Color Stability of Different Aesthetic Resin Composite Materials: A Digital Image Analysis

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Abstract

This study aimed to evaluate and compare the color stability of three commercially available resins composites after exposure to different staining solutions using digital image analysis.A total of ninety-disc shape specimens of a microhybrid composite (Amelogen plus), ultrafine hybrid composite (Essentia), and nanohybrid composite (Beautifil II) were produced in Teflon mould (n=30/ resin composite type). Specimens of each resin composite were then divided into 5 subgroups (n=6/subgroup) and immersed in 200 ml of Pepsi, orange juice, tea, coffee and artificial saliva (control group), respectively. Digital images of the specimens were taken before (baseline) and after 28 days immersion against a black and white background. Adobe Photoshop CS6, Ver.13.0.1 graphic program (AdobeSystems Inc., San Jose, CA, USA) was used to analyze the digital images and calculate the change in color (ΔE). Data were submitted to statistical analysis using one-way ANOVA and Tukey Posthoc test at a significance level of $p<0.05$. This study concluded that all resin composites exhibited color changes after immersion in all staining solutions. However, Amelogene Plus showed better resistance to staining compared to Beautifil II and Essentia.

Keywords: *aesthetic resin, composite materials, image analysis*

Introduction

Composite restorative materials are the most popular esthetic materials used in dental practice. The color instability of composite materials may be the main reason for the replacement of restorations. Discoloration of composite resin caused by extrinsic or intrinsic factor. Intrinsic factors include physical-chemical discoloration reactions in the composite matrix, in surface and deeper layers of the material, triggered by heat, humidity, or UV irradiation. Chemical discoloration has been attributed to a change or oxidation in the amine accelerator, oxidation in the structure of the polymer matrix, and oxidation of the unreacted pendant methacrylate groups [1] . Extrinsic factors are related to the surface absorption of staining agents from exogenous sources or due to the accumulation of plaque [2] , or superficial degradation of the restorative materials and their adsorption of staining agents [3] . The degree of color change can be influenced by various factors such as incomplete polymerization, chemical reactivity, water sorption, oral hygiene, diet, and surface smoothness of the restoration[(4,5)]. The composition of the composite resin and the characteristics of the particles have a direct effect on the surface smoothness and susceptibility to extrinsic staining [6] . Consumption of certain drinks such as Tea and coffee may affect the physical properties and aesthetic of composite restoration.The effect of drinks on the properties of restorative resins may be directly related to the amount and frequency of its intake [2]. The aim of this study was to evaluate and compare the color stability of three commercially available resins composite: Amelogen Plus (Microhybrid), Essentia (ultrafine hybrid), Beautiful II (Nanohybrid) after exposure to different staining solutions for 28 days using digital image analysis. The null hypothesis tested was that there is no difference in color changes (ΔE) between the tested composite materials after 4 weeks of immersion in different staining solutions.

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Materials and Method

One microhybrid composite (Amelogen plus, Ultradent), one ultrafine hybrid composite (Essentia, GC), and one nanohybrid composite (Beautifil II, Shufo) were evaluated in this study. For each brand, the enamel shade was selected. A total of ninety-disc shape specimens of composite materials were produced in Teflon mould (10 mm diameter x 1 mm thick). After filling the mould with the composite, the discs were covered with glass slides, to exclude atmospheric oxygen, and then cured by visible light for 40 s, using a dental curing unit (Optilux, Demetron Res Crop, Danbury, USA) with an irradiance of 850 $mW.cm^{-2}$, which monitored with a radiometer (Kerr/Demetron, Danbury, USA). Light-curing was repeated on the opposite surface for another 40 s. After which, specimens were stored in an incubator at 37□ for 24 hours. Specimens of each resin composite brand were then divided into 5 subgroups (n=6/subgroup) according to the immersion solutions represented by Pepsi, orange juice, tea, and coffee or artificial saliva which constituted the control group. The digital images acquisition of all specimen groups was taken before immersion (baseline) by digital imaging technique using an SLR camera (Nikon D5200, Nikon Corporation, Japan) with a 105mm camera macro lens (Sigma 105 EX Macro, Sigma, Japan). The camera was fixed perpendicularly on stand clamp holder (10 cm distance from the specimen) and set on manual mode, which allowed total control of shutter speed 1/6, ISO 1250, f-stop 3.5. These measurements were remained unchanged during taking shots and three images were obtained for each sample against a white as well as a black background.For the digital imaging method, four fluorescent tubes were mounted on a costume made photostand with tubes perpendicular to the front plane that hold the discs, being 20 cm away from the specimen and illuminating at an angle of 45°. Two 6,500-K fluorescent tubes (Philips PL-C 18W/865, Koninklijke Philips Electronics N.V., Eindhoven, Netherlands) were placed in the lower sockets and were combined with two 2,700 K (Philips PL-C 18W/827) fluorescent tubes placed in the upper sockets [7] . After baseline images acquisition were made, specimens were then immersed in 200 ml of each staining solution and kept in an incubator at 37 °C for 28 days. Staining solutions were changed every week to avoid bacteria or yeast contamination. After the staining period, the specimens were gently rinsed with distilled water and air-dried. Imaging measurements were repeated for each sample to determine the color variation.

The digital images were transferred to a personal computer (PC), saved as TIFF images and were analyzed using the Adobe Photoshop CS6, Ver.13.0.1 graphic program (AdobeSystems Inc., San Jose, CA, USA). For standardized calculations, a measurement template was created in the middle third of the samples that consisted of a square area of 50 pixels. The CIE L*a*b* values of these particular areas were calculated using the eyedropper tool. The color data obtained directly in color picker palette tab for (L, a and b) parameters (Figure1). Color changes (ΔE) were calculated as follows:

$$\Delta E= [(L_1^*-L_2^*)^2+(a_1^*-a_2^*)^2+(b_1^*-b_2^*)^2]^{0.5}$$ [8] .

where L* is lightness (0 = black; 100 = white), a* is green-red component (−a* = green; +a* = red), b* is blue-yellow component (−b* = blue; +b* = yellow), subscript 1 is the baseline measurement before the immersion and subscript 2 is the measurement after 28 days immersion in staining solution.

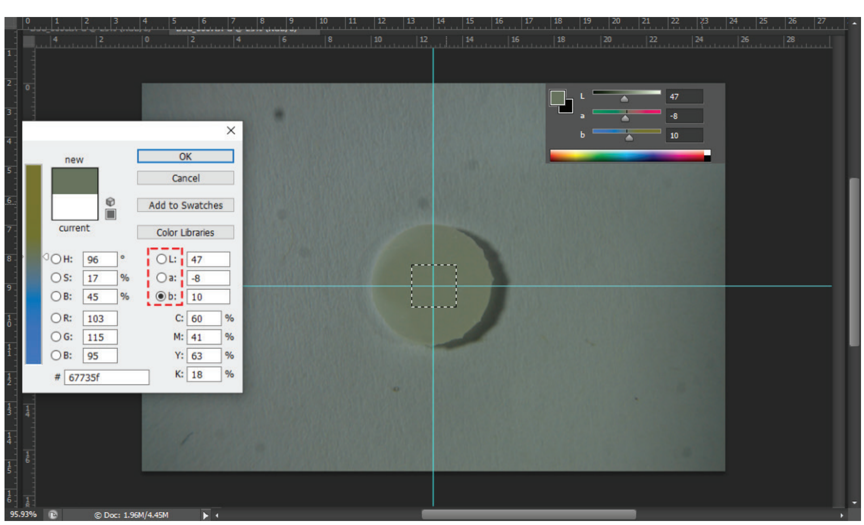

Figure 1: Adobe photoshop program shows how to pick the color data from the sample (L=47, a=-8, b=10) red dotted area.

Data of color change acquired from black, white backgrounds were submitted to statistical analysis using one-way ANOVA and Tukey Posthoc test for multiple comparisons between groups at a significance level of $p<0.05$. Statistical analysis performed using the Statistical Package for the Social Sciences (Version 24; SPSS Inc., IBM, Chicago, Illinois, USA).

Results

Tables 1 and 2 show ΔE±(SD) of all tested composite resins after 28 days immersion in different staining solutions on a black and white background, respectively. The lowest ΔE value observed for Amelogen Plus composite resin in artificial saliva on a black background (1.42±(0.45)), on the other hand, the highest ΔE value observed for Essentia composite resin in coffee on white background (28.0±(1.12)). Regarding staining solutions, coffee caused the highest ΔE in all composite resins, followed by tea, orange, Pepsi and artificial saliva, as shown in tables 1 and 2.

In the black background data set (Table 1), there were significant differences in ΔE in each brand of resin composite between the different staining solutions ($p<0.05$), except between the artificial saliva and Pepsi, there was no significant difference in ΔE in all brands of resin composites ($p>0.05$). Also, there were significant differences ($p<0.05$) in ΔE between the three composite resins in each staining solution except between Amelogen Plus and Beautiful II in artificial saliva, Pepsi, orange and tea ($p>0.05$), there was no significant difference in ΔE. Similarly, there was no significant difference in ΔE between Essentia and Beautiful II composite resins in orange staining solution ($p>0.05$), as shown in table 1.

Table 1: Change in color ΔE ± (SD) measured on the black background of all tested composite after 28 days immersion in different staining solutions.

Black background	Artificial Saliva	Pepsi	Orange	Tea	Coffee
Amelogen Plus	1.42±(0.45) a,d	2.53±(0.58)a,e	4.41±(0.95)f	8.66±(0.81)h	11.72±(0.56)
Essentia	2.87±(0.29) b	3.69±(0.46)b	5.52±(0.73)g	12.09±(1.08)	22.23±(1.06)
Beautiful II	1.76±(0.3) c,d	2.18±(0.83)c,e	5.14±(0.16)f,g	9.82±(0.87)h	13.39±(0.93)
Superscript small letters represent non-significant difference between relevant groups.					

In the white background data set (Table 2), there were significant differences in ΔE in each brand of resin composite between the different staining solutions ($p<0.05$) except in Amelogen Plus and Beautiful II there was no significant difference in ΔE between the artificial saliva and Pepsi ($p>0.05$). Also, there were significant differences ($p<0.05$) in ΔE between the three composite resins in each staining solution. However, there was no significant difference in ΔE between Amelogen Plus and Beautiful II in coffee solution ($p>0.05$), as shown in table 2.

Table 2: Change in color ΔE ± (SD) measured on the white background of all tested composite after 28 days immersion in different staining solutions.

White background	Artificial Saliva	Pepsi	Orange	Tea	Coffee
Amelogen Plus	1.8±(0.58)a	2.8±(0.68)a	5.9±(0.6)	11.85±(0.51)	18.0±(0.93)c
Essentia	5.18±(0.52)	7.85±(0.47)	12.03±(0.32)	18.22±(0.79)	28.0±(1.12)
Beautiful II	3.01±(0.73)b	4.07±(0.82)b	7.92±(0.57)	14.75±(1.42)	19.64±(1.99)c
Superscript small letters represent non-significant difference between relevant groups					

Discussion

As a composite restorative material are continuously exposed to saliva, food stains and beverage pigments, it is important to determine its susceptibility to color change [3]. In the present study, we investigated the effects of beverages tea, coffee, Pepsi and orange juice on the color stability of different composite materials. The artificial saliva constituted the control group. The results of the present study showed that there is a difference in color changes ΔE between the tested resin composites after immersion in different staining agents.

For standardization of staining conditions, we perform an "in vitro" study to control all variables such as food or drinking habits, tooth brushing. All the tested composites were of enamel translucency A2 shade, enamel translucency was selected because it is used as the most external layer and being in contact with staining agents. The immersion time for each composite group was 28 days in accordance with previous studies. Ardu et al. in 2017 reported that the immersion time for 28 days simulated about 2 years of drink consumption [9]. Ertas et al. considered 28 days is equivalent to about 2.5 years of clinical aging (24 h in vitro staining corresponds to 1 month in vivo) [10].

Digital imaging system is a reliable method for determining the color of teeth and gingiva when used with the appropriate calibration protocols [11]. In this study, the digital imaging system was selected to evaluate the color changes against white and black background which were used to allow a double evaluation to simulate two different clinical situations [9]; black background can mimic the situation, where no tooth structure exists in the back. i.e., class IV composite filling. White background can mimic class I, II, III, V and veneers, where one of the walls is still present.

Results of this study revealed that all tested composite showed significant color changes after immersion in the tested solution. Amelogen Plus was more stain-resistant followed by Beautiful II, while Essentia seems to be the most prone to staining. It seems that Essentia extensively colored in these staining solutions. The slightly different ranking obtained with the two different backgrounds may be related to different opacity of the composites which might modify the color perception on different backgrounds.The general behavior trend of the tested composites is confirming that Essentia has less color stability than Amelogene Plus and Beautiful II.

Findings of this study may depend on the hydrophilicity of the resin matrixes of these three resin composites and their filler particles. The differences in the staining resistance between these resin composites may be attributed to the different filler size and load which may affect the overall resin content in the cured composite. Essentia contains prepolymerized filler of resin, which together with the resin matrix, may increase the resin content in the composite, hence the water sorption and staining susceptibility consequently. It has been reported that increased resin content in the composite may increase the water sorption significantly especially in the first week of immersion in the staining solution [12].

The structure of resin matrix and filler type may have a direct impact on the susceptibility to extrinsic staining. the presence of UDMA, Bis-MEPP, Bis-EMA in the Essentia resin composite in this study did not enhance the staining resistance as has been proposed by previous studies[(13,14)]. This may be due to the concurrent presence of Bis-GMA and TEGDMA in resin composition, which were present in the other two tested resin composites in this study.

Regarding the staining solution tested, coffee showed the most staining capacity, followed by tea, orange, Pepsi and artificial saliva (Control group). Changes in ΔE value were greater for the tested staining solutions than for the control group, so the staining effect of a staining solution varied according to its ingredients. These results are in agreement with many previous studies which shown various staining potential of these drinks and this may be related to their composition and properties[(3,5,15)].

The highest values of ΔE reached was in coffee and this could be related to its acidity (pH 4.5), both adsorption and sub-surface absorption of coffee colorant [9]. The degree of polarity of the staining agent determines their degree of penetration into the resin materials. Less degree of polarity, such as coffee, can easily penetrate into the polymer matrix [16]. Both coffee and tea contain a large amount of staining agents like Gallic acid, which could be another reason for the staining capacity of these materials. This finding is in agreement with the study conducted by Ardu et al. [9]. Some studies reported that a solution with a lower pH can attack the composite surface, causing some changes and increasing pigment absorption [4]. Although Pepsi had a low pH, which can damage the surface integrity of the materials, it did not cause as much staining as coffee and tea. This may due to the absence of yellow colorant, which is abundant in coffee and tea [1], these findings were in agreement with other studies which found that coffee and tea produced more discoloration than cola [17, 18].

Conclusion

This study concluded that staining solutions affected the color stability of the tested resin composites significantly in a clinically unacceptable level, except for Amelogene Plus and Beautiful II in artificial saliva and Pepsi, which were acceptable clinically. Also, Essentia resin composite performed inferior to Amelogene Plus and Beautiful II in terms of color stability.

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Conflict of Interest: None to declare.

Ethical Clearance:All experimental protocols were approved under the College of Dentistry, University of Baghdad, Baghdad, Iraq and all experiments were carried out in accordance with approved guidelines.

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