RELATIONSHIP AND EFFECTS BETWEEN POLYWAVE AND MONOWAVE HEALING TECHNOLOGIES WITH INFLUENCE ON THE PHYSICO-MECHANICAL PROPERTIES OF MATERIALS AND CLINICAL RELEVANCE: A LITERATURE REVIEW

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ABSTRACT

Composite resins are materials that enable a range of consistencies, allowing them to be molded into the desired shape and converted through the polymerization reaction into a rigid, resistant, aesthetic and durable material. Since the light curing unit is the essential part of the resin curing process to achieve clinical success and the properties proposed by the manufacturer in the long term, the radiant energy of these units must be sufficient within the spectral range necessary to activate the photoinitiators present in the restorative material. Therefore, insufficient energy would affect the physical-mechanical properties of composite resins, reducing bond strength, increasing marginal wear, decreasing biocompatibility and increasing bacterial colonization. Thus, the aim of this study was to carry out a literature review about photopolymerization units with Polywave and Monowave technology, highlighting their clinically relevant advantages, emphasizing the relationship with photoinitiators and physical-mechanical properties.

Keywords: Light curing. Monowave. Polywave. Photo-initiator.

INTRODUCTION

Composite resins are materials used to restore and replace tooth tissue lost through infectious processes or trauma, and to seat and cement prefabricated dental devices. These materials allow for the possibility of a range of consistencies, from fluid to rigid, which allows them to be molded into the desired shape and converted through the polymerization reaction into a rigid, resistant, aesthetic and durable material. (ANUSAVICE et al., 2013)

The polymerization of composite resin-based materials occurs by converting the resin matrix monomers into a crosslinked polymeric network. This process can be initiated by external light (photoinitiator + amines) or through chemical agents (benzoyl peroxide + amines). (SIM et al., 2012)

The light-curing unit (LCU) is an essential part of the resin curing process to achieve long-term clinical success and manufacturer's proposed properties. (SIM et al., 2012) In the 2000s, aiming to eradicate the problems associated with halogen curing lights, the use of Light-emitting diode (LED) lights was started. These use LED lamps combining two different semiconductors to produce light instead of hot filaments. Thus, they consume less energy, do not need cooling fans and have a longer service life without significant loss of light intensity. (ANUSAVICE et al., 2013)

The first and second generation LED lights used only Monowave (single-peak) technology and did not cure the phenylpropanedione and acyl phosphine oxide initiator systems. The first-generation LEDs had an intensity of approximately 400mW/cm2, while the second-generation ones reached intensities of up to 1000mW/cm2. Today, third-generation LEDs feature Polywave (dual/multi-peak) technology, avoiding wavelength compatibility issues, as well as featuring higher light intensities and multiple cure modes (high, low and soft start). (GAN et al., 2018)

Camphorquinone (CQ) is a photoinitiator that has color limitation, so other initiators were introduced, such as phenylpropanedione and phosphine oxides, with trimethylbenzoyl-diphenylphosphine oxide (TPO) being the best known. In a study carried out by Santini, A. et al. (2012) experimental resins containing only TPO showed comparable or higher conversion degrees than those containing CQ with a tertiary amine. In addition, these materials showed greater color stability compared to materials containing CQ and also those initiated by phenylpropanedione and bis-acylphosphine oxide. However, TPO has light absorption spectra shifted towards the ultraviolet range, which are incompatible with the emission spectra of Monowave LED curing units, which are limited to 420-490nm to match the CQ absorption peak. Therefore, regardless of the LED light intensity, there may be an inability to cure resin-based materials that contain other initiators. (BORTOLOTTO; BETANCOURT; KREJCI, 2016; SANTINI et al., 2012)

The polymerization shrinkage and the degree of conversion are crucial for the clinical success of composite resin restorations. Polymerization shrinkage refers to the shortening of the distance between molecules, due to the formation of covalent bonds. In many cases, this phenomenon has negative clinical effects. (RO et al., 2015). The degree of conversion refers to the amount of monomer that has been converted into the polymer chain, thus being related to the polymerization process of the composite. If the conversion is low, the longevity of the restoration is compromised, with this, the power density emitted by the light sources must be at least 300mW/cm2 to 400 mW/cm2 for an increment of 1.5mm to 2mm of composite resin. The more effective the light-curing unit, the more photons will be available for absorption and the more photoinitiators will be excited, favoring polymerization. (LIMA et al., 2016)

The aim of this study was to carry out a literature review about photopolymerization units with Polywave and Monowave technology, highlighting their clinically relevant advantages, emphasizing the relationship with photoinitiators and physical-mechanical properties.

LITERATURE REVIEW

To carry out this study, a literature review was carried out in the PubMed, Scielo, Portal Capes and BVS databases, using the descriptors “Polywave”, “degree of conversion” and “polymerization shrinkage”. Articles were searched between 2012 and 2019.

Miletic et al., 2012 determined the degree of conversion (DC) of resins containing TPO initiator cured by Polywave or Monowave LED. To the resin blends based on equal percentage by weight (% by weight) of BisGMA and TEGDMA the following initiators were added: 0.2% by weight of CQ + 0.8% by weight of ethyl 4-dimethylaminobenzoate (EDMAB) (Group 1); 1% by weight TPO (Group 2) and 0.1% by weight CQ + 0.4% by weight EDMAB + 0.5% by weight TPO (Group 3). Half of the samples in each group (n=5) were cured using Polywave LED (bluephase1 G2, Ivoclar Vivadent) or Monowave LED (bluephase1, Ivoclar Vivadent). DC was measured using micro-Raman spectroscopy within 5 minutes and then 1,3,6,24 and 48 hours post-irradiation. Data were analyzed using general linear model and bidirectional ANOVA for the factors “time”, “material”, “surface” and “LCU” α=0.05. As a result, the initial DC values obtained after light curing remained similar for a period of 48 hours. Bluephase1 G2 produced the largest CG in Group 2, followed by Group 3 and Group 1. Bluephase1 resulted in the largest CG in Group 1, followed by Groups 2 and 3 (p<0.05). It is concluded that unfilled resin materials containing TPO and CQ-amine initiators are effectively cured using bluephase1 G2. Resin blend with the same % by weight of initiators is light cured better when TPO is the only initiator, compared to CQ-amine alone or the combined TPO and CQ-amine system. After initial light curing, no further conversion of uncured monomers was detected in an unfilled resin material for 48 hours at 37ºC.

Santini et al. 2012 sought to determine the DC and Knoop microhardness (KHN) of resin-based composites containing trimethylbenzoyl-diphenylphosphine oxide (TPO) cured by Polywave and Monowave LEDs (LCUs). They were divided into 3 groups (n=5 each) of EvoCeram Tetric (Ivoclar Vivadent), Vit-l-escence (Ultradent) and Herculite XRV Ultra (Kerr), prepared in Teflon molds (5mm in diameter and 2mm thick) and cured with Polywave Bluephase1 G2 (Ivoclar Vivadent), Polywave Valo (Ultradent) or Bluephase1 Monowave (Ivoclar Vivadent; control), resulting in 9 groups. DC and KHN were evaluated using micro-Raman and Knoop microhardness spectroscopy, respectively. To confirm the presence or absence of TPO in the three uncured materials, high performance liquid chromatography and nuclear magnetic resonance spectroscopy were used. Data were statistically analyzed by one-way and two-way ANOVA, and DC and KHN were correlated using Pearson's correlation ($\alpha=0.05$). As a result, TPO was confirmed on Tetric EvoCeram and Vit-l-escence, but not on Herculite XRV Ultra. The 3 UCLs produced comparable KHN for Tetric EvoCeram and Herculite XRV Ultra ($p>0.05$). Both Polywave LCUs resulted in significantly higher KHN for Vit-l-escence and superior DC in EvoCeram Tetric and Vit-l-escence than Bluephase Monowave1 ($p<0.05$). However, Bluephase1 had a higher DC than the two LCUs in Herculite XRV Ultra ($p<0.05$). Pearson's correlation coefficient was $r=0.818$. It is concluded that Polywave LED LCUs improved monomer-to-polymer conversion and KHN in composites containing TPO, but not in Herculite XRV Ultra.

Sim et al., 2012 investigated how dual peak LED units affect the polymerization of composite resins containing co-initiator. They used five composite resins containing the co-initiator: Aelite LS Posterior (AL), Tetric EvoCeram (TE) and Vit-l-escence (VI); only CQ: Grandio (GD) and Filtek Z350 (Z3), were light cured using four different light curing units. Among them, Bluephase G2 (BP) and G-light (GL) were dual peak LEDs. As a result, BP and GL had no consistent effect on the microhardness of AL, TE and VI on the upper and lower surfaces of resin samples. Among the samples, AL and VI showed the smallest (9.86 to 10.41mm) and the largest (17.58 to 19.21mm) polymerization shrinkage, respectively. The effect of BP and GL on sample contraction was not consistent. GD had the highest flexural properties [strength (FS) and modulus (FM)] and TE had the lowest flexural and compressive properties [strength (CS) and modulus (CM)] among specimens. On the same resin, the maximum differences of FS and CS due to different LCUs were 10.3 to 21.0% and 3.6 to 9.2%, respectively. Furthermore, the influences of BP and GL on FS and CS were not consistent. It was concluded that the tested dual peak LED units did not have a consistent synergistic effect on the polymerization of composite resins containing co-initiator, compared to QTH and single peak LED. The choice of LCU does not seem to be a determinant of the photopolymerization of composite resins with co-initiators.

Brandt et al., 2013 evaluated the thermal and mechanical properties of composite resins containing CQ and/or phenylpropanedione (PPD) photoinitiators when photoactivated with a halogen lamp (XL2500/3M-ESPE), Monowave (LED units UltraBlueIS/DMC) and Polywave (UltraLume5/Ultradent). A blend of BisGMA, UDMA, BisEMA and TEGDMA was prepared with the same % by weight of CQ and/or PPD photoinitiators and 65% by weight of silanized filler particles. Compressive strength (CS), diametral tensile strength (DTS) and diametral modulus (DM) were tested. Thermogravimetric analysis was performed and the residual monomer lost was verified. Dynamic mechanical thermal analysis was used to analyze the glass transition temperature (Tg) and the storage modulus at 37°C. DC was performed on the same DMA samples using mid-infrared (mid IR) spectroscopy. As a result: CQ, CQ/PPD and PPD obtained the same results for all mechanical properties (CS, DTS and DM), residual monomer loss and storage modulus at 37°C, regardless of the LCU used. The Tg results showed that the combination of PPD-UltraLume5 produced the highest values. The DC showed that the CQ-UltraLume5 combination resulted in the highest values and PPD-XL2500 in the lowest DC values. It was concluded that PPD is not only an effective photosensitizer, but also has similar efficiency to CQ in composite resins.

Lucey et al., 2014 evaluated the DC of resin-based materials (RBMs) cured with dual peak or single peak LED LCUs. Samples of Vit-l-escence (Ultradent) and Herculite XRV Ultra (Kerr) and Delton Clear and Delton Opaque (Dentsply) fissure sealants were prepared (n=3 per group) and cured with one of the double peak LCUs (blue phase) G2; Ivoclar Vivadent or Valo; Ultradent) or a single peak (blue phase; Ivoclar Vivadent). To confirm the presence or absence of primers other than CQ, high performance liquid chromatography and nuclear magnetic resonance spectroscopy were used. DC was determined using micro-Raman spectroscopy. Data were analyzed using the general linear model ANOVA; $\alpha=0.05$. As a result, with Herculite XRV Ultra, the single peak LCU provided higher DC values than either of the two double peak LCUs ($p<0.05$). Both crack sealants had higher DC compared to the two RBMs ($p<0.05$); 2,4,6-Trimethylbenzoyl-diphenylphosphine oxide (Lucirin TPO) was found only in Vit-l-escence. It was concluded that dual peak LED LCUs may not be the most suitable for curing materials that do not contain Lucirin TPO. A clear sealant showed better cure throughout the material and may be more appropriate than opaque versions in deep fissure.

Price; Ferracane; Shortall, 2015 evaluated the scientific evidence on the depth of cure of bulk fill resin composites (BFRCs). A literature review was carried out concluding that, in general, an irradiance of the light curing units ranged from 650 to 1330mW / cm2 and the exposure time from 5 to 60 seconds. Curing lights that emitted irradiance greater than or equal to 1000mW / cm2 and exposure times greater than or equal to 20 seconds favorable results in depth of cure. Concluding that high cure rates by BFRCs depend on factors such as material, irradiance and exposure time. Polywaves were useful but not essential in polymerization with alternative photoinitiators.

Ro et al., 2015 tested 457 and 473nm lasers, alone or in combination, under different light conditions. Four composite resins were light cured using five different laser applications (530mW / cm2 457nm only, 530mW / cm2 473nm only, 177mW / cm2 457 + 177mW / cm2 473nm, 265mW / cm2 457 + 265mW / cm2 473nm, and 354+mW / cm2 457nm 354mW / cm2 473nm). An LED unit was used for comparison purposes. On the upper surfaces after 24 hours, the microhardness obtained with LED and lasers ranged from 42.4-65.5 and 38.9-67.7Hv, respectively. And on the lower surfaces, 25.2-56.1 and 18.5-55.7 Hv. Of the conditions used, 354 mW / cm2 457nm + 354mW / cm2 473nm presented greater microhardness (33.8-55.6Hv). On the upper and lower surfaces at lower total light intensity, 354 (177 × 2) mW/cm2 ranged from 39.0-60.5 and 18.5-52.8Hv, respectively. 530mW / cm2 at 457nm produced the smallest polymerization shrinkage. However, the shrinkage values obtained under the five laser conditions were similar. The study concluded that the 457 and 473nm lasers are useful for curing composite resins alone or in combination with much lower light intensities than the LED unit.

Bortolotto, Betancourt and Krejci, 2016 evaluated the influence of light curing agents on the marginal adaptation of cavities restored with self-etching adhesive containing CQ and 1-phenyl-1,2-propanedione initiators, and hybrid composite. Twenty-four class V (3 groups, n=8) with margins located in enamel and dentin were restored with Clearfil S3 Bond and Clearfil APX PLT, and cured with LED Monowave, LED Polywave and halogen light curing. Marginal adaptation was evaluated with a scanning electron microscope before and after thermomechanical loading. In enamel continuous margins were found in % significantly smaller (74.5 ± 12.6) in the group cured by LED Polywave when compared to LED Monowave (87.6 ± 9.5) and halogen light curing (94.4 ± 9, 1). It is concluded that the presence of fractures in enamel and composite was significantly higher in the group cured with LED Polywave, probably due to the increase in friability of the materials resulting from a better degree of cure.

De Oliveira et al., 2016 evaluated the effect of the combination of CQ and TPO on the color and cure profile of resin-based composites. Experimental composites were produced with different concentrations of CQ and TPO: only CQ, 3CQ: 1TPO, 1CQ: 1TPO, 1CQ: 3TPO and only TPO. The Polywave LED was characterized using a beam profiler. Block-shaped samples (5mm×5mm×3mm depth) were cured in a custom mold with Polywave LED positioned to compare the regions exposed to 420-495nm and 380-420nm LED emissions. To map the healing profile, the DC of the longitudinal sections of each block was evaluated by FT-NIR. Color, light transmittance and light absorption during curing were evaluated on samples 1 to 3mm thick. Data were analyzed using the ANOVA/Tukey test (α=0.05; β=0.2). As a result, although the Polywave LED beam profile is not uniform, up to a depth of 2mm, no differences were found in the DC between composites containing CQ with 50% TPO added, regardless of position under the cure tip. Composites with higher TPO concentration showed a decrease in DC starting at a depth of 1mm, while composites with higher or similar CQ concentrations did not show a lower DC up to a depth of 3mm. Higher TPO concentration reduced initial yellowing and color change after curing, and lower CQ concentration reduced light absorption at greater depths.

Harlow et al., 2016 measured the light transmission in the “violet” ($350 \leq \lambda \leq 425$ nm) and “blue” ($425 < \lambda \leq 550$nm) spectral ranges from a Polywave LED curing light, through different thicknesses of four resin-based composites (RBCs). Samples of conventional RBCs (Tetric EvoCeram A2, FiltekSupreme Ultra A2B) and bulk curing resins (Tetric EvoCeram Bulk Fill IVA and SureFil SDR Flow U) were prepared. Three samples of each RBC were made in thicknesses of 0.1, 0.7, 1.2 and 4mm. Samples from the uncured RBCs were affixed to the inlet opening of a six inch integrating sphere and light cured once for 20s using Polywave LED (Bluephase G2) in its high power setting. The spectral radiant power transmitted through each RBC in the “violet” and “blue” regions was measured using a fiber optic spectrometer. As a result, as the resin thickness increased, an exponential attenuation of transmitted light was measured (R2>0.98). The attenuation was greater in the "violet" spectral regions than in the "blue" regions. At the light end, the violet light component represented 15.4% of the light emission. After passing through 4mm of resin, violet light represented only between 1.2% and 3.1% of the transmitted light, depending on the resin. Depending on the RBC, approximately 100mW of Bluephase G2 was transmitted through 0.1mm of resin in the "violet" range, dropping to a maximum of 11mW after passing through 2mm of resin and to only 2mW at 4mm depth. It was concluded that increasing the thickness of the RBC results in an exponential decrease in light transmission. This attenuation is RBC dependent, with shorter wavelengths (violet) attenuated to a greater extent than longer wavelengths (blue). Thus, despite the increased translucency of bulk-curing RBCs, it is unlikely that the less than 425nm spectral radiant power of a curing light will be effective at a depth of 4mm or more.

Contreras, 2017 evaluated the effectiveness of different photoactivation modes of bulk fill composite resins compared to conventional resins, analyzing their influence on irradiance, degree of conversion and formation of internal and marginal cracks in class II vertical slot restorations after artificial aging. Class II incisors were cut, abraded and prepared in 160 bovine incisors to simulate posterior teeth. The specimens were divided into 4 groups according to the restorative material used: Tetric N-Ceram Bulk Fill (TB), Admira Fusion X-tra Bulk Fill (AB), Tetric N-Ceram (TC) and GrandioSO (GO). Bulk fill resins were inserted in a single increment of 4mm and the other groups were performed using the oblique incremental technique (2mm). Monowave (MW) and Polywave (PW) light curing units were used in both modes (high continuous intensity and ramp). For analysis of irradiance, the Patient Simulator spectroradiometer (MARC-PS) was used. The degree of conversion was tested using the attenuated total reflectance (ATR) of the spectrometer (FTIR). The upper surfaces of the samples were irradiated in loco for 20s. The spectrum of the lower surface was recorded in real time and 15 minutes after irradiation. The slits were tested under a stereomicroscope (50x), the outer marginal slits were evaluated before and after thermomechanical cycling, and, for the internal slit, the specimens were sectioned and then evaluated. Data were submitted to two-way ANOVA and Tukey test. As a result, the LED Monowave irradiance was higher (1822.2 mW/cm2 - AIC; 1748.1 mW/cm2 - R) and the two-factor ANOVA test showed a significant difference ($p<0.05$) for the type of factor. resin. Regarding the degree of conversion, TB resin had the lowest degree and AB the highest. There was a significant difference (<0.05) for marginal gap, the light-cured TC resin PW/AIC had the highest average of marginal gap (13.94µm) and light-cured TC MW/AIC the lowest (9.59µm). And after thermomechanical aging, the GO resin light-cured by PW/R showed greater internal crack when light-cured by MW/AIC (85.05µm). The study concludes that the type of light curing did not influence the degree of conversion. When Polywave is used, there are higher values of external marginal slit. Bulk fill resins have lower marginal and internal crack values after thermomechanical aging when compared to conventional resin restorations.

Derchi et al., 2018 investigated three bulk fill composites (Mat1, Filtek Bulk Fill, 3M ESPE; Mat2, Surefil SDR, Dentsply; Mat3, Tetric Evo Ceram Bulk Fill, Ivoclar Vivadent,) cured by two polyethylene wave lamps (Poly1 , Poly2) and a Monowave. To evaluate the DC, stiffness and roughness after polishing used, respectively, infrared spectroscopy, nanoindentation and atomic force microscopy. As a result, Mat2 exhibited the largest DC with Poly1 and second largest with Monowave, but was less rigid. Mat1 and Mat3 had higher DC with Poly2, while Poly1 scored better than Monowave. Mat3 scored better than Mat1 and was third highest when cured with Poly2. Stiffness was equal to DC for each composite cured by different lamps.

Roughness did not correlate with hardness. And the absolute value of stiffness depends on the composite formulation. Thus, it is concluded that Polywave lamps work better than Monowave lamps, but not in all cases, as Mat2 showed higher DC with Monowave than with Poly2. Although, all lamps guarantee a DC greater than or equal to 50%, except Monowave for Mat1.

Gan et al., 2018 compared the curing efficacy of bulk fill composites using Polywave LED, Monowave LED and conventional halogen lights. Bulk fill resin Tetric N-Ceram (TNC), which contained the Germanic photoinitiator (Ivocerin), and Smart Dentin Replacement (SDR) were used. The composites were placed in cylindrical black polyvinyl molds 4mm in height and 3mm in diameter and polymerized with Bluephase N Polywave High, 1200mW/cm2 (10 seconds); Bluephase N Polywave Low (NL), 650mW/cm2 (18.5 seconds); Bluephase N Polywave softstart, 0-650mW/cm2 (5 seconds); 1200mW/cm2 (10 seconds); B Bluephase N Monowave (NM), 800mW/cm2 (15 seconds); QHL75 (QH), 550mW/cm2 (21.8 seconds). Total energy production was standardized at 12,000mJ/cm2, with the exception of NS. Samples were stored in a light-tight container at 378C for 24 hours and measured on a Knoop microhardness tester (n=6). Data were submitted to one-way statistical analysis of variance/Sheffe post hoc test at a significance level of 0.05. As the results in the hardness test ranged from 38.43% ± 5.19% to 49.25% ± 6.38% for TNC and 50.67% ± 1.54% to 67.62% ± 6.96% for SDR. The highest hardness rates were obtained with NM and the lowest with NL, and they concluded that although no significant difference was observed in the hardness ratios between the curing agents for TNC, the hardness ratio obtained with NM was significantly higher than the ratio of hardness obtained with NL for SDR.

Sahadi et al., 2018 evaluated the effect of two different light curing units on the surface roughness, roughness profile, topography and microhardness of bulk fill composites after in vitro brushing. Valo (Polywave) and Demi Ultra (Monowave) curing lights were used for 10s to cure 3 bulk fill resin composites: Filtek Bulk Fill (FBF) Posterior Restorative, Tetric EvoCeram Bulk Fill (TET) and Surefil SDR Flow (SSF) . The roughness profile, surface roughness, surface morphology and microhardness were examined after 30,000 reciprocal strokes in a toothbrushing machine. Representative SEM images were also obtained. When cured with Demi Ultra, SSF showed the greatest loss of volume compared to other composites and the greatest loss of volume when compared to light curing with Valo. The highest values of surface roughness and roughness profile were found in the SSF after brushing, for the two light curing units tested. FBF had the highest microhardness values. Light-curing TET with Valo resulted in higher microhardness when compared to the use of Demi Ultra. Confocal and SEM images show that brushing resulted in smoother surfaces for FBF and TET. All composites showed loss of surface volume after brushing, this loss depended on the light curing unit used. It was concluded that the choice of the light curing unit did not affect the roughness profile, but, depending on the composite, it did affect the microhardness.

Chen et al., 2019 evaluated in vitro the effect of Monowave and Polywave LEDs on the adhesion of self-adhesive resin cements with dual polymerization to monolithic zirconia. Ninety-six zirconia discs were randomly divided into 4 groups with different combinations of LCUs and resin cements, ES-U200, BS-U200, ES-SC and BS-SC. The resin cements were adhered to the zirconia discs, and the microshear bond strength test (mSBS) was performed after 24 hours of H2O storage (24h) and 10,000 thermal cycles (10k/TC). Failure modes were examined by stereomicroscopy and scanning electron microscopy. The DC was tested immediately after 24 hours. Two-factor ANOVA and Tukey tests were performed for mSBS and DC results, and the chi-square test for failure mode analysis (α=0.05 for all tests). As a result, two-factor ANOVA demonstrated that different combinations of LPUs and resin cements and different levels of artificial aging significantly influenced the micro-shear bond strength values ($P<0.001$). The interactions between two factors were also significant ($P<0.001$). The BS-SC group has relatively high bond strength at the 24-hour and 10k/TC aging levels, no difference was found in the immediate DC (P=0.405 for U200 and P=0.708 for SC). After 24h DC and BS-U200 were significantly higher than ES-U200 values (P=0.002), while BS-SC values were not significantly different from ES-SC values (P=0.284). It was concluded that the emission spectra of the LED units significantly influenced the bond strengths, DC and failure mode of self-adhesive resin cements for zirconia for zirconia at the immediate and artificial aging levels. The LPU must supply energy to match the absorption wavelengths of the photoinitiators present in resin cements.

DISCUSSION

Monowave and Polywave have different emission peaks that can affect resin curing, as for the light curing to be effective, the radiant energy must be sufficient within the spectral range necessary to activate the photoinitiators present in the material. (PRICE; FERRACANE; SHORTALL, 2015) The energy density received by the resin is the mathematical product of irradiance and exposure time. Insufficient energy would affect the physical-mechanical properties of composite resins, reducing bond strength, increasing marginal wear, decreasing biocompatibility and increasing bacterial colonization. (DERCHI et al., 2018) The study by Lima et al., 2016 states that when observing composite resins photoactivated with devices with higher power intensity, regardless of time, they presented a higher degree of conversion, as there are more photons available for absorption, consequently, more photoinitiator molecules are excited promoting greater polymerization. (LIMA et al., 2016)

Composite resins when cured using highly inhomogeneous light sources, polymerization and microhardness are adversely affected. (PRICE; FERRACANE; SHORTALL, 2015) Regarding microhardness, in the study by Sahadi et al., 2018 it was concluded that the choice of the light curing unit did not affect the roughness profile, but, depending on the composite, it did affect the microhardness . (SAHADI, et al., 2018) The study by Price et al., 2015 evaluated calibrated beam profiles of two light curing units showing the average irradiance distribution (mW/cm2) at the light tip, showing that some regions at the tip of light output with non-uniform output provide less than 400mW/cm2, while other regions provide more than 4,500mW/cm2. Even though the average radiant output of one LCU is lower than the other LCU, the one with the lowest average radiant output is preferable because it is wider and has more homogeneous light. This issue can be minor, but not completely overcome by extending the exposure time beyond the manufacturer's recommended time. However, a curing light with inhomogeneous light output can cause temperature changes in the composite resin. Resins cured at elevated temperature (37ºC) increase stress more quickly than samples cured at 23ºC. The reaction rate can increase by 1.90% with every 1°C increase in temperature. It has been reported that after 1 second of the light on, the conversion rate is twice as fast as initially. (PRICE; FERRACANE; SHORTALL, 2015) Thus, the less homogeneous the light output, the higher the temperature, consequently, the greater stress on the material.

In the case of class V composite resin restorations, Bortolotto et al., 2016 evidenced the marginal integrity of these restorations with the same adhesive using different curing lights. There was no difference in the marginal adaptation in the LED Monowave and Halogen groups, which is explained by the similar wavelengths between the two units, which is between 400 and 500nm, thus presenting similar results in the marginal adaptation. While, the group light cured with Polywave showed a better degree of cure, however, as the degree of conversion increases, the resin becomes more friable, that is, the ability of a solid material to be reduced to parts with little effort. (BORTOLOTTO; BETANCOURT; KREJCI, 2016) Thus, the highest degree of cure can result in fragile enamel margins of class V restorations.

Hardness is an indicator of the degree of polymerization, which depends not only on the conversion, but also on the nature and bond between monomers. (GAN et al., 2018) In the study by Gan et al., 2018, there was no significant difference in the hardness ratios between the lights/cure modes for the bulk fill TNC composite, but the hardness ratio obtained with the Monowave technology was significantly higher than the hardness rate achieved with Polywave technology for SDR. This may have occurred due to variation in the composition of the composite, variations in light attenuation, exposure time, type of resulting polymeric network and photoinitiator differences. The advantage of using the third-generation Polywave LED is that it promotes a longer wavelength in a wide spectral range that matches the range to activate CQ and alternative photoinitiators present in the resins. Unlike second-generation Monowave LEDs that emit high values of irradiance, however, these high values can generate heat and consequently damage the pulp. In the study cited, SDR primarily uses CQ as a photoinitiator, so Polywave LED curing offered no advantages. (GAN et al., 2018; BORTOLOTTO; BETANCOURT; KREJCI, 2016; SANTINI et al., 2012; CONTRERAS, 2017)

Miletic et al., 2012 stated that LCU Polywave Bluephase ® G2 performed better than LCU Monowave Bluephase ® in the groups containing TPO and CQ-amine, producing a greater degree of conversion. The combined use of TPO and CQ-amine did not result in increased values compared to using only TPO or CQ-amine. (MILETIC, SANTINI, 2012) This idea is reinforced in the study by Chen et al., 2019, who, when investigating the effect of Monowave and Polywave on the adhesion of resin cements to zirconia, concluded that Polywave LCUs are recommended due to their spectrum of emission cover the absorption wave of CQ and other newly developed photoinitiators. (CHEN et al., 2019) This idea is also reinforced in the study by Santini et al., 2012, where the Polywave LCUs tested also showed better performance in the conversion of monomer to polymer, in addition to higher Knoop microhardness, when compared to the LCU Monowave in composite resins (Tetric EvoCeram and Vit-l-escence) containing TPO. However, the resin (Herculite XRV Ultra) that did not contain the photoinitiator, Monowave performed better than Polywave with greater irradiance and more energy than both Polywave LCUs. (RO et al., 2015) Another photoinitiator is the PPD, which in a study by Brandt et al. concluded that this photoinitiator has similar efficiency to CQ in composite resins. (BRANDT et al., 2013)

Similar to previous studies, Lucey et al., 2014 stated that the Vit-l-escence resin showed higher DC values when cured with Polywave LED (Valo and Bluephase) compared to Monowave, which can also be associated with the presence of the photoinitiator Lucirin TPO in the material. Without Lucirin, the monowave measured tip irradiance was 1567mw/cm2, which was greater than any of the Polywaves LCUs present in the study. Thus, it delivered greater total energy in the CQ absorption region, which could increase the effect of the photochemical reaction in the CQ-amine system. When it came to fissure sealant, the three were similar. (DE OLIVEIRA, et al. 2016)

De Oliveira et al., 2016 stated that compounds containing only CQ and TPO demonstrated homogeneous healing profiles, with similar DC at depths of 1, 2 and 3mm, the DC varied becoming smaller at greater depths. Differences in the DC caused by the photoinitiator system and its interaction with the different wavelengths emitted by the Polywave LED were expected, given the different light attenuation for shorter wavelengths like 380–420nm compared to 420–495nm. Based on Rayleigh scattering theory, light transmission in deeper portions of a restoration would be reduced at shorter wavelengths. Thus, as the TPO maximum has the shorter wavelength range of the emission spectrum (380-420nm) compared to CQ (420-495nm), there will be limitations on the depth of cure for composites containing this photoinitiator, regardless of LED emittance region (380–420nm or 420–495nm spectrum). It was observed that composites containing only TPO demonstrated a decrease in the cure efficiency at a depth of 1mm, while this reduction was only observed at a depth of 3mm in composite with CQ. Thus, the scattering of light by the difference in the refractive index of the organic matter particles seems to reduce the effect of the non-uniform nature of the LED beam profile, but to different extents according to the wavelength. (DE OLIVEIRA et al., 2016; HARLOW et al., 2016)

While the study by Derchi et al., 2018 showed that even specimens of the same material cured with different lamps were similar for any material, which is explained by the morphology of the specimens' surface and the composite formulation, and especially by the fill size and loading, rather than the effects of different lamps. (DERCHI et al., 2018)

In the study by Contreras, 2017 the Monowave 3M ESPE curing light showed higher irradiance value and a significant difference than the Polywave Bluephase N curing light. In Monowave, the different activation modes tested showed no difference in irradiance, while Polywave presented, in ramp mode, a significantly lower irradiance than continuous high intensity mode. This is not quite a disadvantage, as the amount of irradiance emitted in the ramp mode of LED fixtures would be enough to obtain an adequate degree of conversion. (CONTRERAS, 2017)

Although the inclusion of a high concentration of CQ in the composite resin is beneficial to increase the degree of polymerization, which would lead, from an aesthetic point of view, to color incompatibility with neighboring teeth. To reduce this conflict, the inclusion of co-initiators was suggested. (SIM et al., 2012) The combination of CQ and TPO would be hypothesized to increase the depth of cure compared to the CQ-only system, in addition to reducing yellowing and color shift compared to using CQ-only. The presence of TPO reduced the composite's initial yellowing, color change after curing compared to using CQ alone, and the effect was concentration dependent. When using CQ and TPO in a 1:1 ratio, it demonstrated less initial yellowing and less color change after curing, without affecting the depth of cure compared to the CQ-only system, regardless of the LED Polywave wavelength emittance. The chemical reaction of the carbonyl chromophore group, present in CQ, with a tertiary amine after exposure to light, progressively causes a photobleaching effect during curing. Although this photobleaching reduces the initial yellowness, it makes color matching for clinical hue selection difficult. By substituting CQ for TPO there is a reduction of this problem, however, in contrast, additions of 50% of the TPO resulted in reduced curing efficiency in increments greater than 2mm. Thus, the TPO should be limited to 50% or less in conventional composites, requiring the layering technique using increments of up to 2mm. (DE OLIVEIRA, et al. 2016)

By comparing LED curing light and combinations of 457 and 473nm lasers, Ro et al., 2015 concluded that lasers are useful for curing composite resins alone or in combination with much lower light intensities than the LED unit. These have advantages due to their small size, cost-effectiveness and emissions closer to CQ absorption peak. The quality of external light when activating CQ is important. As the LED light bandwidth exceeds 100nm, the number of photons available for excitation of CQ molecules of the corresponding wavelength will be greatly reduced. However, the lasers tested may be more effective because most of their photons are of the same wavelength (monochromatic), which can activate the maximum CQ molecules of the corresponding wavelength. However, the amount of CQ in composite resins is small, generally less than 1% by weight, it is unclear whether the demand and supply of photons and photoinitiator was perfectly balanced. Thus, needing more studies on this subject. However, after aging for 24 hours, the specimens cured with the LED unit showed greater microhardness on the upper surfaces, but the laser works at an approximate light intensity of 350 to 710mW/cm2, which corresponds to approximately 40 to 80% of the light intensity of the LED unit used. This lower light intensity has the benefit of lower polymerization shrinkage compared to LED. (RO et al., 2015)

CONCLUSIONS

Based on the literature review carried out, it was possible to conclude that:

- a curing light with a non-homogeneous light output affects the physical-mechanical properties, generating greater stress on the material.

- photopolymerizers must provide light energy corresponding to the absorption wavelength of the photoinitiators present in the resin, as inadequate cure compromises the clinical longevity of the restorations.

- when the material is cured using Polywave technology, there are better physical-mechanical properties, with the exception of cases where the material has only CQ as a photoinitiator.

- Polywave lamps significantly increased the conversion degree of bulk fill resins compared to Monowave lamps, but not in all cases, however, both lamps guarantee a conversion degree greater than or equal to 50%.

- 1:1 ratio of CQ and TPO showed less yellowing of the restoration, regardless of the Polywave LED wavelength.

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