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Compressive Strength of Esthetic Restorative Materials Polymerized with Quartz-Tungsten-Halogen Light and Blue LED

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This study compared the compressive strength of a composite resin and compomer photoactivated with a conventional quartz-tungsten halogen-light (XL 3000, 3M/SPE) and a blue light-emitting diode (LED) (SmartLite PS; Dentsply/De Trey). Forty disc-shaped specimens were prepared using a split polytetrafluoroethylene matrix (4.0 mm diameter x 8.0 mm hight) in which the materials were inserted incrementally. The curing time of each increment was of 40 s with the QTH and 10 s with the LED. The specimens were randomly assigned to 4 groups (n=10), according to the light source and the restorative material. After storage in distilled water at 37°C ± 2°C for 24 h, the specimens was tested in compressive strength in a universal testing machine with load cell of 500 kgf running at a crosshead speed of 0.5 mm/min. Data (in MPa) were analyzed statistically by ANOVA and Student-Newman-Keuls test ($p<0.05$). For the composite resin, light curing with the QTH source did not produce statistically significant difference ($p>0.05$) in the compressive strength when compared to light curing with the LED source. However, light curing of the compomer with the QTH source resulted in significantly higher compressive strength than the use of the LED unit ($p>0.05$). The composite resin presented significantly higher ($p>0.05$) compressive strength than the compomer, regardless of the light source. In conclusion, the compressive strength of the tested materials photoactivated with a QTH and a LED light source was influenced by the energy density employed and the chemical composition of the esthetic restorative materials.

Key Words: composite resin, compomers, light-curing, LED, QTH light.

INTRODUCTION

New technologies have been continuously investigated in esthetic dentistry with the aim of improving the physical, mechanical and esthetic properties of esthetic restorative materials.

Quartz-tungsten-halogen (QTH) lamps are composed of a quartz tungsten thread found in the bulb, involved by inert gas, filter, refrigerating system and optic fibers for light conduction. These lamps operate on a 450-500 nm wavelength range and are popular visible light sources. However, QTH bulbs have a limited effective lifetime and several factors may contribute to produce an inadequate polymerization output, such as presence of debris on the fiber tip, breakage of the tungsten filaments of the optical fiber and voltage variations. In addition, only little energy of the total energy input is effectively converted into light the remainder being generated as heat (1).

Blue light emitting diodes (LED) produce a stable, efficient, long-lasting output of blue light in a short-wave emission spectrum (450-490 nm), with peak at 470 nm, coinciding with the absorption peak of camphorquinone (468 nm), which is the photoinitiator present in most composites (2). LED units have some advantages over QTH lamps due to their potential lifetime of over 10,000 hours without a significant degradation in light output after this period, no need of cooling system or filters, no noise production during function, operation with batteries and direct conversion of electrical energy into light with little amount of wasted energy and minimum heat generation (2). Light-curing units (LCUs) with one LED producing irradiance have recently been marketed.

Several studies have investigated the influence

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of halogen and LED light-curing on different properties of light-cured composites such as degree of conversion (3-5), depth of cure (6-8), hardness (6,8-13), diametral tensile strength (14), flexural strength (15), abrasion resistance (16) and compressive strength (17). Therefore, research studies investigating the effectiveness of resin-based materials photoactivated with different light sources by compressive strength testing will contribute to elucidate the actual participation of LCUs on the longevity of esthetic restorations in the oral cavity.

The purpose of this study was to evaluate the curing efficacy of a high-irradiance blue LED LCU and a QTH lamp by assessing the compressive strength of a composite resin and a compomer photoactivated with both light sources. The null hypothesis tested is that there is no significant difference in the compressive strength when the materials are photoactivated with the light sources.

MATERIAL AND METHODS

The following materials and LCUs were used in this study: Dyract Ap compomer (Dentsply/Caulk, Milford, DE, USA; batch number 0201001349), TPH Spectrum composite resin (Dentsply/Caulk; batch number 55596). XL 3000 QTH light source (3M/ESPE, St. Paul, MN, USA; light intensity = 470 mW/cm^2; 400-510 nm wavelength range), and Smart Lite PS blue LED light source (Dentsply/DeTrey, Konstanz, Germany; intensity = 950 mW/cm^2; 450-490 nm wavelength range). Before preparation of specimens, the intensity of the QTH and LED sources was measured with curing radiometers, Demetron L.E.D. Radiometer (Demetron/Kerr Corp., Orange, CA. USA; batch number 79302331, and Cure Rite Radiometer (EFOS, Mississauga, Ontario, Canada; batch number 9152), respectively.

Twenty disc-shaped specimens of each material were prepared using a split white polytetrafluoroethylene matrix (4.0 mm diameter x 8.0 mm height). The matrix was placed onto a 2.0-mm-thick glass plate and was filled in 4 approximately 2.0-mm-thick increments. Ten specimens of material were light cured with one of light sources. Each increment was exposed to the QTH and LED LCUs for 40 s and 10 s, respectively. After insertion of the last increment, a transparent polyester strip and a 2.0-mm-thick glass plate were placed onto the matrix and light curing was done through this set. After storage in distilled water at 37^{o}C ± 2^{o}C protected from light during 24 h, the specimens were tested in compressive strength in a universal testing machine (EMIC DL 10.000, São José dos Pinhais, PR, Brazil) with a load cell of 500 kgf and a crosshead speed of 0.5 mm/min. Data were tabulated and analyzed statistically using ANOVA and the Student-Newman-Keuls test (SNK) for pairwise comparisons. Significance level was set at 5%.

RESULTS

Table 1 shows the mean compressive strength values (in MPa) and standard deviations of the resin materials photoactivated with the QTH and LED sources.

The SNK test revealed statistically significant interaction when individual comparison was done between the light sources ($p<0.05$) and between the materials ($p<0.05$) (Table 1). For the composite resin, light curing with the QTH source did not produce significant difference ($p>0.05$) in the compressive strength when compared to light curing with the LED source. However, light curing of the compomer with the QTH source resulted in significantly higher compressive strength than the use of the LED unit ($p>0.05$). The composite resin presented significantly higher ($p>0.05$) compressive strength than the compomer regardless of the light source.

Table 1. Compressive strength means (in MPa) and standard deviations of the resin materials light cured with the QTH and LED sources.

Light source	Material	
	Compomer	Composite resin
QTH light	153.90 ± 44.01 aB	202.23 ± 53.37 aA
LED	109.36 ± 27.41 bB	186.76 ± 38.98 aA

Means followed by same lowercase letters in columns and uppercase letters in rows did not differ significantly (SNK test; $p>0.05$).

DISCUSSION

Compressive strength has a particularly important role in the mastication process since several of the masticatory forces are of compressive nature. The maximum resistance to compression is calculated by the original cross-sectional area of the test specimens and the maximum force applied. The compression forces applied on each side of the test specimens are dissipated into shear forces along the cuneiform area on each side. As a result of the action of the two cones on the cylinder, traction forces arise in the central portion of the mass. Due to this tensile dissipation in the specimen, a matrix that reproduced a cylinder that was twice as long as the diameter (4.0 mm diameter and 8.0 mm length) had to be used in order to have satisfactory results (3).

Significant interaction was noted between the light source and the tested material. The compomer cured with the QTH lamp showed significantly higher mean compressive strength values than those obtained when the material was cured with the LED source. The composite resin light-cured with the QTH lamp also showed higher mean compressive strength values than those obtained with the LED, however without statistical significance. This result suggests that the compressive strength of the composite resin was not affected by the type of light curing unit, which has been found elsewhere (17) (Table 1). Mills et al. (9) found no statistically significant differences in the compressive strength of dental composites photoactivated with two experimental high-power LED prototypes and a commercial QTH lamp. However, light curing with a commercial LED LCU resulted in significantly lower values.

In the present study, the type of material (compomer *vs*. composite resin) had a significant role in light curing. The composite resin presented significantly higher mean compressive strength values than the compomer (Table 1). The literature has shown the chemical composition of dental composites interfere in their mechanical properties (7,8,10,14).

The use of high irradiance with short irradiation time has been recommended to achieve satisfactory depth of cure and improved mechanical properties. However, high irradiance has also been shown to cause high polymerization shrinkage and increased marginal microleakage around composite restorations (18).

Determination of curing time was an important factor in the results obtained in this study, which are consistent with those of previous investigations (6,13). The curing time used for composite photoactivation with both units followed the manufacturer's recommendations. The use of the LED unit allowed shortening the curing time to 10 s due to the high irradiance delivered by this light source. However, the use of high irradiation in a short period of time provides a rapid reaction of polymerization, shortening the pre-gel phase, passing quickly to a rigid state (post-gel phase), reducing the number of chemical reactions for the conversion of monomers into polymers, which may interfere with the mechanical properties of the material.

Light intensity or output power density or irradiance is expressed in W/cm² and represents the number of photons emitted *per* second by a light source *per* unit area of the light-cured point. The energy density for light curing is calculated by multiplying the light intensity by the curing time and is expressed in J/cm² (19,20). The efficiency of LCUs depends on the total energy concept, according to which both intensity and photo-initiation time are important for an efficient light curing of dental composites.

For both materials, the light intensity of the QTH LCU was 470 mW/cm² and the exposure duration was 40 s, while the LED source had intensity of 950 mW/cm² with exposure duration of 10 s. Therefore, the energy density used by the QTH and LED LCU were 18 J/cm² and 9.5 J/cm², respectively. The higher energy output was used for the QTH LCU could help explaining the higher compressive strength obtained when the materials were light activated with the halogen lamp.

The conversion rate presents a direct relationship with the amount of energy applied, which means that higher energy intensity will promote greater monomer conversion with consequent improved mechanical proprieties of the material (4). It may be speculated that the high radiation emitted by the LED LCU Smart Lite PS in short exposure duration, accelerates the curing reaction, reducing the polymer flowability, increasing the modulus of elasticity and shortening the pre-gel phase, which could interfere with the results of resistance to compression. In order to obtain an effective light curing, which means 50 to 60% of monomer conversion, a radiant energy of approximately 16 J/cm² for a 2-mm-thick resin layer is needed. The increase of output power density accelerates reaction speed.

The light-curing process is influenced by the light intensity, time, and output power density used, which consequently influence the mechanical properties of resin materials (6,15). In this study, the compressive strength of the composite resin light-cured with either a halogen lamp or a LED source was similar, while different compressive strengths were obtained for the compomer when photoactivated with each of the light sources. The composite resin presented better results than the compomer. In summary, the influence of the chemical composition of the materials, light intensity, curing time and output power density of the LCUs should be considered on the final outcomes. Further research must be carried out to clarify the mechanical proprieties of composites photoactivated with LED units, addressing the factors mentioned above. In conclusion, the compressive strength of the tested materials photoactivated with a QTH and a LED light source was influenced by the energy density employed and the chemical composition of esthetic restorative materials. Within the limitations of this in vitro study, it may be suggested that the superiority of halogen lamps over LEDs is questionable when different resin-based materials are evaluated.

RESUMO

Este estudo comparou a resistência à compressão de uma resina composta e de um compômero, fotoativados com luz halógena convencional de quarto-tungstênio (QTH) (XL 300, 3M/SPE) e LED azul (SmartLite PS; Dentsply/De Trey). Foram confeccionados 40 espécimes em forma de disco usando uma matriz bipartida de politetrafluoretileno (4,0 mm de diâmetro x 8,0 mm de altura) em que o material foi inserido incrementalmente. O tempo de polimerização de cada incremento foi de 40 s para a luz halógena convencional e de 10 s para o LED. Os espécimes foram aleatoriamente alocados em 4 grupos (n=10), de acordo com a fonte de luz e com o material restaurador. Depois de armazenadas em água destilada a 37°C ± 2°C por 24 h, a resistência à compressão dos espécimes foi testada em uma máquina universal de ensaios com célula de carga de 500 kgf a uma velocidade de carregamento de 0,5 mm/min. Os dados (em MPa) foram analisados estatisticamente por ANOVA e teste de Student-Newman-Keuls ($p<0,05$). Para a resina composta, a fotopolimerização com luz halógena não produziu diferença estatisticamente significante ($p>0,05$) em sua resistência à compressão quando comparada à fotopolimerização com LED. Contudo, a fotopolimerização do compômero com a luz halógena resultou em uma resistência à compressão significativamente maior que a feita o LED ($p>0,05$). A resina composta apresentou resistência à compressão significativamente maior que a do compômero, independente da fonte de luz. Concluiu-se que a resistência à compressão dos materiais fotopolimerizados com luz halógena e LED foi influenciada pela densidade de energia empregada e pela composição química dos materiais restauradores estéticos.

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