http://dx.doi.org/10.1590/1981-86372018000100023125

Color stability of conventional and bulk fill composite resins

Estabilidade cromática de resinas convencionais e resinas bulk fill

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ABSTRACT

Objective
This study compared the color stability of different dental composite resins after prolonged exposure to a coffee solution.

Methods
Sixty-four cylindrical discs (10 mm diameter x 2 mm thickness) were prepared using 8 different dental composite resins (n=8, per group). The specimens were first immersed in artificial saliva for 24 h followed by immersion in a coffee solution for 14 days. The assessment of chromatic variation (ΔE) was performed with the aid of a Vita Easyshade Advanced spectrophotometer (VITA Zahnfabrik, Bad Sackingen, Germany). The color of each specimen was calculated based on the L, a* and b* coordinates of the CIELab system.*

Results
Grandio SO had the lowest average chromatic variation (ΔE=7.77) after immersion in coffee solution. Durafill VS, Grandio and Z350 XT (ΔE=8.58; ΔE=9.52; ΔE=10.39, respectively) showed similar chromatic variation, with no statistical difference in relation to Grandio SO. However, the other dental composite resins evaluated showed statistically higher values of ΔE compared to Grandio SO, and Enamel HRi (ΔE=20.56) demonstrated the highest chromatic variation.

Conclusion
The Bulk Fill and hybrid composite resins from the same manufacturer (Micerium, Avegno, Italy) showed greater chromatic variation than the other composite resins tested. Grandio SO (Voco, Cuxaven, Germany) had the lowest ΔE variation.

Indexing terms: *Biomimetic. Color. Composite resins.*

RESUMO

Objetivo
Comparar diferentes resinas compostas em relação á estabilidade de cor após exposição prolongada em solução de café.

Métodos
Sessenta e quatro discos cilíndricos (10mm x 2mm) foram confeccionados a partir de 8 diferentes marcas comerciais de compósitos (n= 8 por grupo); os espécimes foram imersos em saliva artificial, e posteriormente em café, sendo por conseguinte feita a avaliação da variação cromática (ΔE), utilizando espectrofotômetro Vita Easyshade Advanced (VITA Zahnfabrik, Bad Sackingen, Germany). O padrão de cada espécime foi medido examinando as coordenadas L*, a* e b* do sistema CIELab.

Resultados
A resina composta Grandio SO apresentou a menor média de variação cromática (ΔE= 7,77) após a imersão em solução de café. Semelhantemente, a variação cromática das resinas compostas Durafill VS, Grandio e Z350 XT (ΔE=8,58; ΔE=9,52; ΔE=10.39) que não apresentaram diferença estatística. Todavia, as demais resinas compostas avaliadas apresentaram valores estatisticamente maiores de ΔE em relação a resina Grandio SO, sendo que a resina Enamel HRi (ΔE= 20,56) apresentou a maior variação cromática registrada.

Conclusão
As resinas da categoria bulk fill e as resinas híbridas produzidas pelo mesmo fabricante (Micerium, Avegno, Itália) tiveram alterações cromáticas superiores às demais resinas testadas sendo que a resina GrandioSO (Voco, Cuxaven, Alemanha) foi a que apresentou menor alteração de ΔE.

Termos de indexação: Biomimética. Cor. Resinas compostas.

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Como citar este artigo / How to cite this article
Trevisan TC, Gusson Junior M, Bortolatto JF, Pigossi S, Oliveira Júnior OB, Ricci WA. Color stability of conventional and bulk fill composite resins. RGO, Rev Gaúch Odontol. 2018;66(1):15-20. http://dx.doi.org/10.1590/1981-86372018000100023125

INTRODUCTION

Composite resins are currently the material of choice for both anterior and posterior direct restorations[1], due to their ease of handling, preservation of dental tissue, structural reinforcement, adhesion, low cost and especially the natural appearance of these materials[2-3]. The later is directly related to the current aesthetic appeal of clinicians and patients[4].

In this context, manufacturers are constantly motivated to change the composition of their products in the search for composites with aesthetic characteristics suitable for use in both anterior and posterior teeth, while also reducing the technical sensitivity for clinicians during restorative procedures. Thus, innovations in the materials' market should seek resins combining aesthetic and technical convenience[5], such as those providing the monochrome use and single layer insertion (up to 5mm) . However, chromatic stability is a determining factor for long-term aesthetic results[3,6-7]. When compared to ceramics, composites are more susceptible to aging related degradation pathways[8].

Knowing the nature of the procedure as well as the stability of the different materials especially with regard to new compositions is an imperative factor of success. Many factors influence chromatic stability, such as the type, size and quantity of the filler particles, photoinitiation system, resin matrix, the light curing unit and its irradiance[3,6-7]. The different kinds of resins, especially those characterized as Bulk Fill formulations, contain major variations in the previously mentioned considerations[9]. The adsorption and solubility phenomena also directly affect the physical-chemical stability, generating deleterious effects such as oxidation and hydrolysis. As a consequence, there is a decrease in chromatic stability, increasing the composites' susceptibility to pigmentation.

The alteration in the color of the restorations is an important factor related to the composite resins, as it compromises the visual acceptance of these restorations, impairing their clinical performance in the long term[10]. There is a lack of studies comparing resins with different formulations, especially in the Bulk Fill category. Modifications of the photoinitiators as well as their concentration and also changes in the organic matrix and the filler content are commonly performed in the Bulk Fill resins[11]. Therefore, the aim of this study is to investigate the chromatic stability of eight commercially available composites, including two of the Bulk Fill category. The null hypothesis tested is that there is no influence of the color behavior of different types and commercial brands of composites when immersed in a simulated staining solution (coffee).

METHODS

Sixty-four cylindrical specimens (10 mm x 2 mm) were prepared for the color alteration test using a stainless steel mold with the 8 different commercial brands of composite resins described in Table 1 (n= 8).

The composites were placed in a single layer with the aid of a spatula for composites W1 (BioInspiration WRicci, Maximus Instrumentos Hospitalares, Contagem, Brazil). Next, a polyester strip, a glass slide and a metallic disc weighing 1 kg were placed over the composites for 30 seconds. Then, the slide and the disc were removed and the specimen was light cured for 20 seconds on the HIGH setting. The tip of the light curing unit VALO (Ultradent, St. Jordan, USA) was placed in direct contact with the surface of the polyester strip.

After curing, the sample was removed from the mold and cured for another 20 seconds in HIGH mode on the opposite surface of the first curing to obtain an even surface and homogeneous polymerization to avoid interferences in the results. The light curing unit was calibrated using a spectrophotometer with a cosine correction wave (Ocean Optics, Dunedin, USA), to investigate the spectral profile since none of the tested products presented camphorquinone as photoinitiator. At the beginning of the sample preparation, the intensity of the light was calibrated, producing an intensity of 1100 mW/cm^2. All specimens received the same cumulative energy (40J/cm^2). No polishing was performed on the specimen since the polyester strip produces a high surface smoothness. The specimens were totally immersed in 25 mL/specimen of artificial saliva (Arte & Ciência, Araraquara Brasil, pH: 7.0), and kept for 24 hours in an incubator (SPLabor, SP-200) at 37 ± 1°C. After, they were rinsed with distilled water and dried with absorbent paper.

The initial color of each specimen was measured by the same examiner, in an environment previously standardized with constant lighting at a color temperature of 5500º K, using a Vita Easyshade Advanced spectrophotometer (VITA, Zahnfabrik, Bad Sackingen, Germany). To standardize the reading, the samples were inserted into a white device containing an aperture on

one side with a size compatible with the sample and on the other side with an aperture compatible with the tip of the apparatus. The bottom used to support the sample was a neutral gray card with 18% reflectance (Flexipalette Gray, SmileLine, Switzerland). The spectrophotometer was calibrated after each measurement. The color pattern of each specimen was measured by the coordinates L*, a* and b* of the CIELab system, where L* represents a measure of the luminosity (varying from 0 to 100, and means absolute white to absolute black); and the axis a* and b* represent chromaticity coordinates: +a* indicates the red direction, -a* shows the green direction, +b* gives the yellow direction and -b* indicates the blue direction[17].

Table 1. Materials tested (information provided by manufacturers).

Composite	Manufacturer, Color, Lot Number	Organic Matrix*	Filler (% and average size nm)	Type	Time of Light curing/ increment thickness (mm)
Tetric EvoCeram Bulk Fill	Ivoclar Vivadent, IVA, P84129	Bis-GMA, UDMA	Ba-Al-Si glass, prepolymerized glass and ytterbium fluoride, mixture of spherical oxides (77% and 550nm)	Nanohybrid, Bulk Fill	10-20s/ 4mm
X-tra fil	Voco GMBH, Universal, 1240218	Bis-GMA, UDMA, TEGDMA	Unknown inorganic composition (86%)	Hybrid, Bulk Fill	10s/ 4mm
Enamel Function	Micerium, EF2, 2014000258	Bis-GMA, UDMA, 1,4 Butanodiol dimetacrilato, TEDMA	Glass and SiO2 (75%)	Nanohybrid	20- 40s/ 2mm
Enamel Hri	Micerium, UE2, 2013005582	Bis-GMA, UDMA, 1,4 Butanodiol dimetacrilato TEDMA	Ceramic glass and ZrO2. (80%)	Nanohybrid	20- 40s/ 2mm
Grandio	Voco GMBH, A2, 1228171	Bis-GMA, TEGDMA	Al-Si Glass and SiO2 (87% and 20 - 40nm)	Nanohybrid	20-40s/ 2mm
GrandioSO	Voco GMBH, A2, 1317262	Bis-GMA, Bis-EMA, TEGDMA	Ceramic Glass and SiO2 (89% and 20 - 40nm)	Nanohybrid	10-40s/ 2mm
Z-350 XT	3M ESPE, A2B, 931991	BisGMA, BisEMA, UDMA, TEGDMA, PEGDMA	ZrO2-SiO2 clusters, SiO2 and ZrO2 (78,5% and 5-20 nm)	Nanofilled	20-40s/ 1,5mm
Durafil VS	Hareaus Kulzer, A2, 010217	BisGMA, TEGDMA, UDMA	SiO2, prepolymerized matrix (40% and 0,02 - 20 µm)	Microfilled	20- 40s/ 2mm

Note: *Bis GMA - (bisphenol-A glycidil dimethacrylate), Bis EMA - (bisphenol A ethoxylated dimethacrylate), UDMA - (urethane dimethacrylate), TEGDMA - (triethylene glycol dimethacrylate), PEGDMA - (Polyethylene glycol dimethacrylate), BA-AL-SI - Barium- Aluminum- Silicium, ZrO_2 - zirconium oxide, SIO_2 - silica oxide, Al- Si - Aluminum -Silicium.

In order to evaluate the color stability of the different resins, the specimens were immersed in a 20 mL/specimen coffee solution (Pilão - Sara Lee Cafés do Brasil Ltda, Brasil), and kept at 70o ± 1°C for 14 days. After the experimental period, the specimens were kept for 24 hours in distilled water at 37 ± 1°C and again subjected to quantitative color measurement as previously described. The measurement was performed for each individual specimen, aiming the calculation of the chromatic variation (ΔE) obtained by the following Hunter formula:

$$\Delta Eab^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Finally, the values of ΔE were submitted to statistical analysis by the D'Agostino & Pearson normality test to verify the distribution of normality. Subsequently submitted to ANOVA one-way test, and Tukey test for multiple comparison (San Diego, CA, USA) was used for statistical analysis and all tests were applied at a significance level of 95% ($p<0.05$). Values of $\Delta E \leq 3.3$ were considered clinically acceptable values.

RESULTS

Figure 1 shows the mean ΔE values of the different composite resins tested in this study. Grandio SO (Voco, Cuxaven, Germany) presented the lowest mean of color variation (ΔE= 7.77) after immersion in coffee solution. Similarly, the chromatic variation of composite resins Durafill VS (Hareus Kulzer, Hanau, Germany), Grandio (Voco, Cuxaven, Germany) and Z350 XT (3M ESPE, Minnesota, USA) that showed lower values of ΔE (ΔE=8.58; ΔE=9.52; ΔE=10.39) and did not present statistical difference in

relation to Grandio SO (Voco, Cuxaven, Germany). However, the other composite resins evaluated had statistically higher values of ΔE in relation to the Grandio SO (Voco, Cuxaven, Germany), and the resin Enamel HRi MICERIUM (Micerium, Avegno, Italy) presented higher color variation (ΔE= 20.56) after 14 days immersed in coffee solution. The Bulk Fill resins demonstrated significative color alteration compared to the conventional resins Grandio SO, Z350 XT, Duraffil VS e a Grandio, and ΔE values considered clinically critical.

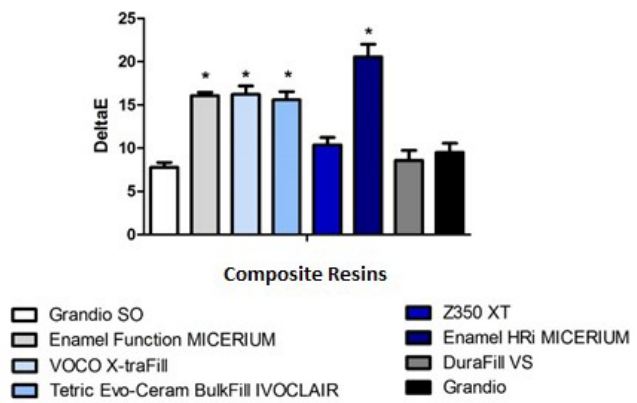

Figure 1. ΔE values of the different composite resins tested (mean and standard deviation); * p≤0.05 compared to Grandio SO.

DISCUSSION

The null hypothesis tested that there is no influence on the color behavior of different types and brands of composites which were polymerized under controlled conditions and subsequent immersion in coffee should be rejected. Dental materials are constantly exposed to pigments through food and biochemical processes of the oral environment[12]. As reported in other studies, the color of a material may be affected by factors such as diet, the materials hydrophilicity, presence of bacterial plaque, degree of polishing and incomplete polymerization[3,6-7]. In this study, we controlled some of these factors when possible; for example, when subjecting the samples to a simulated clinical challenge of constant immersion in coffee at its consumption temperature (70°C) for 14 days. The rinses prior to the measurements were intended to remove surface stains allowing only the evaluation of the intrinsic material change. Another important factor was reading against a neutral gray background.

Several studies use white backgrounds to read the samples because of their high reflectivity. However, this practice has been questioned since in anterior restorations the teeth are constantly contrasted by the dark background of the mouth[3]. For this reason, some studies have also started using a black background for the measurements. In fact, the variations presented are discrepant in the spectrophotometric reading for the two backgrounds. In this study, we tried to avoid the influence of the background. For that, a neutral gray background was chosen. A 18% reflectance neutral gray is recognized as the balance for white balance. A product with adequate colorimetry was used (Flexipallete Gray, Smile Line, Switzerland), thus excluding probable interference. The measurements of the specimens after two time intervals allowed the calculation of the chromatic variation (ΔE) which has demonstrated that values above 1.1 are perceptible, but values above 3.3 are aesthetically problematic[13]. The value considered clinically acceptable is a ΔE≤3.3.

The results showed values much higher than those clinically acceptable, but compatible with the literature that tests immersion in a colored beverage solution (coffee)[6]. Studies correlate that 24 hours of in vitro pigmentation would correspond to approximately 1 month *in vivo*[14]. However, this would occur at temperatures of 37°C. The increase in temperature may accelerate this process, so that values above 50°C would simulate 12 months compared to a month at 37°C in vitro[15]. Therefore, the period of this in vitro study would be equivalent to 14 years in vivo. Coffee is recognized as a highly deleterious solution[14], because it contains substances with a high polarity and affinity for the composites polymer network[6]. As a result, significant color changes are expected in the composites. Suggestions regarding the indication of composites for frequent users of this type of beverage have been discussed in the review articles[3].

Although the degree of conversion was not evaluated in this study, the control of the polymerization energy was rigorous so that each composite received a total dose of energy superior to the one recommended by the manufacturer, but controlled for all the groups, thus reducing the influence of the degree of conversion on the results. In the process of chromatic stability, the organic portion plays a major role in providing the materials appearance[12]. The chemical composition makes it susceptible to adsorption of liquids and pigments. This situation is directly related to the degree of conversion of the composite, which is controlled during the tests by means of a high energy dosage and with a wide spectral

band of light used[12].

The changes of photoinitiators commonly used in lighter color resins and in some composites of the Bulk Fill category can influence their behavior, damaging when they are irradiated by a narrow spectral light source. The instrument selected in this study (Valo, Ultradent, St. Jordan, USA) had its spectral profile evaluated by a spectrophotometer to verify this variable and proved suitable for the polymerization of these different types of materials. As a result, factors impaired by incomplete conversion at the clinical level can be ruled out. Thus, the differences found for the trademarks evaluated are inherent in their chemical compositions.

Each manufacturer develops their system by varying the ratio of organic and inorganic composition even though the chemical basis is the same for most materials. Even among the Bulk Fill resins, there are brands that have altered physical aspects of these materials but the chemistry remains similar to traditional composites[16], such as the resin Xtrafill (Voco, Cuxaven, Germany). However, the Tetric Bulk Fill resin (Ivoclar, Schaan, Liechtenstein) presents variations on traditional composites such as the monomers used and its photoinitiator. It has been reported that the composition of this organic phase may favor the incorporation of pigments. A higher pigmentation ratio was established in resins containing triethylene glycol dimethacrylate (TEGDMA)[7]. In this study, the majority of the composites contain TEGDMA, even in the Bulk Fill category. But the Tetric Bulk Fill resin, which does not contain TEGDMA, presented a high ΔE value, showing worse behavior. This fact can be explained by two propositions: (1) The amount of this chemical in the total composition as well as (2) the volumetric distribution between the organic and inorganic phases. TEGDMA has a direct influence on post-irradiation polymerization. Increasing the amount of this compound increases the degree of immediate conversion, thus reducing the late conversion process[7]. However, since polymerization was controlled in this study, and a high amount of energy was used, it is probable that the post-polymerization conversion process was reduced, and therefore did not interfere in the performance of the products tested. In addition, the fact that in proportion this product may be in small quantity when compared to more hydrophobic products like the UDMA. This is the case of resin Filtek Z350XT (3M ESPE, Minnesota, USA). In spite of containing both UDMA and TEGDMA, the TEGDMA is in a very small amount when compared to the UDMA. Thus, the simple presence of the hydrophilic monomer in the composition will not necessarily impair the chromatic performance of the composite, and the fractional quantity has this greater influence.

Chromatic stability is an equilibrium equation between the composition of the organic phase and the amount and size of filler, since products without TEGDMA and UDMA may exhibit medium behavior when they have a low amount of filler. This is likely to be the reason for the median performance over the other groups of classification of Bulk Fill resins. In non-conventional formulations, as in the case of Tetric Bulk Fill (Ivoclar, Schaan, Liechtenstein), its low amount of filler produces a similar behavior to Xtrafill (Voco, Cuxaven, Germany) which exhibits a larger amount of filler and larger sized particles, but with a conventional resin matrix of more pigment-susceptible monomers including BisGMA and TEGDMA[3]. These two factors have a direct influence on color behavior. A greater amount of filler influences the chromatic changes since this part is not susceptible to staining due to its chemical nature. In fact, in the study in question, the GrandioSO resin (Voco, Cuxaven, Germany) is the one with the highest amount of filler in volume, and showed to be the composite with most favorable color stability[3,6-7].

CONCLUSION

All the materials tested presented high color alteration, with values considered clinically perceptible. Bulk Fill resins and nanohybrid resins produced by the same manufacturer (Micerium, Avegno, Italy) showed higher chromatic changes than the other resins tested, and the GrandioSO resin (Voco, Cuxaven, Germany) showed the lowest ΔE alteration. Therefore, we have demonstrated that the composition of a composite resin system has a direct influence on the chromatic stability of these materials.

Collaborators

TC TREVISAN, execution of methodology, writing the manuscript and submission for publication. M GUSSON JÚNIOR, execution of methodology. JF Bortollato, collaboration in the scientific writing and translation of the article. S PIGOSSI, statistical analysis. OB OLIVEIRA JÚNIOR, study design and writing the manuscript. WA RICCI, project coordination, within the research line BIOinspiration, acquisition and selection of materials, and writing.

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Received on: 9/5/2017
Final version resubmitted on: 17/8/2017
Approved on: 17/9/2017