage and light intensity as well as influence the degree of conversion, diametral tensile strength, sorption, and solubility of a nanofilled composite resin. The null hypothesis tested in this study was that the different battery levels of a cordless LED unit would not influence the performance of the equipment and the properties of the composite resin evaluated.

METHODS AND MATERIALS

Battery Voltage and Light Intensity Measurements

In order to determine the power percentage corresponding to each battery level, three new similar cordless LED units (Coltolux, Coltente, Feldwiesenstrasse, Switzerland) were fully charged as recommended by the manufacturer and used until they were completely unloaded. The maximum number of cycles that could be completed with the fully charged batteries (100%) was determined (150 cycles of 60 seconds), and based on that number, the number of cycles corresponding to 50% and 10% battery levels was determined. The battery voltage (V) and light intensity (mW/cm^2) of the cordless LED units were individually checked for all light cycles reached by the equipment. For this, a voltage tester and a luxmeter probe (PHYWE Systems, Gottingen, Germany) were connected to a digital multimeter unit (HGL 2000N, PCE, Tobarra, Spain) in order to make the measurements before and during each light cycle for battery voltage and light intensity, respectively. The data for both measurements were tabulated and recorded. Since no significant differences were observed in the performance of the three cordless LED units for the different battery levels evaluated ($p>0.05$), we used a single unit to carry out the next experimental steps. The battery voltage (V) and light intensity (mW/cm^2) verified for the complete discharging (150 cycles of 60 seconds) of the selected cordless LED unit were recorded and plotted (Figure 1).

Specimen Preparation

Nanofilled composite resin specimens (Filtek Supreme XT, shade A2B, 3M-ESPE, St Paul, MN, USA) were prepared in a stainless steel matrix (5 mm in diameter × 2 mm in height) for all tests. Discs were light-cured through a Mylar strip for 20 seconds using the cordless LED unit with different battery levels according to the experimental groups: high battery level (HL, 100%); medium battery level (ML, 50%); and low battery level (LL, 10%).

Degree of Conversion

The degree of conversion of the composite resin specimens (n=10) was accessed in a Fourier transform infrared spectroscopy (FTIR) unit (Tensor 27, Bruker, Ettlingen, Germany). The number of remaining carbon double bonds was determined. The remaining unconverted carbon double bonds were calculated by comparing the percentage of aliphatic C=C (vinyl) (1638 cm^{-1}) and aromatic C=C absorption (1608 cm^{-1}) between cured and uncured specimens. The spectra of the cured and uncured specimens were obtained using 128 scans at a resolution of 4 cm^{-1}, within the range from 1000 to 6000 cm^{-1}. The spectra were subtracted from the background spectra using software provided with the FTIR unit (OMNIC 6.1, Nicolet Instrument Corp, Madison, WI, USA). The acquired spectra were expanded and analyzed in the region of interest from 1560 to 1670 cm^{-1}. The degree of conversion was calculated using the standard baseline technique and a comparison of peak area at 1639 cm^{-1} (aliphatic C=C) and internal standard peak at 1609 cm^{-1} (aromatic C=C). Then, the degree of conversion (DC) was calculated by the following equation:

$$DC(\%) = [1 - \frac{Cured\ aliphatic/aromatic\ ratio}{Uncured\ aliphatic/aromatic\ ratio}] \times 100$$

Diametral Tensile Strength

A diametral tensile strength test was performed in the specimens previously used for obtaining degree of conversion (n=10) using a mechanical testing machine (DL 2000, EMIC, São José dos Pinhais, Brazil). Specimens were positioned vertically on the testing machine between a stainless steel flat tip and

Table 1 *Means ± Standard Deviations for the Tests Performed According to the Battery Level (%) of the Groups* [a]

Groups	Battery Voltage, V	Light Intensity, mW/cm^2	Degree of Conversion, %	Diametral Tensile Strength, MPa	Sorption, µg/mm^3	Solubility, µg/mm^3
HL (100%)	7.8 ± 0.02^{A}	831.7 ± 3.6^{A}	31.3 ± 2.1^{A}	52.2 ± 1.5^{A}	16.1 ± 6.2^{A}	-10.6 ± 5.3^{A}
ML (50%)	7.5 ± 0.01^{B}	737.8 ± 5.0^{B}	30.1 ± 1.0^{A}	49.6 ± 2.1^{A}	26.5 ± 3.9^{B}	7.2 ± 5.0^{B}
LL (10%)	7.3 ± 0.02^{C}	656.2 ± 5.3^{C}	20.9 ± 1.2^{B}	46.8 ± 3.2^{B}	30.2 ± 10.8^{B}	13.3 ± 8.4^{B}

[a] *Different capital letters represent significant differences within the columns (vertical analysis) for each test; Tukey honestly significant difference test ($p<0.05$).*

base; a compressive load was applied vertically on the lateral portion of the cylinder at a crosshead speed of 0.5 mm/min, producing tensile stresses perpendicular to the vertical plane passing through the center of the specimen until failure. After each compressive test, the fracture load *(F)* was recorded in Newtons (N), and the diametral tensile strength (σ_t) was calculated (MPa) as follows:

$$\sigma_t = 2F/\pi dh$$

where, d is the diameter (5 mm), h the height (2 mm) of specimens, and the constant π is 3.1416.

Sorption and Solubility

The sorption and solubility of the composite resin was verified for each experimental group in new specimens (n=10). After preparation, the specimens were stored in a desiccator with silica gel and maintained in an oven at 37°C for 24 hours. Next, the specimens were weighed on an analytical balance with 0.01 mg accuracy (AG200, Gehaka, São Paulo, Brazil) at 24-hour intervals until a constant weight was obtained, which was considered $m1$. Then, the specimens were individually placed in plastic vials containing 10 mL of artificial saliva and stored at 37°C. The specimens were weighed at intervals of 1, 24, 48, and 72 hours to progressively scan sorption. After the weighing procedures, the specimens were newly immersed in the storage medium and kept in an oven at 37°C. After 7 days, the specimens were removed from storage, excess liquid was dried with absorbent papers, and specimens were weighed to obtain $m2$. Then, the specimens were taken to the desiccator with silica gel at 37°C to eliminate the absorbed saliva and were weighed daily until reaching constant mass, which was considered $m3$.

The major and minor diameters and thickness of the specimens were measured at four points using a digital caliper (CD6 CS, Mitutoyo, Kanagawa, Japan) after final drying in $m1$. These measures were used to obtain the volume (V) of each specimen (mm^3) and to calculate the sorption (Sor) and solubility (Sol) rates, according to the following:

$$Sor = \frac{m2 - m3}{V} \qquad Sol = \frac{m1 - m3}{V}$$

where, $m1$ is the mass of the specimen (µg) before the immersion in liquid medium, $m2$ is the mass of the specimen (µg) after the immersion in liquid medium over 7 days, $m3$ is the mass of the specimen (µg) after desiccation until reaching constant mass, and V is the volume (mm^3).[17]

Statistical Analysis

Data for all tests were checked for homoscedasticity and submitted to one-way analysis of variance followed by a Tukey honestly significant difference test. Correlations between light intensity and battery voltage, degree of conversion, diametral tensile strength, sorption, and solubility were checked by Pearson correlation test. All tests were conducted at 95% confidence level using a statistical package (SigmaPlot 12.0, Systat Software, San Jose, CA, USA).

RESULTS

The results for degree of conversion, diametral tensile strength (σ_t), sorption, and solubility are shown in Table 1. Lower degree of conversion was observed for the LL group compared with the HL and ML groups ($p<0.001$), which showed similar results ($p=0.182$). Lower σ_t was also verified for the LL group compared with the HL ($p<0.001$) and ML ($p=0.035$) groups, which had no difference between them ($p=0.052$). Higher sorption was detected for the ML ($p=0.012$) and LL ($p<0.001$) groups compared with the HL group, but these groups were similar ($p=0.535$). Lower solubility was observed for the HL group than for the ML ($p<0.001$) and LL ($p<0.001$) groups, which showed no significant differences ($p=0.104$). Positive correlation was observed between light intensity and the following factors: battery level (99%), degree of conversion (86%), and diametral strength (70%); negative correlation was detected between light intensity

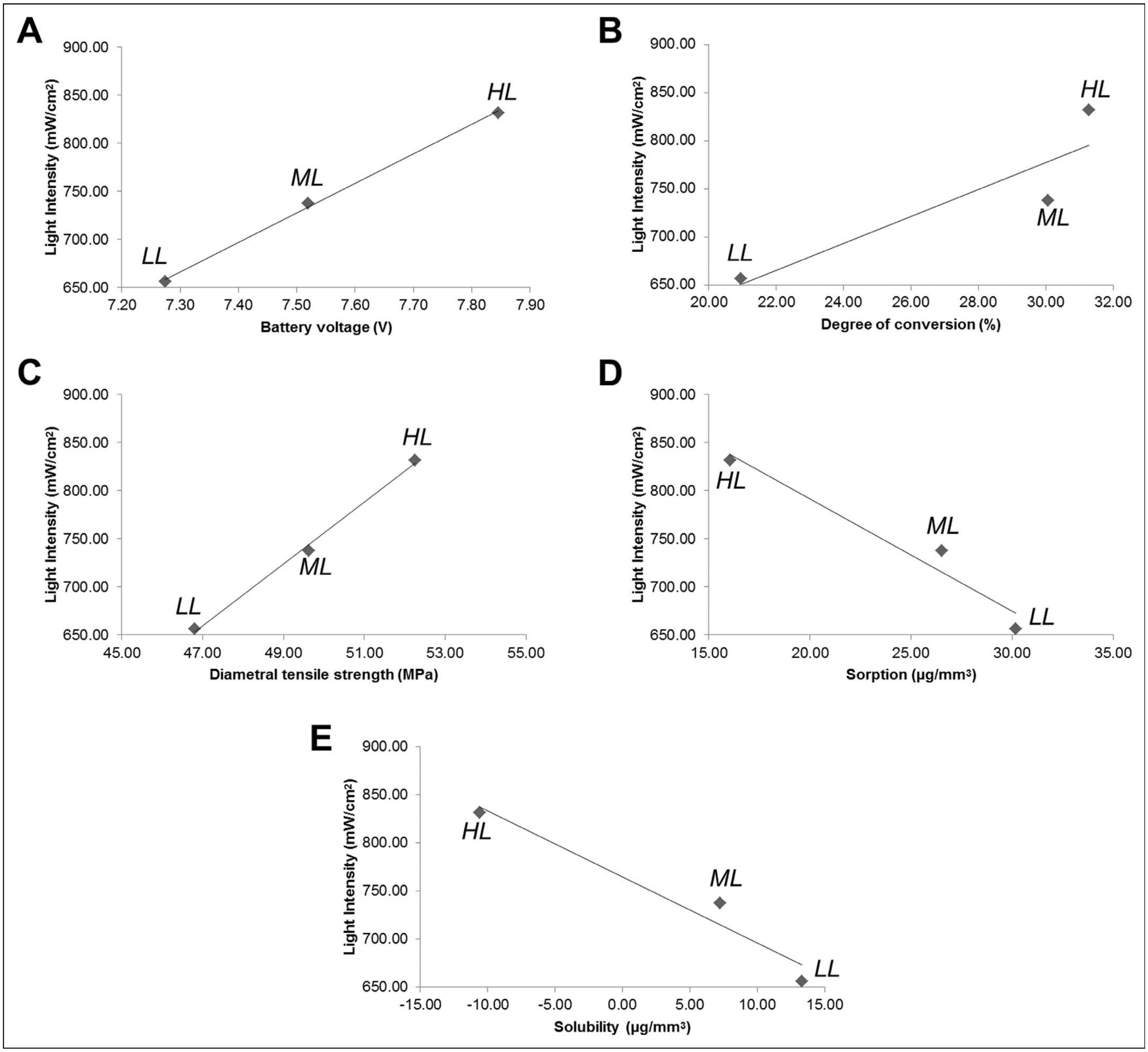

Figure 2 *Graph plotting of the correlation results between the light intensity (mW/cm^2) and the different factors tested: A, battery voltage (V); B, degree of conversion (%); C, diametral tensile strength (MPa); D, sorption (μg/mm^3); E, solubility (μg/mm^3); *HL, high battery level; ML, medium battery level; LL, low battery level.*

and sorption (–63%) and solubility (–83%) ($p<0.001$). The results for the Pearson correlation test are plotted in Figure 2.

DISCUSSION

The null hypothesis was rejected; the battery level of the cordless LED unit affected the battery voltage and light intensity of the equipment in addition to the degree of conversion, diametral tensile strength (σ_t), sorption, and solubility of the nanofilled composite resin evaluated.

In light-cured materials, the degree of conversion is determined by the product of irradiation of light and exposure time.[18] The conversion of monomers is proportional to the square root of the light intensity applied to the composite,[19] and according to our results, the light intensity of a cordless LED unit can be influenced by battery voltage, thereby affecting the degree of conversion, diametral tensile strength, sorption, and solubility of composite resins. Thus, one may assume that the light intensity of the cordless LED units is also dependent upon the battery level.

No studies have reported the association between the battery level of cordless LED units and the changes in the properties of light-cured restorative materials. However, the relationships between the degree of conversion and mechanical properties of composites have been shown.[20] Low battery levels affect the battery voltage and consequently influence the light intensity of cordless LED units, also changing some properties of composite resins. Currently, composite resin restorations are widely used in restorative dentistry, both in anterior and posterior applications.[21] These restorations are constantly under stress from masticatory function. From this point of view, besides selecting composite resins with suitable properties, clinicians must be careful to check that cordless light-curing units are appropriately charged, as this is a decisive step to ensure adequate performance for light-cured polymeric restorations.

The development of stresses in dental composite restorations depends on the material composition, including type of monomer; amount and type of inorganic filler; interactions between filler and matrix; polymerization parameters, such as degree of conversion and rate of polymerization; material positioning; and light-curing technique.[22,23] Adequate polymerization is a critical factor for obtaining acceptable physical and mechanical performance from dental composites.[22,24] During the curing process, the light passing through the composite is absorbed by the resin and dispersed by the filler content.[25] The light intensity and its effectiveness of cure is reduced in deeper increments, mainly above 2.0 mm.[26] The reduction in the battery level of a cordless LED unit can also affect the degree of conversion of composites, because it results in reduced battery voltage/light intensity, producing less resistant dental restorations as shown by the diametral tensile strength test.

The present study was initially conducted using three LED units from a single manufacturer; after verifying homogeneity among the equipment, one unit was selected for specimen preparation according to the experimental conditions. Although the LED curing light units commercially available present similar energy source provided by a lithium-ion battery,[16] differences among the performance of products from different manufacturers can be observed. Thus, the results presented by this study cannot be directly considered for all other cordless LED equipment.

In the oral cavity, composite resin restorations are continuously exposed to chemical agents present in saliva, food, and drinks, which can contribute to degradation of the organic matrix.[27] Several factors influence the absorption of oral fluids by composites, for example, hydrophilicity of the polymer matrix, density of the composite filler material, porosity, and solvents.[17] Water molecules can induce degradation of composites by two mechanisms. First, molecules diffuse into the polymer network and fill the free volume between the microvoids, causing plastification and swelling of the polymer and initiating the breakup of chains with elution of the monomers.[17,27] These molecules also tend to deteriorate the siloxane bonds through a hydrolysis reaction, causing detachment of filler particles.[27,28] Although a 50% reduction in the battery level did not significantly affect the degree of conversion and diametral strength of the composite evaluated, it did affect the sorption and solubility properties of the restorative material evaluated in this study. This finding can be critical for the longevity of composite restorations. Negative solubility values were observed for the HL specimens because the $m3$ (mass after desiccation) was higher than the $m1$ (mass before immersion). A possible explanation for these findings is that the fluid absorbed during storage was probably confined and included as part of the polymeric structure of the composite material.[13]

As observed, the capacity of composites to absorb fluids from the oral environment and solubilize components can be influenced by the battery level of cordless LED curing units. This is probably due to the reduced light intensity reaching the composite resin during polymerization. These events lead to degradation and softening of the composites, mainly in the presence of acids, which may reduce some physical and mechanical properties such as hardness, strength, and modulus of elasticity, besides favoring increased surface roughening.[29] These effects can be even more pronounced because several factors related to the chemical structure of polymer networks also determine the extent to which the material is affected by the aqueous medium surrounding it.[30] Important features include chemical hydrophilicity of the polymer and differences in solubility between the polymer and the solvent.[31] Structural parameters include the density and porosity of the polymeric network.[22,23,25] The properties related to the inorganic particles of the material are also significant.[26] Moreover, the increased levels of sorption and solubility on composite resins can lead to damage of the soft tissues adjacent to these restorations, which become more susceptible to plaque accumulation.[32]

The parameters observed in this study support an inverse relationship between the battery voltage/light intensity and sorption/solubility, while a proportional behavior was detected to the battery voltage/light intensity, degree of conversion, and diametral strength decrease. This study used laboratory conditions for light-curing, in which no distance remained between the tip of the light source and the restorative material. Considering our findings, the situation may be worse in clinical situations, when the distance between the light source and the polymeric restorative material is increased by limiting factors, such as in the restoration of deep cavities, fiber post luting, or when indirect restorations are interposed.

Therefore, clinicians must be careful when using light-curing with cordless LED units powered by battery sources, because once the battery is running out of charge, battery voltage and light intensity are affected, resulting in decreased properties for composite resin restorations. Despite the intrinsic limitations of the present study, such as the *in vitro* design and the analysis of a single cordless LED unit and composite resin material, our results help to clarify how the battery level (battery voltage/light intensity) of these curing units influences the properties of composite restorations. Further studies taking into consideration additional laboratory tests and clinical outcomes with different cordless LED units and other resin-based materials, such as composites, adhesives systems, and resin cements, would be beneficial.

CONCLUSIONS

Within the limitations of the present study it was concluded that the different battery levels of a cordless LED unit affected its battery voltage/light intensity, consequently influencing the degree of conversion, diametral tensile strength, sorption, and solubility of a nanofilled composite resin.

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Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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REFERENCES

1. Sadowsky SJ (2006) An overview of treatment considerations for esthetic restorations: A review of the literature *Journal of Prosthetic Dentistry* **96(6)** 433-442. DOI 10.1016/j.prosdent.2006.09.018.
2. Ferracane JL (2008) Buonocore Lecture. Placing dental composites—A stressful experience *Operative Dentistry* **33(3)** 247-257. DOI 10.2341/07-BL2.
3. da Silva EM, Poskus LT, & Guimaraes JG (2008) Influence of light-polymerization modes on the degree of conversion and mechanical properties of resin composites: A comparative analysis between a hybrid and a nanofilled composite *Operative Dentistry* **33(3)** 287-293. DOI 10.2341/07-81.
4. Friedl KH, Schmalz G, Hiller KA, & Markl A (2000) Marginal adaption of Class V restorations with and without “softstart-polymerization” *Operative Dentistry* **25(1)** 26-32.
5. Rueggeberg FA (2011) State-of-the-art: Dental photocuring—A review *Dental Materials* **27(1)** 39-52. DOI 10.1016/j.dental.2010.10.021.
6. Watanabe H, Kazama R, Asai T, Kanaya F, Ishizaki H, Fukushima M, & Okiji T (2015) Efficiency of dual-cured resin cement polymerization induced by high-intensity LED curing units through ceramic material *Operative Dentistry* **40(2)** 153-162. DOI 10.2341/13-357-L.
7. Musanje L, & Darvell BW (2006) Curing-light attenuation in filled-resin restorative materials *Dental Materials* **22(9)** 804-817. DOI 10.1016/j.dental.2005.11.009.
8. Peutzfeldt A, & Asmussen E (2005) Resin composite properties and energy density of light cure *Journal of Dental Research* **84(7)** 659-662.
9. Halvorson RH, Erickson RL, & Davidson CL (2003) An energy conversion relationship predictive of conversion profiles and depth of cure for resin-based composite *Operative Dentistry* **28(3)** 307-314.
10. Feng L, Carvalho R, & Suh BI (2009) Insufficient cure under the condition of high irradiance and short irradiation time *Dental Materials* **25(3)** 283-289. DOI 10.1016/j.dental.2008.07.007.
11. Sideridou I, Tserki V, & Papanastasiou G (2003) Study of water sorption, solubility and modulus of elasticity of light-cured dimethacrylate-based dental resins *Biomaterials* **24(4)** 655-665.
12. Soderholm KJ, Mukherjee R, & Longmate J (1996) Filler leachability of composites stored in distilled water or artificial saliva *Journal of Dental Research* **75(9)** 1692-1699.
13. Giannini M, Di Francescantonio M, Pacheco RR, Cidreira Boaro LC, & Braga RR (2014) Characterization of water

sorption, solubility, and roughness of silorane- and methacrylate-based composite resins *Operative Dentistry* **39(3)** 264-272. DOI 10.2341/12-526-L.

14. Heintze SD, Forjanic M, Ohmiti K, & Rousson V (2010) Surface deterioration of dental materials after simulated toothbrushing in relation to brushing time and load *Dental Materials* **26(4)** 306-319. DOI 10.1016/j.dental.2009.11.152.
15. Hofmann N, Renner J, Hugo B, & Klaiber B (2002) Elution of leachable components from resin composites after plasma arc vs standard or soft-start halogen light irradiation *Journal of Dentistry* **30(5-6)** 223-232.
16. Sarret DC (2009) Spectral curing lights and evolving product technology *ADA Professional Prodocuts Review* **4(4)** 2-12.
17. Almeida GS, Poskus LT, Guimaraes JG, & da Silva EM (2010) The effect of mouthrinses on salivary sorption, solubility and surface degradation of a nanofilled and a hybrid resin composite *Operative Dentistry* **35(1)** 105-111. DOI 10.2341/09-080-L.
18. Silikas N, Eliades G, & Watts DC (2000) Light intensity effects on resin-composite degree of conversion and shrinkage strain *Dental Materials* **16(4)** 292-296.
19. Odian G (1991) *Principles of Polymerization* Wiley, New York, NY.
20. Aleixo AR, Guiraldo RD, Fugolin AP, Berger SB, Consani RL, Correr AB, Gonini-Junior A, & Lopes MB (2014) Evaluation of contraction stress, conversion degree, and cross-link density in low-shrinkage composites *Photomedicine and Laser Surgery* **32(5)** 267-273. DOI 10.1089/pho.2013.3678.
21. Astvaldsdottir A, Dagerhamn J, van Dijken JW, Naimi-Akbar A, Sandborgh-Englund G, Tranaeus S, & Nilsson M (2015) Longevity of posterior resin composite restorations in adults—A systematic review *Journal of Dentistry* DOI 10.1016/j.jdent.2015.05.001.
22. Bicalho AA, Valdivia AD, Barreto BC, Tantbirojn D, Versluis A, & Soares CJ (2014) Incremental filling technique and composite material—Part II: Shrinkage and shrinkage stresses *Operative Dentistry* **39(2)** E83-92. DOI 10.2341/12-442-L.
23. Bicalho AA, Pereira RD, Zanatta RF, Franco SD, Tantbirojn D, Versluis A, & Soares CJ (2014) Incremental filling technique and composite material—Part I: Cuspal deformation, bond strength, and physical properties *Operative Dentistry* **39(2)** E71-E82. DOI 10.2341/12-441-L.
24. Shimizu Y, Tsujimoto A, Furuichi T, Suzuki T, Tsubota K, Miyazaki M, & Platt JA (2015) Influence of light intensity on surface free energy and dentin bond strength of core build-up resins *Operative Dentistry* **40(1)** 87-95. DOI 10.2341/13-283-L.
25. Valinoti AC, Neves BG, da Silva EM, & Maia LC (2008) Surface degradation of composite resins by acidic medicines and pH-cycling *Journal of Applied Oral Sciences* **16(4)** 257-265.
26. Moraes RR, Sinhoreti MA, Correr-Sobrinho L, Ogliari FA, Piva E, & Petzhold CL (2010) Preparation and evaluation of dental resin luting agents with increasing content of bisphenol-A ethoxylated dimethacrylate *Journal of Biomaterials Applications* **24(5)** 453-473. DOI 10.1177/0885328208098594.
27. Sideridou ID, & Karabela MM (2011) Sorption of water, ethanol or ethanol/water solutions by light-cured dental dimethacrylate resins *Dental Materials* **27(10)** 1003-1010. DOI 10.1016/j.dental.2011.06.007.
28. Dos Santos PA, Garcia PP, De Oliveira AL, Chinelatti MA, & Palma-Dibb RG (2010) Chemical and morphological features of dental composite resin: Influence of light curing units and immersion media *Microscopy Research and Technique* **73(3)** 176-181. DOI 10.1002/jemt.20769.
29. Asmussen E (1984) Softening of BISGMA-based polymers by ethanol and by organic acids of plaque *Scandanavian Journal of Dental Research* **92(3)** 257-261.
30. Nishiyama N, Suzuki K, Yoshida H, Teshima H, & Nemoto K (2004) Hydrolytic stability of methacrylamide in acidic aqueous solution *Biomaterials* **25(6)** 965-969.
31. Vouvoudi EC, & Sideridou ID (2013) Effect of food/oral-simulating liquids on dynamic mechanical thermal properties of dental nanohybrid light-cured resin composites *Dental Materials* **29(8)** 842-850. DOI 10.1016/j.dental.2013.04.013.
32. Litonjua LA, Cabanilla LL, & Abbott LJ (2012) Plaque formation and marginal gingivitis associated with restorative materials *Compendium of Continuing Education in Dentistry* **33(1)** e6-e10.