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Influence of Modulated Photo-Activation on Shrinkage Stress and Degree of Conversion of Bulk-Fill Composites

Marilia Mattar de Amoêdo Campos Velo[1], Linda Wang[1], Adilson Yoshio Furuse[1], Letícia Ferreira de Freitas Brianezzi[1], Cassiana Koch Scotti[1], Giovanna Speranza Zabeu[1], Rafael Massunari Maenosono[1], Rafael Francisco Lia Mondelli[1]

[1]Department of Operative Dentistry, Endodontics and Dental Materials, School of Dentistry, USP Universidade de São Paulo, SP, Brazil

Correspondence: Dra. Marilia Mattar de Amoêdo Campos Velo, Alameda Doutor Otávio Pinheiro Brisolla 9-75, 17012-901 Bauru, SP, Brasil. Tel: +55-14-3235-8265. e-mail: mariliavelo@yahoo.com.br

This study aimed to evaluate the polymerization properties of bulk-fill materials (low and high-viscosity) by using high-intensity continuous light and intermittent photo-activation in terms of polymerization shrinkage stress and degree of conversion (DC). The following Bulk-fill and Conventional nanofilled resin composites were evaluated: Filtek Z350XT Flow (3M/ESPE), SureFil SDR Flow (Dentsply), Filtek Bulk Fill Flow (3M/ESPE), Filtek Z350XT (3M/ESPE) and Filtek Bulk Fill Posterior (3M/ESPE). A LED device (DB 685, Dabi Atlante) was used for both protocols: continuous uniform and intermittent photo-activation (light-on and light-off cycles) with identical radiant exposure (14 J/cm^2). The polymerization shrinkage stress (n=6) was evaluated by inserting a single increment of 12 mm^3 between two stainless steel plates (6×2 mm) adapted to a Universal Testing Machine (UTM), at different times. Measurements were recorded after photo-activation. The degree of conversion was evaluated by Fourier transformed infrared spectroscope (FTIR) with an attenuated total reflectance (ATR) accessory (n=5). Data were analyzed by three-way ANOVA and Tukey's HSD ($\alpha=0.05$) tests. Bulk Fill Posterior presented higher shrinkage stress values when photo-activated with the intermittent technique ($p<0.05$). The intermittent photo-activation increased the degree of conversion for the low-viscosity bulk-fills ($p<0.05$). Therefore, the use of modulated photo-activation (intermittent) must be indicated with caution since its use can influence the shrinkage stress and degree of conversion of composites, which varies according to the resin formulations.

Key Words: bulk-fill composites, degree of conversion, modulated photo-activation, shrinkage stress.

Introduction

Bulk-fill resin-based composites were launched with the purpose of providing bulk placement into dental cavities while offering good performance and clinical practicality (1). However, despite the common commercial classification of bulk-fill materials, different monomer and filler formulations are available, which may impact the polymerization kinetics (2). Despite the promising results shown by bulk-fill resin composites, polymerizing up to 4mm-thick increments without adversely effecting polymerization shrinkage stress, the material composition may influence the curing characteristics since the overall properties of resin composite materials are usually composition-dependent (3).

Reducing shrinkage stress by changing the polymerization rate can influence the efficacy of the material. Moreover, the quality of the polymer network formed is dependent upon the overall degree of conversion (DC), since this conversion is correlated with the volumetric shrinkage in the polymerization process (4). Therefore, since all available bulk-fill resins involve the addition of newer low-shrinkage monomers, understanding their dynamics regarding polymerization shrinkage and DC, as well as the interaction with photo-activation, is essential.

In order to reduce polymerization rates and extend the time allowed for viscous flow (and consequently, for non-rigid shrinkage), several photo-activation protocols (modulated methods) have been developed to overcome the issues related to polymerization, such as volume shrinkage and generation of interface stresses as alternatives to continuous high-intensity irradiation (5,6). A low light intensity increases the period that the resin remains with a low elasticity modulus (pre-gel phase), allowing molecular accommodation and relieving shrinkage stress (7).

According to Daugherty et al. (8), the degree of polymerization of bulk-fill composites increases with longer exposure time. In addition, the use of modulated methods of photo-activation (continuous, ramp, intermittent pulse and pulse delayed, for example) for different formulations of resin composites may influence their mechanical properties, such as microhardness, DC and shrinkage stress. Protocols such as soft-start and pulse delay have been shown to decrease stress when compared with continuous photoactivation (9,10), but at the same time, they have been also associated with a concurrent reduction in the DC, which, in turn, might deteriorate the mechanical properties of the restoration (11).

Conversely, the intermittent pulse photo-activation method (a low-irradiance protocol) consists of photo-activation of the resin composite in light-on and light-off cycles (1 second each), which could modify the polymerization kinetics of the resin composites by reducing the gap formation of the restoration interface (12) and could also improve the DC, the maximum light intensity peak is achieved every time the light is emitted. Intermittent photo-activation is time-efficient, clinically relevant and is unlike the continuous uniform polymerization technique, which immediately provides maximal light intensity, causing the hardening of the resin composites in a few seconds, severely limiting its flow (7).

So far, no information is available in the literature on the effects of a low-irradiance protocol on the polymerization shrinkage stress and DC of low and high-viscosity bulk-fill resin composites. Thus, the aim of the present study is to evaluate the polymerization properties of bulk-fill materials (low and high-viscosity) by using high-intensity continuous light and intermittent photo-activation in terms of polymerization shrinkage stress and DC. The null hypotheses evaluated were that: (a) neither the high-intensity continuous nor the intermittent photo-activation protocols would influence the polymerization shrinkage stress of bulk-fill (low and high-viscosity) resin composites; and (b) none of the photo-activation protocols would influence the DC of bulk-fill (low and high-viscosity) resin composites.

Material and Methods

Five commercial resin-based composites were assessed in the present study: three flowable composites [conventional (Filtek Z350XT Flow; 3M/ESPE, St. Paul, MN, USA); bulk-fill (Surefil SDR; Dentsply, Konstanz, BW, Germany and Filtek Bulk Fill Flow; 3M/ESPE, St. Paul, MN, USA)] utilized as liner materials and 2 high-viscosity composites [conventional (Z350XT; 3M/ESPE, St. Paul, MN, USA) and bulk-fill (Filtek Bulk Fill Posterior; 3M/ESPE, St. Paul, MN, USA)] utilized as filler material. Product specifications are presented in Table 1.

Measurements of Polymerization Shrinkage Stress

Measurements of polymerization shrinkage stress were performed as previously described in the literature (13). Constant volumes (12 mm^3) of all materials were inserted in a single increment between two rectangular stainless-steel plates (6×2 mm) adapted to a UTM (INSTRON 3342, Illinois Tool Works, Norwood, USA) with 1 mm thickness between the steel plates, presenting high compliance (defined by low resistance of shrinkage stresses without repositioning of the plates).

Ten groups were evaluated (n=6). The number of the samples were based on previous pilot studies performed by our group and in the previous literature (14). To improve micromechanical retention to the stainless-steel plates, the surfaces were sandblasted with 50 µm Al_2O_3 particles. Once in position, the resin composite specimens were photo-activated by using both continuous and intermittent photo-activation protocols. The interval between on and off during the intermittent photo-activation was 1 s; the photo-activation was performed twice the time of high-intensity continuous photo-activation (for 10 and 20 s, respectively) with the same radiant exposure (14 J/cm^2). The photo-activation was performed at a standard distance of 1 mm from the test material.

For both protocols, a LED-curing device (DB 685, Dabi Atlante, Ribeirão Preto, SP, Brazil) with a 440 to 480nm wavelength and 8 mm diameter curing tip, operating at 1400 mW/cm^2 was used. The irradiance from the curing light was previously measured with a radiometer (RD-7, Ecel Indústria e Comércio Ltda., Ribeirão Preto, SP, Brazil). The diameter curing tip established uniform photo-activation for all resin composite specimens (6×2×1 mm; width, length and height, respectively) evaluated. The forces generated during polymerization shrinkage were detected by a load cell (10 kgf) and continuously recorded from the beginning of the photo-activation until it reached 300 s. Data were transferred in real time to an attached computer and four periods were selected for the purpose of evaluation: 20, 65, 120 and 300 s. The shrinkage stress was calculated following the equation:

$$T\ (Mpa) = \frac{F\ (N)}{A\ (mm^2)}$$

DC measurements

DC measurements were conducted by using a Fourier transformed infrared spectroscope (FTIR – Shimadzu Corporation, Model IR Prestige 21, Kyoto, Japan) with an attenuated total reflectance (ATR – Smart Miracle TM) accessory. Samples were prepared by using a silicon mold to standardize the diameter (2.5 mm) and material thickness (1 mm). Ten groups with five replicates were produced (n=5).

Calculation of DC

The DC for the resin composites assessed was calculated by comparing the height of particular peaks in the spectra derived from the cured and uncured resin. A graph was obtained by a software (IR solution-control software), which the percentage of unreacted carbon double bonds C=C was from the peak height ratio of the methacrylate C=C (at 1638 cm^{-1}) and those of an internal standard aromatic carbon double bond (at 1608 cm^{-1}) during the polymerization, in relation to the uncured material.

The percentage of DC was calculated for each sample as follows:

DC (%) = [1 - (1638 cm^{-1}/1608 cm^{-1})peak height after photo-activation / (1638 cm^{-1}/1608 cm^{-1})peak height before photo-activation] x 100

Statistical Analysis

Data were statistically analyzed with the Statistica software (Statsoft®, Tulsa, OK, USA). Normal distribution was verified by using the Kolmogorov-Smirnov's test. Since the assumptions were satisfied, shrinkage values were analyzed by using three-way ANOVA and the Tukey's post-hoc test.

For all analyses, 5% was considered the level of significance.

Results

The shrinkage stress for each evaluated material as a function of time according to the polymerization mode are presented in Table 2. Low-viscosity bulk-fill resin composites (Surefil SDR Bulk Fill Flow and Filtek Bulk Fill Flow) showed significant differences in the values of shrinkage stress, which was lower than high-viscosity resin composites (Filtek Z350 XT and Filtek Bulk Fill Posterior) ($p<0.05$). Significant differences were observed between the high-viscosity resin composites only in the intermittent mode for 300 s ($p<0.05$). Among the low-viscosity tested materials, the Filtek Z350 XT Flow showed significantly greater shrinkage stress than all tested materials evaluated for all times. Differences were also found for the Filtek Z350 XT and Filtek Bulk Fill Posterior at 300s for both activation protocols ($p<0.05$) (Table 2). Figure 1 shows the profile of the shrinkage development as a function of time for the resin composites tested according to the photo-activation protocol. Z350XT Flow presented the highest shrinkage values. For DC, all flowable resin composites showed the highest values only when the intermittent photo-activation

Table 1. Resin composites studied, listed in bulk-fill and conventional categories*

Material	Classification	Shade	Manufacturer	Resin matrix / filler content	Filler	
					Composition	Load (wt%/vol%)
Filtek™ Z350 XT Flow	Conventional Low viscosity (liner material)	A2	3M ESPE, St. Paul, MN, USA	BISGMA, TEGDMA, EDMAB / Silica: 75nm/Zirconia: 5-10nm	Silane treated ceramic and silica; substituted dimethacrylate; ytterbium fluoride; reated polycaprolactone polymer; EDMAB; benzotriazol; diphenyliodonium hexafluorophosphate	65/46
Surefil SDR Bulk Fill Flow	Bulk-Fill Low viscosity (liner material)	Universal	Dentsply, Konstanz, Germany	UDMA, TEGDMA, EBPDM / Filler Size (average): 4.6 µm	Barium and strontium, alumino-fluoro-silicate glass particles	68/64
Filtek™ Bulk Fill Flow	Bulk-Fill Low viscosity (liner material)	A2	3M ESPE, St. Paul, MN, USA	UDMA, BISEMA, BISGMA, TEGDMA / Silica/Zirconia: 0.01 a 3.5µm Ytterbium trifluoride: 0.1 - 5µm	Silane treated ceramic; substituted dimethacrylate; ytterbium fluoride; benzotriazol; ethyl 4-Dimethyl Aminobenzoate	76.5/58.4
Filtek™ Z350 XT	Conventional High viscosity (filler material)	A2	3M ESPE, St. Paul, MN, USA	BISGMA, BISEMA, TEGDMA, UDMA / Silica: 20nm/Zirconia: 4-11nm	Silane treated ceramic, silica and zirconia; Polyethylene Glycol Dimethacrylate; 2,6-Di-Tert-Butyl-P-Cresol	78.5/59.5
Filtek™ Bulk Fill Posterior	Bulk-Fill High viscosity (filler material)	A2	3M ESPE, St. Paul, MN, USA	BISGMA, BISEMA, UDMA / Silica: 20nm Zirconia: 4-11nm Ytterbium trifluoride:100nm	Silane treated ceramic, silica and zirconia; aromatic urethane dimethacrylate; ytterbium fluoride; DDDMA; water; modified Methacrylate monomer; EDMAB; benzotriazol	64.5/42.5

UDMA: Diurethane Dimethacrylate; TEGDMA: Triethylene Glycol Dimathacrylate; EBPDMA: Ethoxylated BISGMA; BISEMA: Bisphenol A Polyethylene Glycol Diether Dimethacrylate; BISGMA: Bisphenol A Diglycidyl Ether Dimethacrylate; DDDMA: 1,12-Dodecane Dimathycrilate; EDMAB: Ethyl 4-Dimethyl Aminobenzoate; DDMA: Dodecandiol Dimethacrylate. *All informations were supplied by the manufacturers.

was used (Table 3).

Discussion

Reducing polymerization shrinkage stress is of usual concern to dental clinicians when performing direct posterior resin-based composite restorations, which has been associated with marginal failure, recurrent caries and dental fracture (15). The magnitude of generated polymerization shrinkage stress depends upon several factors, such as the configuration factor (*C*-factor) of the cavity (13), the rate of polymerization, the filler type and distribution, resin monomers, and the photo-activation technique (4). In the present study, regarding differences in the polymerization shrinkage stress among all low-viscosity resin composites evaluated, neither the continuous nor the intermittent photo-activation protocols influenced the bulk-fill materials. In a previous study (16), it was demonstrated that modulated methods did not reduce stress and gap formation for conventional composites. We demonstrated that the intermittent modulated method can have influence depending of the resin composite used.

Table 2. Mean ± standard deviation (SD) of the shrinkage stress (Mpa) as function of time of the materials according to the photo-activation protocol (n=6)

Resin composites	Photo-activation protocols	20	65	120	300
Filtek™ Z350 XT Flow	C	0.52 ± 0.01^{dA}	0.56 ± 0.01^{dA}	0.64 ± 0.01^{dB}	0.70 ± 0.01^{dB}
	I	0.46 ± 0.02^{cA}	0.52 ± 0.02^{dA}	0.62 ± 0.01^{dB}	0.66 ± 0.01^{eB}
Surefil SDR Bulk Fill Flow	C	0.23 ± 0.02^{bA}	0.26 ± 0.02^{bA}	0.34 ± 0.02^{bB}	0.40 ± 0.02^{bB}
	I	0.21 ± 0.01^{bA}	0.25 ± 0.01^{bA}	0.21 ± 0.02^{bB}	0.39 ± 0.02^{bB}
Filtek Bulk Fill Flow	C	0.13 ± 0.01^{aA}	0.15 ± 0.01^{aA}	0.17 ± 0.02^{aB}	0.23 ± 0.02^{aB}
	I	0.09 ± 0.01^{aA}	0.11 ± 0.01^{aAB}	0.26 ± 0.02^{aBC}	0.21 ± 0.02^{aC}
Filtek Z350 XT	C	0.31 ± 0.03^{cA}	0.33 ± 0.02^{cA}	0.43 ± 0.02^{cB}	0.48 ± 0.01^{cB}
	I	0.25 ± 0.02^{bA}	0.29 ± 0.02^{cA}	0.40 ± 0.03^{cB}	0.47 ± 0.05^{cC}
Filtek Bulk Fill Posterior	C	0.26 ± 0.02^{bA}	0.30 ± 0.02^{cA}	0.41 ± 0.03^{cB}	0.50 ± 0.03^{cC}
	I	0.27 ± 0.04^{bA}	0.33 ± 0.04^{cA}	0.45 ± 0.05^{cB}	0.53 ± 0.05^{dC}

n= 6, $p<0.05$ C: continuous photo-activation; I: intermittent photo-activation. Distinct lower-case letters indicate statistically significant differences among columns (time) in the same row (for each resin composite light-activated using the same polymerization mode). Distinct upper-case letters indicate statistically significant differences among rows (for each resin composite light-activated using the same polymerization mode) in the same column (time).

Firstly, special attention was given to the amount of energy delivered by the two photo-activation protocols because it was proven that adequate curing times (20 s, 40 s) with high irradiance (1,000 mW/cm²) is essential to ensure adequate polymerization of the resin composite

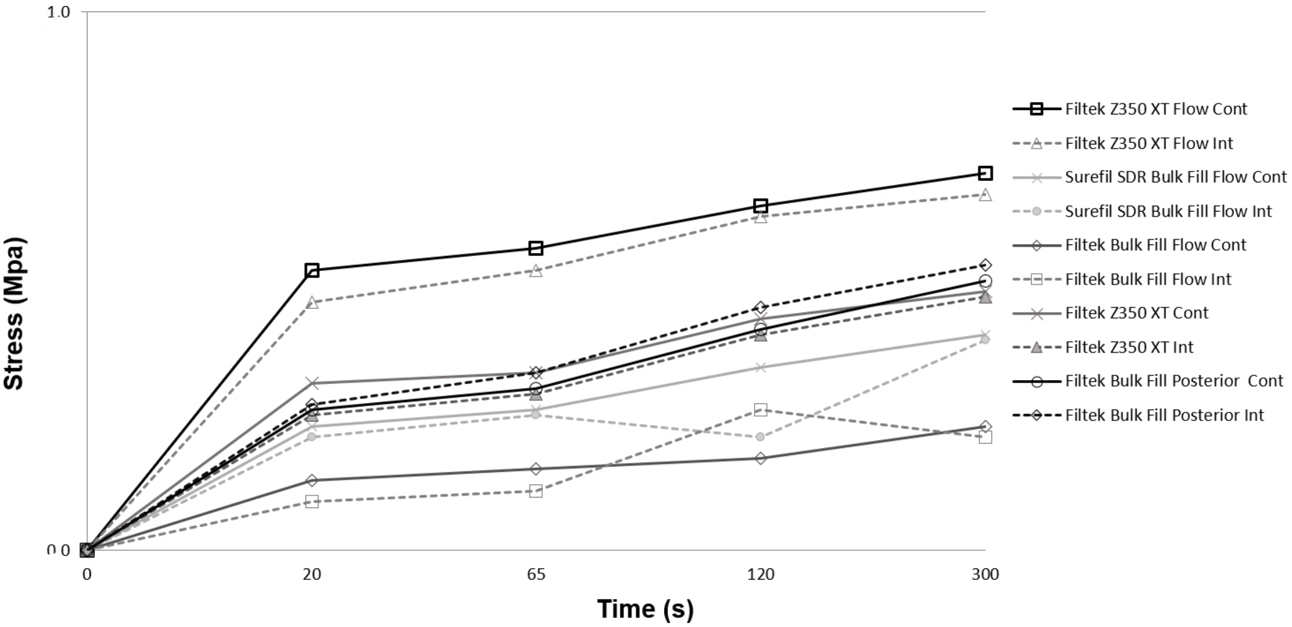

Figure 1. Graph of the comparison of the shrinkage development (averaged curves, n=6) as a function of time for the resin composites tested according to the photo-activation protocol. Dotted lines = intermittent protocol; Whole lines=Continuous protocol

(17). The intermittent photo-activation technique consists of photo-activation of the resin composite in *light-on* and *light-off* cycles, where the interval between on and off is alternated in 1 s. In this technique, the photo-activation was performed twice the time of high-intensity continuous photo-activation in order to ensure that the same amount of energy (radiant exposure) was delivered (14 J/cm^2).

Low-viscosity Bulk-fill resin composites showed lower shrinkage stress than the Z350XT flow. The flowable resin composite SDR was chosen to be studied herein because it is one of the first marketed composites in this material class and low shrinkage stress regarding SDR low-viscosity bulk-fill have been previously reported; therefore, the placement of 4 mm thickness is possible due their higher translucency and incorporation of a photoactive group in the methacrylate resin (18).

The magnitude of polymerization shrinkage experienced by resin-based materials is determined by its fraction of filler volume, the composition and DC of the resin matrix (4,18). Thus, the reduced shrinkage stress of the SDR low-viscosity bulk-fill could be explained by the incorporation of a modulator embedded in the center of the polymerizable urethane dimethacrylate resin matrix of the material, which slows the rate of polymerization and reduces shrinkage stress (19). In addition, the lower filler content of the low-viscosity bulk-fill resin composites result in a lower modulus and is considered a contributing factor to the reduced polymerization shrinkage stress (20).

The difference between the shrinkage stress development profile (in time) of the Filtek Bulk Fill Flow and the others occurred mainly in the early stages of the photo polymerization process (Table 2). The thermal expansion that develops earlier produces a lower net shrinkage of the resin composite and is one of the dominant contributing factors to the reduced final stress values of the Filtek Bulk Fill Flow composite (21). Therefore, the initial stress reduction during the polymerization stress in the Filtek Bulk Fill Flow (Table 2) is associated with the thermal expansion of the composite during photo polymerization. In addition, this material presents a low modulus, which attenuates the shrinkage stress since the polymerization of materials with a higher modulus results in greater stresses.

Table 3. Mean (± SD) DC (%) of the composite materials according to the photo-activation protocol (n=5)

Resin composites	Degree of Conversion (%)	
	Continuous photo-activation	Intermittent photo-activation
Filtek Z350 XT Flow	58.88±0.65b	60.57±1.75b
Surefil SDR Bulk Fill Flow	55.84±0.85c	59.21±0.64b
Filtek Bulk Fill Flow	52.03±1.63de	56.05±1.53bc
Filtek Z350 XT	51.77±1.29ce	45.15±1.45a
Filtek Bulk Fill Posterior	53.28±0.7ce	50.05±2.11e

Distinct lower-case letters from columns and lines indicate statistically significant differences (p<0.05).

Regarding the polymerization mode, several clinical approaches have been proposed to minimize polymerization shrinkage stress, including incremental layering techniques, the use of low-modulus liners and modulated photo-activation protocols (22). When modulated photo-activation was used, only the Filtek Bulk Fill Posterior generated higher shrinkage stress than the other ones for all times (Table 2 and Fig. 1). This result is relevant since we can hypothesize that the effect of modulated activation mode on resin composites depends of their composition and must be properly indicated. For instance, our data showed lower shrinkage stress values when modulated activation was used for the Z350XT Flow after 5 min of polymerization reaction (Table 2). The same effect was presented by the Z350 in the beginning of the reaction; therefore, this method can be applied for these composites in the clinical practice.

On the other hand, the current results showed that the intermittent photo-activation curing was quite effective in improving the DC values of low-viscosity bulk-fill resins and the Z350XT Flow when compared to continuous photo-activation (Table 3). This fact could be explained because this method may provide a higher amount of energy, since the polymerization process is more dependent on the total energy available for photo-activation than the light intensity (23). It explains the higher DC presented by the intermittent method in flowable composites. Thus, the second hypothesis was rejected.

The DC was investigated because the composition modifications, the elastic modulus and the different photo-activation methods could interfere in the final DC (24). During the polymerization reaction, all monomers in the composite material should convert into polymers;(24) however, it is well known that the reaction is self-limited due to increase in viscosity, and a resin-based material can never reach a full degree of conversion. While a high DC is important to improve both mechanical and biological properties such as microhardness and low biodegration, respectively (25), low polymerization shrinkage stress is important to avoid gaps development in the adhesive interface, cusp deflection, secondary caries and post-operative sensitivity (4,26). Nonetheless, those two goals seem to be antagonistic to conventional resin composites, as it is also known that DC and shrinkage are closely related properties (18). Since all available bulk-fill resins involve the addition of newer low-shrinkage monomers, understanding their dynamics regarding polymerization shrinkage and

DC, as well as the interaction with photo-activation, was essential herein.

The minimum DC for a clinically satisfactory restoration has not yet been defined and is not precise. Nevertheless, it is suggested that, at least for occlusally placed restorative layers, DC values below 55% may be contraindicated (24). In the current results, high-viscosity resin composites presented lower DC values in both photo-activation protocols than low-viscosity materials (Table 3). However, when continuous photo-activation was employed to high-viscosity resin composites, they presented higher DC values than with the intermittent protocol. For the intermittent protocol, the Filtek Bulk Fill Posterior presented better results than the Z350XT (Table 3). This is a relevant data, since the DC values can be lower when the selected protocol is the intermittent photo-activation for the use of high-viscosity bulk-fill resin composites than when continuous photo-activation was used. The higher DC values of the low-viscosity materials (Table 3) may be due to the higher translucency of these resin composites (2). Perhaps the time intervals (1 s) of the intermittent photo-activation can influence greater molecular movement by affecting the flowability and, consequently, the DC, showing promising data for this protocol when used with bulk-fill flowable resin composites.

However, the findings of the present research (Table 2) did not show favorable results regarding the development of reduced polymerization stress for the high-viscosity bulk-fill resin composite investigated (Filtek Bulk Fill Posterior), given that it developed a similar or higher shrinkage stress than the Z350XT, independent of the polymerization mode used. This higher shrinkage stress for high-viscosity materials may be attributed to their higher filler content (Table 1), which is directly proportional to the formation of increased polymerization stress by reducing the material's flow capacity.

In addition, the Z350XT Flow presented the highest shrinkage values in all periods evaluated and after 300 s, when continuous photo-activation was used (Table 2). Some flowable resin composites generally contain a greater amount of TEGDMA and can be expected to be less rigid than conventional hybrids (25), and because they are less rigid, they flow more easily in the cavity, especially in the initial polymerization times, independent of the polymerization mode used. This explains the significant difference found between the initial and final values (Table 2). Thus, their lower rigidity may be a counteracting factor to promote higher polymerization stress values of the restorations.

Overall, the present study showed that, in comparison with a conventional posterior resin composite, the use of a Bulk-fill high-viscosity resin composite does not result in reduction of shrinkage stress. Bulk-fill low-viscosity resin composites presented better polymerization properties in terms of polymerization shrinkage stress and DC values. There are some limitations of the current study that must be highlight. The photo-activation time is critical for ideal resin composite photo-polymerization. Although there are concerns regarding manufacturers recommendations for curing time of photo-initiated resin composites, in the present study, no attempt was made to determine ideal curing times and the depth of cure was not evaluated.

Within the limitations of the present *in vitro* study, this may support the intended use of a low-viscosity bulk-fill resin composite, using both photo-activation techniques since different curing lights did not perform differently. However, the use of intermittent activation improved the DC values for low-viscosity bulk-fill resins and the Z350XT Flow. Therefore, the use of modulated photo-activation (intermittent) must be indicated with caution since its use can influence the shrinkage stress and degree of conversion of composites, which varies according to the resin formulations but further studies are necessary to evaluate other factors such as DC and hardness in depth to indicate this technique.

Resumo

O presente estudo teve como objetivo avaliar as propriedades de polimerização de materiais bulk-fill (baixa e alta viscosidade) utilizando luz contínua de alta intensidade e fotoativação intermitente em relação ao estresse de contração de polimerização e grau de conversão (DC). As seguintes resinas compostas Bulk-fill e nanohíbridas convencionais foram avaliadas: Filtek Z350XT Flow (3M/ESPE), SureFil SDR Flow (Dentsply), Filtek Bulk Fill Flow (3M/ESPE), Filtek Z350XT (3M/ESPE) e Filtek Bulk Fill Posterior (3M/ESPE). Um dispositivo de LED (DB 685, Dabi Atlante) foi utilizado nos dois protocolos: fotoativação contínua e intermitente contínua (ciclos de liga e desliga) com exposição idêntica (14 J/cm^2). A tensão de contração de polimerização (n=6) foi avaliada através da inserção de um incremento único de 12 mm^3 entre duas placas de aço inoxidável (6×2 mm) adaptadas a uma Máquina de Ensaio Universal (UTM), em tempos diferentes. As medições foram registradas após a fotoativação. O grau de conversão foi avaliado por FTIR-ATR (n=5). Os dados foram analisados pelos testes ANOVA a três fatores e teste de Tukey (α=0,05). A resina Bulk Fill Posterior apresentou maiores valores de tensão de contração quando fotoativadas com a técnica intermitente (p<0,05). A fotoativação intermitente aumentou o grau de conversão nas resinas bulk-fill de baixa viscosidade (p<0,05). Portanto, o uso de fotoativação modulada (intermitente) deve ser indicado com cautela, uma vez que seu uso pode influenciar a tensão de contração e o grau de conversão dos compósitos, o que varia de acordo com as formulações da resina.

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