

Influence of different power densities during polymerization on the color of composite resins

Brunelly Cardoso de Jesus Santos¹, Jefferson Chaves Moreira²,
Yasmin Alves do Nascimento³, Daniel Maranha da Rocha³,
Adriano Augusto Melo de Mendonça³, Lycia Gardenia dos Santos Oliveira³,
Eduardo Bresciani², Daiana Conceição Broll Repeke³, Flavia Pardo Salata Nahsan³

¹ Federal University of Sergipe, Department of Dentistry, Street Cláudio Batista s/n, Zip Code: 49060-676, Sergipe, Aracaju, Brazil.

² São Paulo State University (Unesp), Institute of Science and Technology, Department of Restorative Dentistry, Avenue Engenheiro Francisco José Longo, n° 777, Zip Code: 12245-000, São Paulo, São José dos Campos, Brazil.

³ Federal University of Sergipe, Program in Dentistry, Street Cláudio Batista s/n, Zip Code: 49060-676, Sergipe, Aracaju, Brazil.

e-mail: chaves.moreira@unesp.br, brunellycardoso1@gmail.com, amin.odonto@gmail.com, drmaranha@hotmail.com, adri_amm@yahoo.com.br, lycia_gso@hotmail.com, eduardo.bresciani@unesp.br, daiana@brollortodontia.com.br, flavia_odonto@hotmail.com

ABSTRACT

This study evaluated the influence of different levels of power density on resin polymerization in the staining of composite resins. Thirty-six specimens were made with composite resin (Z350 3M ESPE) with cylindrical Teflon matrix (8 mm X 1 mm). The light curing was performed with different degrees of power density for each group (n=12): 300mW/cm², 700mW/cm² e 1000mW/cm². Afterwards, the specimens had their color checked, with the help of a spectrophotometer and immersed in coffee solution during 7 days. After, a new measuring was done (CIEL*a*b* color system). Results showed, for Δa, only G1000 group obtained a significantly lower value, and the same result was found in the evaluation of Δb. For ΔE and ΔL, no significant differences were found between groups. It is concluded that, low and medium power density entails more reddish and bluish composite resin, while the specimens submitted to high power density and then immersed in coffee did not present color change in a short term.

Keywords: Composite resin. Staining. Light curing.

1. INTRODUCTION

The use of composite resins has increased significantly over the last years and currently is the major dental material for direct restorations [1], which is due to the optimization of physical and mechanical properties [1-3]. Despite its good performance among some limitations, this material requires an adequate polymerization, otherwise, it may present extrinsic and intrinsic staining [2-8].

Most resin composites used today in Dentistry are presented initially as monomers converted into polymer chains using light sources [9]. There is a direct relationship between the degree of conversion of monomers and the longevity of restorations [10, 11]. A satisfactory polymerization provides resins with good biocompatibility, hardness, physicochemical properties and resistance to masticatory forces to which they are subjected [11, 13]. It also provides greater aesthetic stability, because an insufficient cure induces higher water absorption and incorporation of substances [3, 12, 14]. Overall, the change of resin color makes restorative cycles to be initiated early [8, 15].

The color stability of composite resins depends on the degree of conversion of monomers into polymers throughout a sufficient polymerization [8, 16, 17] and it is affected by the system and the technical condition of polymerization [18]. The delivered radiant exposure and the power density of the photopolymerizer should agree with the energy requirement of the resin so there is a complete conversion of monomers into polymers [19, 20]. The higher the power density, the higher the number of photons and the greater is the depth and effectiveness of polymerization [21].

The insufficient conversion of monomers into polymers may result in the staining of composite resins

[11, 12, 14, 22, 23]. Thus, different polymerization techniques provide higher or lower light intensity to the composite.

However, there are no studies in the scientific literature assessing the influence of different power densities specifically on the staining of composite resins.

In this light, it is appropriate to assess the direct influence of different power densities and the consequent degree of conversion on composite resins subjected to staining after immersion in dye beverages.

2. MATERIALS AND METHODS

2.1 Preparation of specimens

Thirty-six composite resin (Charisma Diamond, Kulzer, Hanau, Germany) specimens were produced, with 12 specimens for each group.

The sample was calculated at $\alpha=0.5$, 96% test power, and $n=12$ teeth per group.

To produce the samples, a Teflon matrix was used, with an internal diameter of 8 mm and a thickness of 1 mm. The resin was inserted in a single increment in the matrix hole and the resin was pressed with the help of polyester strips in the edges of the matrix to prevent excesses. Photopolymerization occurred with different power densities according to the groups suggested in the study.

The same operator produced all specimens in a laboratory, with a temperature of 23°C.

2.2 Groups

The photopolymerizer used was the VALO Colors Fucsia (Ultradent, South Jordan, USA), which presents fixed power density emission, therefore, plastic cylinder devices were produced with the same diameter of the light point of the device but with different lengths, aiming to modulate the power density to reach the composite resin samples.

The power density values of each group were G300 (300mW/cm²), G700 (700mW/cm²), and G1000 (1000mW/cm²). The power density was properly verified before photopolymerization with a radiometer (RD7, ECEL, Ribeirão Preto, São Paulo, Brazil) and the samples were separated into the three different groups.

During the photopolymerization process, the appliance was positioned with the point centered in the samples so the entire extension of the resin was polymerized for 10 seconds.

2.3 Storage

The specimens were stored immersed in deionized water, in a plastic recipient, with separated compartments numbered according to each group, for 24 hours, and maintained in a 37°C stove.

After 24 hours, the color and opacity of each sample were assessed three times with an X-Rite Color 962 spectrophotometer (Danaher Corporation, Michigan, USA), and the final result was the mean of the three (L*, a*, and b*) values and the mean of the three opacity values. The CIEL*a*b* was the analysis system.

After the initial registration of color, the samples were immersed in a coffee solution prepared with 25 g of instant coffee (Nescafé Tradição, Nestlé Brasil Ltd., Araras, São Paulo, Brazil) and 100 mL of water, for seven days in a 37°C stove.

After this interval, the resins were removed from the stove, washed in a recipient with water, and dried with absorbent towels. After drying, the color was reassessed with the X-Rite 962 spectrophotometer (Grand Rapids, Michigan, USA) with three repetitions per specimen for the final color reading.

2.4 vStatistical analysis

T-paired tests were performed to verify potential differences in the initial and final conditions for each parameter of the study. Two-way ANOVA was applied with repeated measures to verify the presence of differences between the conditions studied considering the time (before and after darkening) and power of the photopolymerizer, as well as the influence of the interaction of these factors. Lastly, one-way ANOVA was performed to compare the Delta results obtained for each light power used ($p<0.05$).

3. RESULTS

For Δa , the value was significantly lower for G1000 (2.9) when compared to groups G700 (5.3) and G300 (4.9).

Similarly, for Δb , only G1000 (10) was significantly different from the other two groups (G700=2.25 and G300=0.26).

There were no differences among the groups for both ΔE and ΔL .

Table 1: Values and standard deviation related to ΔE , ΔL , Δa , and Δb in the different power densities of each group.

| Groups | ΔE (SD)* | ΔL (SD)* | Δa (SD)* | Δb (SD)* |
|--------|---------------------------------|----------------------------------|---------------------------------|----------------------------------|
| G1000 | 15 ($\pm 4,3$) ^f | -10,2 ($\pm 2,0$) ^a | 2,9 ($\pm 0,86$) ^b | 10 ($\pm 5,2$) ^c |
| G700 | 13,5 ($\pm 2,9$) ^f | -12 ($\pm 2,8$) ^a | 5,3 ($\pm 0,5$) ^c | 2,25 ($\pm 2,2$) ^a |
| G300 | 13 ($\pm 1,8$) ^f | -11,8 ($\pm 1,9$) ^a | 4,9 ($\pm 0,73$) ^c | 0,26 ($\pm 2,65$) ^a |

G1000- Light-cured specimens with a power density of 1000 mW/cm²; G700- Light-cured specimens with a power density of 700 mW/cm²; G300- Light-cured specimens with a power density of 300 mW/cm²

SD- Standard Deviation. *Different letters between columns show significantly diferente statistics ($p < 0.05$).

Annova to 1 Criterion and Paired T Test($p < 0,05$).

4. DISCUSSION

The present study assessed the influence of different power densities on the color change of composite resins, after immersion in coffee. Considering the results, there were statistically significant differences. Thus, the null hypothesis should be rejected.

The International Commission of L'Eclairage developed the system to measure colors based on human perception (CIE L*, a*, b*). The variable L* corresponds to the black-white luminosity coordinate, a* indicates the color coordinate along the red-green axis, and b* indicates the color coordinate along the yellow-blue axis [19, 20]. A positive ΔL value means that the object tends to white (brighter) and negative Δb and Δa values mean that the tooth tends to be less yellow and less red, respectively [21].

The Δa values in the present study were lower for G1000 when compared to the other two groups, showing a more reddish color direction for G700 and G300. Although the present study found the Δa value similar to G1000, the data in the study by Imai et al. 2013 with indirect resin after immersion in tea and polymerization with different systems showed less reddish samples after immersion in tea. The similarity of values only in G1000 may hypothetically be due to the polymerization with higher power density, with a greater conversion of monomers into polymers [12, 14, 22].

Composite resins, after polymerization, change color due to the presence of photoinitiator amines such as camphorquinone (CQ) [23]. In the present study, the lowest Δb values were found for G700 and G300, indicating a more bluish color tendency when compared to G1000. Considering CQ provides a more yellowish color for composite resins after polymerization with high power density, it is assumed that such CQ may have had more influence on the color than staining with coffee after seven days. Similar to the specimens of group G1000 in the present study, IMAI et al. 2013 [10] obtained more yellowish samples when immersed in tea.

The degree of conversion is related to be associated with composite resin staining [24, 25]. However, in a study [24] using Fourier transform infrared spectroscopy to evaluate the degree of conversion by light-curing units (LCUs), the authors affirm there is no correlation among degree of conversion and superficial staining. Soares et al. (2013) [26] showed that the soft-start light activation results in chemical degradation of organic matrix in resin composite. In this study the authors did not evaluated the degree of conversion, but the use of medium and low power density resulted in color alteration of the composite resin. Thus, considering the scientific literature, the light curing mode might interfere in the composite resin staining susceptibility.

In a study performed with composite resins immersed in tea and distilled water, IMAI *et al.* 2013 [10] showed that immersion in water did not change the brightness (L^*) of the composite resin but immersion in tea decreased these values, reducing brightness. In the present study, when comparing the three groups, the ΔL values did not differ despite the lower values of G300 and G700, tending to less bright specimens.

Although the Δa and Δb values were different among the groups, the complete color change in the specimen, represented by ΔE , did not differ. However, the values are high when compared to the ones found by IMAI *et al.* (2013) [10] after the staining of indirect resins in tea, and the values found by PIRES DE SOUZA *et al.*, 2007 [27], but without staining.

Composite resin suffers hygroscopic expansion in the first 24 hours [27, 28], potentially causing intrinsic staining, which leads to a different degree of light dispersion when in smaller and bigger particles [29]. According to DOMINGOS *et al.* 2011 [6], the composition and characteristics of resin particles have a direct impact on the susceptibility to staining. The composite resin used in the study (Charisma™ Diamond, Hanau, Germany) presents the base of TCD-DI-HEA of UDMA. The UDMA is more resistant to staining than Bis-GMA, considering it is more resistant to sorption and solubility [6]. CATELAN *et al.* (2011) [30] performed a study with composite resin samples, which were stored in deionized water after production, differing only in the storage time. In such study, the samples spent only two minutes immersed in deionized water, while in the present study, the samples remained for 24 hours, agreeing with the study by NASSIM *et al.* (2010) [31], considering that water sorption occurs more intensely over the first hours after polymerization.

Polishing was performed after the samples spent 24 hours immersed in deionized water, with abrasive rubbers for composite resin, for five seconds on each side. This procedure was performed to simulate the execution of the clinical steps usually performed, preventing that the use of the polyester matrix strip would leave the surface extremely smooth due to the outbreak of the organic matrix [32, 33]. The same methodological step occurred in the studies by PLASTER *et al.* (2016) [34], SELIG *et al.* (2015) [35], and ERDEMIR *et al.* (2012) [36], only varying the time and polishing mechanism.

Besides resin composition, the application of high light intensity is recommended to optimize the hydrolytic stability and the color stability of composite resins [10, 37]. A study performed by YAN-FANG (2002) [38] showed that composite resins suffer a higher degree of staining when they are underpolymerized. However, the author did not report the levels of power density related to an inadequate polymerization of the composite resin and its consequent losses of aesthetic and functional properties. The photopolymerizer used in the present study was the Valo Colors Fucsia (Ultradent, South Jordan, USA). This appliance was selected for presenting an extensive energy power, reaching up to 3200 mW/cm², a collimated light beam, according to the manufacturer, thus making its trajectory more precise and preventing the energy dissipation that allows standardization at the moment of polymerizing the specimens for each group.

Staining was performed with an instant coffee solution. According to AWLIYA, NAHEDH (2012) [39] and LEMPEL *et al.* (2017) [40], coffee is one of the beverages mostly associated with the staining of dental restorative materials, therefore, it was the dye solution selected to assess the color stability of the composite resin, besides being a widespread and popular beverage. The staining potential of composite resins is a consensus in the literature, considered a multifactorial occurrence caused mainly by structural failures in composite resins associated with the frequent ingestion of foods rich in pigments [30, 31, 38, 41].

The quantitative assessment of ΔL , Δa , and Δb was performed, as in other studies [3, 10, 15, 42], using a spectrophotometer, because of the subjectivity of the color assessment. This subjectivity is a result of some factors such as the position of the observer and the object under observation concerning the light, as well as the emotional condition of the observer and the aging of the object [43].

This is the first study in the literature that shows the influence of different power densities on the color of composite resins. The great majority of studies [3, 10, 15, 42] focuses, however, on assessing polymerization shrinkage. Nevertheless, it is worth noting the need for further *in vitro* studies in this direction, aiming to optimize the performance of resin materials.

5. CONCLUSIONS

The use of medium and low power density results in a more reddish and bluish composite resin. A high power of density and immersion in coffee does not change the color of the nanoparticulate composite resin, in the short term.

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ORCID

| | |
|------------------------------------|---|
| Brunelly Cardoso de Jesus Santos | https://orcid.org/0000-0003-1441-416X |
| Jefferson Chaves Moreira | https://orcid.org/0000-0003-4276-4810 |
| Yasmin Alves do Nascimento | https://orcid.org/0000-0003-4840-7830 |
| Daniel Maranha da Rocha | https://orcid.org/0000-0003-1825-8168 |
| Adriano Augusto Melo de Mendonça | https://orcid.org/0000-0002-2365-5718 |
| Lycia Gardenia dos Santos Oliveira | https://orcid.org/0000-0001-7681-2871 |
| Eduardo Bresciani | https://orcid.org/0000-0001-9299-8792 |
| Daiana Conceição Broll Repeke | https://orcid.org/0000-0001-5824-5244 |
| Flavia Pardo Salata Nahsan | https://orcid.org/0000-0002-3547-8886 |