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Effect of Coloring Beverages on Color Stability of Single Shade Restorative Material: An *In Vitro* Study

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Abstract

BACKGROUND: Color mismatch between tooth structure and restoration is a common reason for restoration replacement. This is due, in part, to the diverse chemical structure of both substrates, which display a different staining potential resulting in a significant color mismatch.

AIM: The aim of the study was to evaluates the color change of single shade resin composite and compare it to fibrous-filled resin composite (FRc) after storage in coloring beverages.

METHODS: Trapezoidal Class V cavities were prepared on the buccal and lingual surfaces of 30 premolars. Cavities on the buccal surface were restored with Omnichroma (ON) and palatal surface with FRc. Specimens were stored on water, tea, and coffee solutions for 24 h and 72 h. The color change was measured after each immersion time and statistically analyzed using three-way analysis of variance (ANOVA) (α = 0.05).

RESULTS: Three-way ANOVA showed that different materials had a significant effect on both ΔL and Δa ($p < 0.001$). For both materials, ON in coffee showed the highest Δb values when compared to FRc for the same period. No difference between ON and FRc when stored in tea for 24 h and 72 h.

CONCLUSION: Structural color property of ON can enhance the color perception of restoration to compensate for any color change after consuming coloring food and beverages.

Introduction

Resin composites are the most popular restorative materials in dental practice for anterior and posterior direct restorations. They achieved through superior mechanical and esthetical characteristics. Composite resins are intended to mimic tooth color while maintaining surface polish and color over time. However, a major disadvantage of resin composites is color instability when subjected to prolonged services in a harsh oral environment. That might leads to restoration failure and the need for restoration replacement [1], [2].

Color can be altered due to intrinsic and/or extrinsic staining factors. Extrinsic factors involve absorption of staining solutions, accumulation of plaque, and adsorption of the surface stains [3]. While superficial staining involves adhesion or penetration of exogenous colorants such as coffee, tea, and nicotine [4]. Furthermore, degradation of the restoration surface is a common condition in the oral environment, which can result in increased surface roughness and increase adsorption of staining agents [5].

On the other hand, the intrinsic factors involve the degradation of the resin matrix and fillers-matrix interface [6]. Endogenous discolorations are irreversible, while exogenous discolorations can be removed by polishing. Therefore, the compositional variation such as resin matrix type, photoinitiator systems, and inorganic fillers loading and characteristics may drastically impact the color stability [7]. Among those factors, inorganic fillers' chemicophysical characteristics have a direct impact on composite resin surface property and their susceptibility to extrinsic staining [8].

The present study evaluates the effect of coloring beverage consumption on the color stability of two commercial resin composites with different filler shapes and compositions. The null hypotheses were: (1) Different coloring beverages (coffee and tea) did not influence the color parameters and (2) tested resin composites showed no color difference after storage in the coloring solutions.

Materials and Methods

Freshly extracted 30 human premolars were collected for the study protocol. The Ethics Committee of the Azhar University (Egypt) has approved the use of extracted human teeth in anonymized form (2019–19). Premolar teeth included in this study were extracted due to orthodontic or periodontal reasons with intact surface (non-carious). All teeth were cleaned from calculus deposits and/or soft-tissue debris using an ultrasonic scaler and polished with a prophylaxis paste. After cleaning, teeth with visible cracks or caries were replaced with other teeth that match the above-mentioned criteria.

Class V cavities with standardized trapezoidal outline were prepared on the buccal and lingual surfaces (5 mm width, 3 mm length, and 1.5 mm depth) coronal to the cementoenamel junction using No.56 fissure carbide bur (Komet, Germany). To standardize the cavity dimensions and preparation, a rubber index was prepared with the desired dimensions and used to mark the cavity outline before preparation. All cavities were prepared by the same operator (WG) and final dimensions were checked using digital caliber (Mitutoyo CD-15C, Mitutoyo, Kanagawa, Japan).

After water-rinsing and air-drying, the cavities were acid-etched with 37% phosphoric acid gel for 20 s, then rinsed with water spray (5 s), and dried gently with an air stream. The bonding agent (Bond Force, Tokuyama Dental, Japan) was applied according to the manufacturer's instructions and light-cured for 20 s using an LED curing unit (1000 mW/cm^2, 3M Elipar Deep Cure-S LED, 3M Oral Care, St. Paul, MN, USA). The prepared cavities were packed with the designated resin composites and covered with a celluloid strip. Afterward, they were light-cured for 40 s (1000 mW/cm^2, 3M Elipar Deep Cure-S LED). For each tooth, the buccal surface was restored with Omnichroma (ON) composite (ON, n = 30) and palatal surface was restored with fiber-reinforced composite (FRc, n = 30). The specimens were then stored for 24 h in distal water before color measurement. Compositions of used resin composites are listed in the supplementary Table 1. A spectrophotometer (Vita Easy shade compact, Vita, Zahnfabrik, Bad Sackingen, Germany) was used to measure the color parameters and was expressed using International Commission on Illumination System (CIE L*a*b*) where; L* coordinate representing color luminosity (white to black), a* (green to red), and b* (blue to yellow) both representing the chromaticity of the color. The color changes (ΔE^*) were calculated [9], [10] as follows:

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

All specimens were stored in distilled water for 3 days at 37°C and color assessment was conducted. Then, specimens were divided into two subgroups (n = 15, each) based on the immersion media. After baseline color measurements, teeth were measured after coffee and tea immersion at 37° for 24 h and 72 h simulating 1 month and 3 months of beverage combustion [5]. Immersion solutions were freshly prepared and replaced every 24 h. The coffee solution was prepared by dissolving 3.5 g of Nescafe (Nescafe gold, Nestle, Egypt) in 300 mL of boiled distilled water while tea solution (Yellow Label Tea; Lipton, Egypt) was prepared by immersion of two prefabricated tea bags (2 g) into 300 ml of boiling distilled water for 10 min.

Statistical analysis

Data for water immersion were excluded from the analysis due to no variation in color parameters after 3 days of water storage. Color parameter data showed normal distribution when checked using Kolmogorov–Smirnov test. Color parameter data have met the assumption of homogeneity of variance ($p > 0.05$ for ΔL, Δa, Δb, and ΔE) when checked using Levene test. Three-way analysis of variance (ANOVA) was used to compare between storage media (coffee vs. tea), materials (ON vs. FRc), and immersion time (24 h vs. 72 h) followed by multiple comparisons with Tukey honestly significant difference. A significant level was set at 5% ($\alpha = 0.05$). Statistical analysis was performed with IBM Statistical Package for the Social Sciences (version 26, Armonk, NY, USA)

Results

Results of color parameters are presented in Tables 1 and 2 and the change of color parameters is presented in Figure 1. Three-way ANOVA showed that different materials had a significant effect on both ΔL and Δa ($p < 0.001$).

Table 1: Significance of three-way ANOVA results for the tested variables

Variables	ΔL	Δa	Δb	ΔE
Materials	<0.001*	<0.001*	<0.001*	0.178NS
Immersion time	<0.001*	<0.001*	<0.001*	<0.001*
Storage media	<0.001*	0.148NS	0.002*	<0.001*
Materials×Immersion time	0.955NS	0.268NS	0.031*	0.989NS
Materials×Storage media	0.395NS	0.135NS	0.039*	0.303NS
Immersion time×Storage media	0.001*	0.268NS	0.160NS	0.018*
Materials×Immersion time×Storage media	0.860NS	0.720 SN	0.005*	0.958NS

*Significance, NS: Non-significant, ANOVA: Analysis of variance.

While, storage media had a significant effect on ΔL and Δb ($p < 0.001$ and $p = 0.002$, respectively). For ΔL and Δb, all the interactions of tested materials used with follow-up and storage media showed an insignificant effect ($p > 0.05$). The interaction between follow-up and storage media was significant for ΔL and ΔE. All variables and their interaction significantly affected Δb ($p < 0.05$) except the interaction between follow-up and storage media ($p = 0.160$).

Table 2: Different color parameters for tested groups

Materials	Media	Immersion time	ΔL	Δa	Δb	ΔE
ON	Coffee	24 h	-7.9 ± 7.4^{AB}	1.2 ± 0.7^{A}	6.5 ± 3^{AB}	12.2 ± 3.2^{BC}
		72 h	-15 ± 5.1^{C}	2.1 ± 0.8^{A}	8.9 ± 2.8^{A}	18.1 ± 3.1^{A}
	Tea	24 h	-3.7 ± 1.9^{A}	1.3 ± 0.9^{A}	3 ± 4^{BC}	5.8 ± 2.8^{D}
		72 h	-6.7 ± 0.9^{AB}	1.4 ± 0.7^{A}	2.1 ± 3.6^{C}	7.7 ± 2^{CD}
FRc	Coffee	24 h	-9.7 ± 2.8^{B}	1.6 ± 0.3^{A}	0.6 ± 3.1^{C}	10.4 ± 2^{CD}
		72 h	-15.6 ± 3.7^{C}	2.3 ± 0.5^{A}	0.9 ± 3.2^{C}	16.2 ± 2.9^{AB}
	Tea	24 h	-3.1 ± 1.1^{A}	2.2 ± 0.5^{A}	3.9 ± 0.9^{BC}	5.5 ± 0.9^{D}
		72 h	-6.3 ± 2.4^{AB}	2.3 ± 0.5^{A}	3 ± 1.2^{BC}	7.5 ± 2.1^{CD}

Different letter within each column indicates significant difference P < 0.05, ON: Omnichroma, FRc: Fiber-reinforced composite.

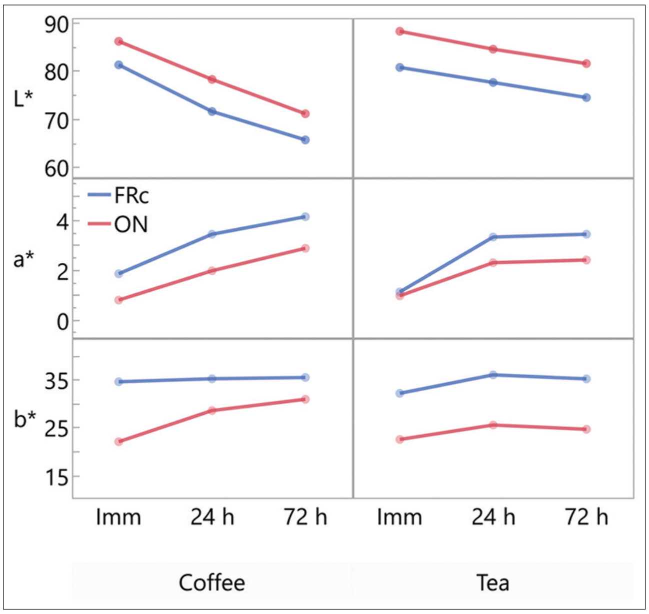

Figure 1: Line chart showing the change of the color parameters for both tested composites. Sever increase in b for Omnichroma when stored in coffee for 72 h compared to limited change for fiber-reinforced composite*

The multiple comparisons showed that for both materials, storage in the coffee for 72 h resulted in the highest ΔL followed by coffee – 24 h and tea – 72 h with no difference between each other's ($p > 0.05$). Tea storage for 24 h leads to the least change in ΔL for both composites. For Δa, no difference between each group was shown. For Δb, storage of ON in coffee for 72 h showed the highest significant values when compared to FRc for the same period. FRc showed a limited change in b* after 72 h (Figure 1). No difference between ON and FRc stored in tea for 24 h and 72 h.

For ΔE, no difference between ON and FRc compared to each other for each storage media and period. Coffee resulted in a significant increase in ΔE after 72 h compared to tea storage for the same period.

Discussion

Color stability is a fundamental factor for long-term esthetic results of tooth-colored restorations [11]. The clinical success of esthetic restoration depends on the initial color match and color stability of the esthetic materials during service. The extent of discoloration has been shown to depend on the restorative materials composition, curing time, curing device, and aging/storage conditions [12], [13].

Several studies have reported discoloration of dental composites by colored solutions [1], [3], [5], [11], [14], [15], [16], [17], [18], [19], [20]. Color change of resinous materials is mainly related to the absorption or adsorption of coloring substances, such as those found in the daily diet. In the present study, specimens were exposed to commonly consumed beverages such as tea and coffee. In addition, water was also used as a control storage media; however, no change was detected in color. Water degradation of resin composite starts immediately after storage due to the presence of residual monomer after polymerization, nonetheless, this effect is limited to light transmission parameters rather than transparency and color parameters, particularly after short-term water storage for up to 7 days [6]. Coffee and tea as hot beverages commonly used as coloring solutions, while Pepsi is used as cold beverages. Only mild acidity beverages with 4.5–5 pH were used in the present study. Pepsi was excluded due to its higher acidity (pH = 2.5) which may increase the degradation of tested composites and initiate demineralization of tooth enamel [15]. Tea and coffee contain a large amount of gallic acid, which could be a reason for increasing the staining capacity of these solutions as confirmed by Kumari *et al*. [16]. In addition, yellow coffee stains characterized by low polarity and a delayed-release that showed increased penetration potential into the organic phase of substances [17], [18]. On the other hand, tea has yellow stains with a high polarity which precipitate on the surface through adsorption. The results showing the discoloration potential of coffee to be greater than tea are following previous studies [19], [21].

In this study, Vita Easyshade was used because it is a reliable and accurate device with 90% accuracy [22]. The CIE L*a*b* color system used in this study is a recommended method for dental purposes. The system uses the human perception to characterizes the color and defines it with three spatial coordinates, L*, a*, and b*. ΔL* represents the change in the brightness of a shade, while Δa* represents the changes in red-green coordinate, while Δb* represents the changes yellow-blue color coordinate [23]. In the present study, ON showed a higher increase in the b* parameter compared to FRc. Properly, as coffee contains tannins that are white-yellowish to light brown [24]. In addition, the lower pH of coffee is below the critical point of enamel demineralization so it may facilitate the entry of tannin substances into the tooth enamel through the formed porosity and led to elevated b*. During the 72-h immersion, the higher and significant change in b* value occurred in the ON group compared to the FRC group. The change in b* for ON in the present study might be explained by discoloration of the surrounding structure to the restoration. Color parameters were evaluated for different restorative after placement in the natural tooth to simulate the true clinical variations [24]. Although color change is considered a disadvantage in esthetic restorations, the structure colors property of ON is considered an advantage as it helps in masking the restoration to match with the stained tooth structure. That will result in pseudofluctuation of restoration color with the change in surrounding tooth/environment.

According to the manufacturer, the single shade ON resin composite has structural colors property that smart chromatic technology is capable to control the optical properties of the resin composite. This approach has enabled the engineering of a resin composite that responds to light waves at a given frequency by perfectly reflecting a specific wavelength by submicron-sized structures inside the tooth color space [25]. Traditional composites on the other hand, obtain their color chemically by incorporating pigment hues into the composite formulas.

Both ON and FRc showed a significant change in the color parameters when stored in different staining/coloring solutions. A presumable reason is that both restorations are direct restorative materials that suffer from incomplete polymerization at the outer layer. Acrylate-based resins materials exhibit an oxygen inhibited surface layer when cured in air [26], [27]. Thus, Mylar strips application results in a smooth surface finish and can eliminate the uncured layer on the surface. However, the outer surface layer of resin composite shows a lower degree of polymerization which can exhibit increased discoloration [27].

Within the limitation of our study, it can be concluded that ON with structural color property can compensate for the color changes of the surrounding structure particularly, with patients that have a higher affinity for consuming coloring food and beverages.

References

1. Inokoshi S, Burrow MF, Kataumi M, Yamada T, Takatsu T. Opacity and color changes of tooth-colored restorative materials. Oper Dent. 1996;21(2):73-80.
   PMid:8957922
2. Yannikakis SA, Zissis AJ, Polyzois GL, Caroni C. Color stability of provisional resin restorative materials. J Prosthet Dent. 1998;80(5):533-9. https://doi.org/10.1016/s0022-3913(98)70028-9
   PMid:9813802
3. Gupta R, Bhatheja A, John AG, Ramchandran M, Raina AA, Behera A, *et al*. Effect of beverages on color stability of resin composites: An *in vitro* study. J Appl Dent Sci. 2019;5(2):92-5.
4. Sundfeld RH, Sundfeld-Neto D, Machado LS, Franco LM, Fagundes TC, Briso AL. Microabrasion in tooth enamel discoloration defects: Three cases with long-term follow-ups. J Appl Oral Sci. 2014;22(4):347-54. https://doi.org/10.1590/1678-775720130672
   PMid:25141208
5. Ertaş E, Güler AU, Yücel AC, Köprülü H, Güler E. Color stability of resin composites after immersion in different drinks. Dent Mater J. 2006;25(2):371-6.
   PMid:16916243
6. Almasabi W, Tichy A, Abdou A, Hosaka K, Nakajima M. Effect of water storage and thermocycling on light transmission properties, translucency and refractive index of nanofilled flowable composites. Dent Mater J. 2021;40(3):599-605. https://doi.org/10.4012/dmj.2020-154
   PMid:33361663
7. Ashok NG, Jayalakshmi S. Factors that influence the color stability of composite restorations. Int J Orofac Biol. 2017;1(1):1-3.
8. Mundim FM, da Fonseca Roberti Garcia L, de Carvalho Panzeri Pires-de-Souza F. Effect of staining solutions and repolishing on color stability of direct composites. J Appl Oral Sci. 2010;18(3):249-54. https://doi.org/10.1590/s1678-77572010000300009
   PMid:20857002
9. Sayed M, Hiraishi N, Matin K, Abdou A, Burrow MF, Tagami J. Effect of silver-containing agents on the ultra-structural morphology of dentinal collagen. Dent Mater. 2020;36(7):936-44. https://doi.org/10.1016/j.dental.2020.04.028
   PMid:32475750
10. Sayed M, Tsuda Y, Matin K, Abdou A, Martin K, Burrow MF, *et al*. Effects of mechanical abrasion challenge on sound and demineralized dentin surfaces treated with SDF. Sci Rep. 2020;10(1):19884. https://doi.org/10.1038/s41598-020-77035-9
    PMid:33199833
11. Kolbeck C, Rosentritt M, Lang R, Handel G. Discoloration of facing and restorative composites by UV-irradiation and staining food. Dent Mater. 2006;22(1):63-8. https://doi.org/10.1016/j.dental.2005.01.021
    PMid:15993940
12. Buchalla W, Attin T, Hilgers RD, Hellwig E. The effect of water storage and light exposure on the color and translucency of a hybrid and a microfilled composite. J Prosthet Dent. 2002;87(3):264-70. https://doi.org/10.1067/mpr.2002.121743
    PMid:11941352
13. Janda R, Roulet JF, Latta M, Steffin G, Rüttermann S. Color stability of resin-based filling materials after aging when cured with plasma or halogen light. Eur J Oral Sci. 2005;113(3):251-7. https://doi.org/10.1111/j.1600-0722.2005.00217.x
    PMid:15953251
14. Ezzeldin N, Mohamed M, Abdou A. Physical characteristics of two moisture tolerant fissure sealants immersed in commercial products with different pH range. Tanta Dent J. 2019;16(2):80.
15. Al-Taie LA, Al-Aubaydi AF, Al-Shamma AM. The effect of pepsi cola beverage on surface roughness of two composite resins (*in vitro* study). Mustansiriya Dent J. 2018;7(1):9-14.
16. Kumari RV, Nagaraj H, Siddaraju K, Poluri RK. Evaluation of the effect of surface polishing, oral beverages and food colorants on color stability and surface roughness of nanocomposite resins. J Int Oral Health. 2015;7(7):63-70.
    PMid:26229373
17. Bagheri R, Burrow MF, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. J Dent. 2005;33(5):389-98. https://doi.org/10.1016/j.jdent.2004.10.018
    PMid:15833394
18. Um CM, Ruyter IE. Staining of resin-based veneering materials with coffee and tea. Quintessence Int. 1991;22(5):377-86.
    PMid:1924691
19. Topcu FT, Sahinkesen G, Yamanel K, Erdemir U, Oktay EA, Ersahan S. Influence of different drinks on the colour stability of dental resin composites. Eur J Dent. 2009;3(1):50-6.
    PMid:19262731
20. Hutami SN, Triaminingsih S, Indrani DJ. Effect of tooth immersion in the coffee drink with different types of coffee roast temperature on tooth discoloration. J Phys Conf Ser. 2018;1073(3):32026.
21. dos Santos Domingos PA, Garcia PP, de Oliveira AL, Palma-Dibb RG. Composite resin color stability: Influence of light sources and immersion media. J Appl Oral Sci. 2011;19(3):204-11. https://doi.org/10.1590/s1678-77572011000300005

PMid:21625734

22. Theodore MR, Harold OH, Edward JS Jr. Sturdevant's Art and Science of Operative Dentistry. Edinburgh: Elsevier Mosby; 2006.
23. Nasim I, Neelakantan P, Sujeer R, Subbarao CV. Color stability of microfilled, microhybrid and nanocomposite resins--an *in vitro* study. J Dent. 2010;38 Suppl 2:e137-42.
24. Riad MI, Gamal WM, Morsy AS. Color matching of a single shade structurally colored universal resin composite with. Egypt Dent J. 2020;66(4):2721-7.
25. Ergücü Z, Türkün LS, Aladag A. Color stability of nanocomposites polished with one-step systems. Oper Dent. 2008;33(4):413-20. https://doi.org/10.2341/07-107

PMid:18666499

26. Robertson L, Phaneuf M, Haimeur A, Pesun I, França R. Degree of conversion and oxygen-inhibited layer effect of three dental adhesives. Dent J. 2016;4(4):37. https://doi.org/10.3390/dj4040037

PMid:29563479

27. Rueggeberg FA, Margeson DH. The effect of oxygen inhibition on an unfilled/filled composite system. J Dent Res. 1990;69(10):1652-8. https://doi.org/10.1177/00220345900690100501

PMid:2212209

Supplementary file

Supplementary Table 1: Resin composite materials used in the present study

Material (code)	Specifications	Composition		Manufacturer (Batch number)
		supplementary file	supplementary file	
Omnichroma	Single shade universal composite	Spherical silica-zirconia filler (0.3 μm, range: 0.2–0.6 μm). (79 wt% [68 vol%])	UDMA, TEGDMA, Mequinol, Dibutyl hydroxyl toluene, and UV absorber	Tokuyama Dental, Tokyo, Japan. (009 E39)
Alert Fiber-reinforced composite	Condensable fiber reinforced composite	Microfilamentous glass fiber (60–80 μm in length), silicon dioxide, barium-borosilicate glass, micro fine silica (0.8 μm irregular shape particles). (84 wt% [67 vol%])	Bis-GMA, dimethacrylates groups	Jeneric/Pentron, Wallingford, CT, USA (6931490)

Bis-GMA: Bisphenol A-glycidylmethacryalte, TEGDMA: Triethylene glycol dimethacrylate, UDMA: Urethane dimethacrylate.