Flexural strength and modulus of elasticity of four dental composites polymerized with light emitting diode (LED) and halogen light

Resistência flexural e módulo de elasticidade de resinas compostas polimerizadas com LED e luz halógena

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Abstract

The purpose of this investigation was to evaluate the flexural strength (FS) and modulus of elasticity (ME) of three microhybrid resins (Filtek Z250; Charisma; P60) and one submicrohybrid resin (Concept) using LED or halogen light polymerization. Twenty specimens (25x2x2 mm) *per* tested material were prepared and polymerized using a halogen or LED curing unit and stored in distilled water. FS and ME tests were performed on an Instron universal testing machine (0.75mm/min). ANOVA and multiple comparisons (SNK) showed that the two polymerization systems resulted in no significant differences (p>0.05) in the FS of Charisma and Filtek Z250. The two curing systems also produced similar results in the ME of Charisma, Concept and Filtek Z250. Significant differences were found in FS and ME, with the halogen curing light system showing better results than the LED system. The LED LCU systems did not exhibit a superior performance in our investigation of any of the composite resins, in terms of flexural strength and modulus of elasticity.

Uniterms

Light curing unit (LCU), mechanics properties; dental materials; composite resins

Introduction

The curing of dental composites with blue light, which was introduced in the 1970s, initially showed several drawbacks[2]. Today, the curing of composite resins depends on the intensity and spectral output of the curing unit and on the chemical characteristics of the resin composition[9].

The ideal curing system is one that is simple to use, has a longer bulb life, an infinite curing depth and can cure all composites regardless of the type of photoinitiator[4,15].

Very slight changes in the intensity of the light unit cause significant alterations in the degree of conversion on a superficial area of the composite resin[17]. Thus, the main factors responsible for the success of restorations with photoactivated resins are sufficient light intensity, correct wavelength and appropriate time of polymerization[1,2]. However, unlike polymerization of chemically activated resins, polymerization in photoactivated systems does not take place in the entire mass but only where the light reaches into the absorption spectrum of the camphorquinone photoinitiator[16].

Several studies have addressed the application of blue LED technology to cure light-activated dental materials and to overcome the problems inherent to halogen LCUs[8,18,20,22,23].

According to some authors, composite resins polymerized with a powerful LED LCU can attain similar mechanical properties as those cured with a halogen LCU[10,13-4]. However, LED sources with a lower irradiance than halogen sources have also achieved a greater depth of cure and flexural strength[20].

This way, the aim of this study was to evaluate the flexural strength and modulus of elasticity of four different composites in function of curing system employed (LED LCU and a halogen LCU).

Materials and Methods

Four commercial composite resins were evaluated in this study: three hybrid composite resins, Filtek Z250 and P-60 (3M Dental Products, St Paul, MN 55 144), Charisma (Heraeus Kulzer GmbH, Wehrheim, DE 63450) and one submicrohybrid resin, Concept (Vigodent, Bonsucesso, RJ, Brazil). Table 1 gives details of the tested materials and their compositions, specifications and manufacturers.

Table 1. Description of materials

	Charisma	Concept	P-60	Filtek Z250
Manufacturer	Heraeus Kulzer GmbH Wehrheim, Germany	Vigodent Ind Bonsucesso, RJ Brazil	3M Dental Products St. Paul,MN USA	3M Dental Products St. Paul,MN USA
Batch	8 609.71	010/02	3-NF/8100A2	0-EF/1370A2
Shade	A2	A2	A2	A2
Valid	2004-09	2004-06	2006-7	2004-07
Type	microhybrid	submicrohybrid	hybrid	microhybrid
Resin Matrix	Bis-GMA TEGDMA	Bis-GMA UDMA Bis-EMA	Bis-GMA UDMA Bis-EMA	Bis-GMA UDMA Bis-EMA
Filler type	Ba-Al-Si glass	Ba-Al-Si glass	Zirconia/silica†	Zirconia/silica†
Filler level (wt %)	83,.5 %‡	77,5 %#	–	82 %†
Filler level (vol %)	64 %‡	–	61%†	60 %†
Particle size (μm)	0,2-2 μm‡	0,04-2 μm#	0,6μm †	0,19-3,3 μm†

References:
‡ Heraeus/Kulzer technical manual and home page
# Vigodent technical manual and home page
† 3M/Espe technical manual and homepage

Twenty rectangular specimens of each composite resin were prepared using a split stainless steel mould 25mm long, 2mm wide and 2mm thick placed on a glass slide. Using a glass slide, a Mylar strip was pressed on top of the mould to remove excess material. During the photopolymerization, the tip of the light sources was held against the strip.

A LED LCU (Ultrablue I, DMC Equipamentos, São Carlos) with an intensity of 180 mW/cm^2 and a halogen LCU (LC 2500, 3M Dental Products, St

Paul, MN 55 144) with an intensity of 455 mW/cm^2 determined with a radiometer (Curing lightmeter 105, DMC Equipamentos, São Carlos) were used in this study.The top surfaces of the restoration materials were light-cured through a clear polyester matrix strip using the LED LCU and a halogen LCU. Following polymerization, the specimens were removed from the mould, excess material was cut off with a scalpel, and their dimensions were measured with a precision caliper. The cured specimens were then transferred to a dark polypropylene bottle containing distilled water at 37^{o}C ± 1 and stored for thirty days.

After storage, the specimens polymerized by LED LCU and by halogen LCU were subjected to mechanical tests. Flexural strength and modulus of elasticity were evaluated according to the ISO 4049 standard. The specimens were placed in a three-point bending apparatus on two parallel supports 20mm apart and loaded until fracture occurred at a crosshead speed of 0.75mm/min on an Instron universal testing machine (Model 4411, Instron Corp., Canton, MA).

The flexural strength was calculated in MPa, using the following equation: $\sigma = 3Fl \bullet 2bh^2$, where F is the maximum load, L is the distance between the specimen supports, b is the width and h is the height of the specimen. The modulus of elasticity in GPa was calculated from the stress-strain curve using the mechanical tester's computer linked to the testing machine.

The flexural strength and modulus of elasticity were determined and mean and standard deviation were calculated for the experimental groups. The values were compared by factorial analysis of variance (ANOVA), using the SPSS software (SPSS 8.0, SPSS Inc., Chicago, IL 60611). When F-tests were significant, *Post-hoc* Student-Newman-Keuls multiple comparison intervals were also performed to identify statistically homogeneous subsets ($p<0.05$).

Results

Tables 2 and 3 list the flexural strength and modulus of elasticity produced by the different polymerization systems, as well as their standard deviation.

Table 2 – Flexural strength (MPa±SD) values of tested materials using LED and halogen light polymerization

Activation source	Material			
	Charisma	Concept	Filtek Z-250	P-60
Halogen	77.81±17.1 A,a	96.62±15.4 A,a	97.89±28.36 A,a	104.65±29.7 A,a
LED	79.21±15.6 A,a	70.55±20.1 B,b	104.81±22.5 A,c	88.29±26.9 B,a

Different letters represent statistically significant differences (p<0.05). Capital letters represent comparisons between polymerization systems, and minuscule letters represent comparisons between materials.

Table 3 – Modulus of elasticity (GPa±SD) values of tested materials using LED and halogen light polymerization

Activation source Material				
	Charisma	Concept	Filtek Z-250	P-60
Halogen	0.570±0.21 A,a	0.637±0.25 A,a	0.700±0.11 A,ab	0.994±0.30 A,b
LED	0.506±0.75 A,a	0.453±0.35 A,a	0.692±0.85 A,b	0.672±0.14 B,b

Different letters represent statistically significant differences (p<0.05). Capital letters represent comparisons between polymerization systems, and minuscule letters represent comparisons between materials.

The flexural strength of Concept (96.62 MPa) and P-60 (104.65 MPa) polymerized with halogen LCU was statistically superior ($p<0.05$) to LED LCU (Concept: 70.55 MPa; P-60: 88.29 MPa).

No statistically significant differences were found ($p>0.05$) in the Charisma, Concept and Filtek group when they were polymerized with either LED LCU or a conventional halogen LCU, regardless of the modulus of elasticity. The only exception was the P-60 composite resin, which showed a higher average when polymerized with the halogen light system (0.99 GPa) than with LED polymerization (0.672 GPa).

Multiple comparisons of the flexural strength values of all the tested materials showed similar averages when polymerized with halogen light. The LED activation showed similar averages for Charisma and P-60.

A two-way ANOVA indicated that the material ($p>0.05$) and light curing unit ($p>0.05$) factors had no statistically significant effect on the flexural strength or the modulus of elasticity.

Discussion

The physicochemical process of composite resin polymerization is usually initiated by a photoinitiator activated by visible light at an estimated wavelength of 370-500 nm[15]. The effectiveness of the photopolymerization process depends on the particular chemical characteristics of the composite resins and on the light sources[4,8].

The proportion between the mechanical properties and underpolymerization is closely related and exerts a considerable influence on the clinical performance of composite resins[7,19]. Considering a satisfactory clinical threshold, the physical and mechanical properties play a fundamental role in the longevity of a restoration[3,11]. Investigations into the mechanical properties of restorative materials, such as compressive and flexural strength, and flexural modulus, are made specifically in cases where high biting forces and stresses can exacerbate inherent material defects[13,14,20,23].

The mean flexural strength of Charisma and FiltekZ250 specimens polymerized with the halogen LCU was statistically similar to that polymerized with LED LCU. In terms of the modulus of elasticity, no statistically significant differences were found when the specimens were polymerized with either LED LCU or a conventional halogen LCU. The average modulus of elasticity of the composite resin P-60 was higher when it was polymerized with halogen LCU than with LED LCU.

The results obtained here indicated the materials had equivalent average flexural strength and modulus of elasticity. However, when a mechanical superiority evidenced statistically occurred in a specific group, it resulted from the polymerization by halogen LCU, in agreement with the findings of Stahl et al.[20] (2000) and Jandt et al.[10] (2000).

The halogen unit LC 2500 (3M/Espe) with a 455 mW/cm^2 light irradiance used in this study exceeds the minimum irradiance required for complete polymerization of materials up to 2mm in depth. In addition to other aspects inherent to the material, this physical aspect probably provides a better explanation of the results obtained with this LCU. However, it should be kept in mind that, despite the substantial difference in light irradiance between the devices tested here, LED Ultrablue LCU with 180 mW/cm^2 power showed statistically similar results to those of the halogen LCU for two of the four composite resins analyzed in this study.

Several studies have been conducted to compare the mechanical properties of composite resins polymerized by halogen LCU or LED LCU[14,20,23]. Dunn & Bush[6] (2002) found low mechanical properties for composites cured by commercially available LED LCU when compared with halogen LCU. In their comparison of the efficacy of two LCUs, Micali & Basting[12] (2004) found that the LED LCU is as effective in polymerizing hybrid composite resins as the halogen LCU is. The results obtained here are congruent with other studies that showed similar values of flexural strength and modulus of elasticity between the tested LCUs[10,13-4].

The concentration of photosensitive agents and the luminous irradiance of LCUs can interfere in some of the mechanical properties of dental composites[7,19]. Today, new polymerization systems have been included in the quest for more effective curing. In addition to camphorquinone, a secondary photoinitiator reacts with blue light, forming free radicals. One of these new systems is 1-phenyl-1,2-propanodione (PPD), which is an alternative photosensor[8,15,18] that absorbs shorter waves, with a maximum absorption peak at around 400nm.

The halogen LCU wavelength varies from 400 to 500 nm. This variation allows both camphorquinone and PPD to be activated and, if their maximum absorption peak is not reached, the nonabsorbed content is transmitted to the tooth as thermal energy[8].

On the other hand, LED wavelength coincides with the maximum absorption of camphorquinone, so it is ideal for the polymerization of materials that contain it as the photoinitiator. However, the range of distribution of LED wavelengths (60nm) is quite small and is inefficient for the sensitization of some photoinitiators such as PPD. These chemical characteristics may fall outside this range and display curing problems, according to Stansbury[21] (2000) and Hammesfahr et al.[8] (2002).

The spectral output of the LED LCU lies within a narrow band with a peak emission of 460 nm to 490 nm, which is close to the maximum absorption spectrum of camphorquinone used in visible light-cured composites[5,8,15]. Hence, it is almost totally absorbed by this photoactivator. This physicochemical peculiarity can explain the equivalence of the results found here, despite the low irradiance power.

The use of new technologies should be conditional to and supported by solid scientific research, which should be well conducted experimentally and well interpreted scientifically. New experiments are therefore recommended to consolidate the use of these new technologies in the curing process of aesthetic restorative materials.

Conclusions

The simulated conditions used in this study lead to the following conclusions:

The composite resins Concept and P-60 presented greater flexural strength when photopolymerized with halogen light.

All the resins presented similar modulus of elasticity values with the two LCUs, with the exception of the composite resin P-60.

The LED system did not prove superior results with any material from the standpoint of flexural strength or elastic modulus.

Resumo

O objetivo deste estudo foi avaliar a resistência flexural (FS) e o môdulo de elasticidade (ME) de três resinas micro-híbridas (Filtek Z250; Charisma; P60) e uma submicrohibrida (Concept) utilizando LED ou polimerização por luz halógena. Vinte espécimes (25x2x2 mm) de cada resina composta foram confeccionados e polimerizados usando LED ou luz halógena e posteriormente armazenados em água destilada a 37º C ± 1 durante 30 dias. Testes de FS e ME foram realizados em uma máquina de ensaio universal Instron (0.75mm/min). ANOVA e comparações múltiplas (SNK) mostraram que os dois sistemas de polimerização não apresenrtaram diferenças significantes (p>0.05) para a FS da Charisma e Filtek Z250. Os dois métodos de polimerização também produziram resultados similares para o ME da Charisma, Concept e Filtek Z250. Diferenças significantes de FS e ME foram encontradas com o sistema halógeno, apresentando melhores resultados que o sistema LED. As diferenças significativas na resistência flexural e módulo de elasticidade sempre apontaram uma superioridade para o sistema de luz halógena em comparação ao LED.

Unitermos

Polimerização, propriedades mecânicas, resinas compostas

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