Original Article

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The Color Change of a Novel Single-shade Composite Immersed in Different Beverages

Farklı İçeceklere Batırılma Sonrası Yeni Nesil Tek Renk Kompozitin Renk Değişimi

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ABSTRACT

Objective: The purpose of this study was to evaluate the effects of different beverages on the color change of a novel single-shade composite and two different composite resins.

Methods: Three different resin composites were used: Microhybrid (MH), single- shade supra-nanohybrid (SS) and nano-ceramic composite resin (NC). Totally, 120 disc-shaped samples were prepared (N=40) and subdivided into 4 groups according to the immersion beverages:tea, coffee, cola and distilled water (control) (n=10). CIELAB coordinates were obtained using a spectrophotometer device and color change (ΔE) before and after immersion in beverages were calculated. For statistical analysis, two-way ANOVA and Bonferroni tests were used ($p<0.05$).

Results: Coffee showed significantly the highest ΔE values compared to other tested beverages for all resin composites. Besides, tea exhibited significantly higher ΔE values than distilled water. Tea showed significantly higher ΔE values than cola for SS and MH. Regarding the resin composites, SS showed significantly the highest ΔE values than other tested composites after immersion in coffee. SS showed significantly higher ΔE values than MH after immersion in tea. NC showed significantly higher ΔE values than MH after immersion in cola ($p<0.05$).

Conclusion: Coffee caused the highest color change in all tested composites. Besides, SS supra-nanohybrid composite showed significantly higher color change than MH composite after immersion in coffee and tea.

Keywords: Color, composite, microhybrid, single-shade, nanohybrid, nano-ceramic

ÖZ

Amaç: Bu çalışmanın amacı, farklı içeceklerin yeni nesil tek renk kompozitin ve iki farklı kompozit rezinin renk değişimi üzerine etkisini incelemektir.

Yöntemler: Üç farklı rezin kompozit kullanılmıştır: Mikrohibrit (MH), tek renk supra-nanohibrit (SS) ve nano-seramik kompozit rezin (NC). Toplam 120 disk şeklinde örnek hazırlanmış (N=40) ve bekletilme içeceklerine göre 4 gruba ayrılmıştır: Çay, kahve, kola ve distile su (kontrol) (n=10). CIELAB koordinatları, spektrofotometre cihazı kullanılarak elde edilmiş ve renk değişimleri (ΔE) içeceklere batırılma öncesi ve sonrası hesaplanmıştır. İstatistiksel analizler, iki yönlü ANOVA ve Bonferroni testleri kullanılarak yapılmıştır ($p<0,05$).

Bulgular: Kahve, tüm kompozit rezinler için istatistiksel olarak en yüksek ΔE değerleri göstermiştir. Ayrıca, çay, distile suya göre istatistiksel olarak daha yüksek ΔE değerleri sergilemiştir. SS ve MH için çay, kolaya göre istatistiksel olarak daha yüksek ΔE değerleri göstermiştir. Rezin kompozitler kıyaslandığında, kahvede bekletme sonrası SS, diğer test edilen kompozitlere kıyasla istatistiksel olarak en yüksek ΔE değerleri göstermiştir. Çayda bekletme sonrası SS, MH'ye göre istatistiksel olarak daha yüksek ΔE değerleri göstermiştir. Kolada bekletme sonrası NC, MH'ye göre istatistiksel olarak daha yüksek ΔE değerleri göstermiştir ($p<0,05$).

Sonuç: Tüm test edilen kompozitler için kahve en yüksek renk değişimine neden olmuştur. Ayrıca, çay ve kahvede bekletilme sonrası SS-nanohibrit kompozit, MH kompozite göre belirgin olarak daha fazla renk değişimi göstermiştir.

Anahtar Sözcükler: Renk, kompozit, mikrohibrit, tek renk, nanohibrit, nano-seramik

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Introduction

In recent years, microhybrid (MH) composite resins are frequently preferred in either anterior or posterior restorations due to their good esthetic properties and high wear resistance (1). With the developments in nano technology, nano-composite resins are comprised of nano-sized particles which result in better polishability and reduced filler size and increased filler amount and wear resistance (2,3). Especially, new generation nano-ceramic composite resins with superior abrasion and fracture resistance and good polishability have been popular (4).

The different color options of composite resins can provide a restoration that is esthetically similar to natural tooth tissue (5). Composite resins have been launched in multiple enamel and dentin colors with different opacities and translucencies. Therefore, shade matching procedure may be complicated with the inventory, and results in increased cost and chairside time (6). As a result, the tendency to simplify the shade options can ensure the development of universal composite resins which have a universal opacity (7). Recently, a novel, universal composite with a single shade matching all colors from A1 to D4 has been developed, in accordance with the manufacturers' claims (7,8). This property can be obtained from the inclusion of regular spherical fillers, which can produce red to-yellow color as ambient light passes through the restorative material (7). Color shifting of resin composites originates from two main factors: the blending effect (primarily perceptual, subjective, and not measurable) and a quantifiable, physical translucency associated with composition (9). The term "chameleon effect" describes blending effect, color assimilation and color induction (10). This unique property of "blending effect" or "chameleon effect" defines the capability of a restorative material to achieve a color similar to that of its environmental tooth tissues (11).

It was reported that filler particles of resin composites were separated from the organic matrix and that their matrix structure showed signs of deteriorations when restorative materials wereexposed to temperature changes and low pH in the oral conditions (12). There are various studies in the literature on the effects of beverages consumed in daily life on the color change of restorative materials (13,14). However, in the literature, there is limited data on the color change of single-shade composites in beverages such as tea, coffee and cola that are frequently consumed in daily life. Therefore, the aim of this study was to evaluate the effects of different beverages on the color change of a novel single-shade composite and two different types of resin composites. The tested null hypothesis of this in vitro study was that the beverages would not affect the color change of different composite resins.

Methods

The sample size calculation was determined on the estimated effect size between groups according to the literature (12). It was stated that 10 samples were required per each group to obtain a medium effect size (d=0.50) at 90% power and 5% type 1 error rate. Composite resin materials and compositions employed in this in vitro study are shown in Table 1. In this study, three different types of composite resins were used: MH (Filtek Z250, 3M ESPE, USA), single-shade supra-nano hybrid = SS (Omnichroma, Tokuyama Corp., Japan) and nano-ceramic = NC composite resins (CeramX, Dentsply Sirona, Germany). A total of 120 disc-shaped composite resin samples was prepared

Table 1. Material brand names/manufacturers, batch numbers and chemical compositions

Filtek Z250 (A2 shade) **microhybrid=MH**	3M ESPE, St. Paul, MN, USA	NA23939	***Organic matrix composition*** Bis GMA, UDMA, Bis EMA Inorganic Filler Particulate (82 wt%/60 vol%) 0.01-3.5 µm Zirconia-Silica filler
Omnichroma **single-shade supra-nanohybrid=SS**	Tokuyama Dental Corp. (Tokyo, Japan)	038M1	***Organic matrix composition*** 1.6-bis(methacryl-ethyloxycarbonylamino) trimethyl hexane (UDMA), triethylene glycol dimethacrylate (TEGDMA), mequinol, dibutyl hydroxyl toluene and UV absorber. ***Inorganic filler particulate*** (79 wt%, 68 vol%) spherical silica-zirconia filler (mean particle size: 0.3 µm, particle size range: 0.2 to 0.4 µm)
Ceram X SphereTEC one (A2 shade) **nano-ceramic=NC**	Dentsply Sirona (York, USA)	180500110	***Organic matrix composition*** methacrylate modified polysiloxane(organically modified ceramic), dimethacrylate resins, Camphorquinone, Ethyl-4(dimethylamino) benzoate, Bis(4-methyl-phenyl)iodonium hexafluorophosphate ***Inorganic filler particulate*** (72-73 wt%/48-50 vol%) Barium glass, pre-polymerized filler, ytterbium fluoride, 0.1-3 µm filler size (0.6 µm)

BIS-GMA: Bisphenol A glycidyl methacrylate, UDMA: Urethane dimethacrylate, BIS-EMA: Bisphenol A diglycidyl methacrylate ethoxylated, TEGDMA: Triethylene glycol dimethacrylate, µm: Micrometer, Bis-MPEPP: Bis-methacryloxyethoxy phenyl propane, wt%: Weight percentage, vol%: Volume percentage, µm: Micrometer, nm: Nanometer using teflon molds (diameter: 4 mm, thickness: 2 mm) (N=40). Transparent polyester matrix strip and glass slides were used on both surfaces of samples, and finger pressure was applied to these glass coverslips to obtain a flat sample surface. Then, all samples were polymerized (B.O.) for 20 s using a LED light curing unit (Valo, Ultradent, USA) (1,000 mW/cm^2 power). Light intensity was checked periodically with a radiometer (Demetron LED Radiometer, Kerr Corp., USA). Subsequently, the samples were removed from the teflon molds and kept in distilled water for 24 h at 37 °C in a dark vial. The samples were allocated into 4 subgroups according to the immersion beverages: tea (Lipton, Glasgow, Scotland), coffee (Nescafe Classic, Vaud, Switzerland), cola (Coca Cola, Atlanta, United States) and distilled water (control) (n=10). They were immersed in different beverages for 24 hours every day during 6 days, and the beverages were renewed daily (15). Coffee and tea solutions were prepared by dissolving 12 g coffee powder or 3 g tea powder in 250 mL boiled distilled water (16). After each immersion, samples were washed and stored in distilled water.

Color values were measured from the upper surfaces of the samples using a spectrophotometer device (Vita Easy Shade Advance 4.0, VITA Zahnfabrik, Germany) before and after immersion in beverages. Measurements were carried out under D65 standard lighting conditions (14). The spectrophotometer device was calibrated before each measurement. Initial measurements were recorded as CIE (L0, ao, b0) and 6th day measurements as CIE (L1,a1,b1). Measurements were repeated 3 times for each sample and average CIE (L*a*b*) values were calculated. The formula was used to calculate the differences (ΔE) between the acquired measurements:

$$\Delta E^* = [(L1^* - L0^*)^2 + (a1^* - a0^*)^2 + (b1^* - b0^*)^2]^{1/2}$$

All measurements were carried out by a second operator (L.F.) who was unaware of the resin composites and beverages employed in this study.

Statistical Analysis

Statistical analysis was performed using the IBM Statistical Package for Social Sciences 22.0 software (SPSS Inc., Chicago, IL, USA) for Windows. The normality of the variances was analyzed with Shapiro-Wilk test and the homogeneity of the variances were analyzed with Box's M test. The data were normally distributed. Two-way analysis of variance (ANOVA) was used to compare within- and between-group differences. All pairwise comparisons were done using Bonferroni test. Statistical significance was considered at a confidence level of 0.05 for all analyses.

Results

Mean color change values and standard deviations of all tested groups are shown in Table 2. When comparing the beverages, coffee showed significantly the highest color change than other tested beverages for all resin composites ($p<0.05$). Tea exhibited significantly higher color change than distilled water for all composites ($p<0.05$). There were no significant differences in terms of color change between tea and cola and cola and distilled water for NC ($p>0.05$). Tea showed significantly higher color change than cola ($p<0.05$), whereas no significant differences were found in terms of color change between cola and distilled water ($p>0.05$) for SS and MH. When comparing the composite resins, SS showed significantly the highest color change than other tested composite resins after immersion in coffee ($p<0.05$). SS showed significantly higher color change than MH after immersion in tea ($p<0.05$). NC showed significantly higher color change than MH after immersion in cola ($p<0.05$). There were no significant differences in terms of color change among composite resins after immersion in distilled water ($p>0.05$).

Discussion

In the current study, the effects of beverages on the color change of single-shade composite and two different types of composite resins were evaluated. The tested null hypothesis that the beverages would not affect the color change of different types of composite resins, was partially rejected.

When composite resin restorations are exposed to fluids in the oral cavity, the organic matrix structure absorbs fluids (17). The sorption and solubility may produce deleterious effects such as swelling, plasticization and softening, oxidation and hydrolysis on the structure and function of a resin matrix (18,19). Discoloration is one of the common reasons of deterioration of resin composites (20). Microcracks or voids at the filler and matrix interface may lead to penetration of dyes and discoloration (21).

There are two main mechanisms regarding the color change of resin composites: intrinsic and extrinsic factors (15). Internal

Table 2. Mean color change values and standard deviations of all tested groups (ΔE ± SD)

	NC	SS	MH	p
Tea	5.84 ± 2.01^{ABa}	7.12 ± 1.8^{Aa}	4.4 ± 1.18^{Ba}	0.003
Coffee	9.56 ± 1.98^{Ac}	18.45 ± 2.7^{Bb}	8.1 ± 1.51^{Ab}	<0.001
Cola	3.88 ± 2.38^{Aab}	2.56 ± 1.4^{ABc}	1.4 ± 0.81^{Bc}	0.006
Distilled water	2.47 ± 1.46^{b}	2.35 ± 1.45^{Ac}	1.78 ± 0.48^{c}	0.625
p	<0.001	<0.001	<0.001	

*Different capital letters in the same row indicate statistically significant differences.
Different lowercase letters in same column indicate statistically significant differences ($p<0.05$)
SD: Standard deviation

discoloration depends on the structure of the resin composites, the properties of the filler particles, the chemical properties such as water sorption and degree of polymerization (21). External discoloration may occur due to poor oral hygiene, eating habits, and cigarette consumption (22).

Guler et al. (23) indicated that immersion in coffee for 24 h would imitate approximately 30 days of regular consumption. In this study, the similar time-simulation protocol was carried out for the other beverages and the composite resin samples were immersed for 24 h at 37 ^{0}C during 6 days, which corresponded to 6 months of daily use.

Digital color measurement devices have been used to determine the color properties of restorative materials (24). Vita Easyshade is the most preferred spectrophotometer device, as it is reproducible and reliable in terms of color detection (25). In this study, spectrophotometer (Vita Easyshade Advance 4.0) device was used for color measurement of the samples. Subjective errors are thus eliminated, and more importantly, it is more sensitive in measuring small differences than with the naked eye (24). The two systems used for spectrophotometric analysis are CIELAB ve CIEDE 2000 (26). In this study, CIE lab color difference formula was preferred since it was stated in the literature that this formula was widely used.

The CIELAB for evaluating color change measurement; using the equation $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$ is highly recommended compared to the 3 color vector (L *, a * and b *). ΔE is summarized as the difference in 3 color vectors and presents their combined effect on color change (27). In this system, clinically acceptable and desirable ΔE value is considered to be below 3.3. (28). In this study, when the effect of beverages on the color changes of different composite resins were evaluated, ΔE values were determined above the clinically acceptable value for all tested composite resins after immersion in tea and coffee. This finding was in line with Ertaş et al. (29), who indicated that tea and coffee caused significant discoloration on MH and nanohybrid composite resins with color change above acceptability threshold. In this study, with respect to the beverages, coffee caused significantly the highest color change for all tested composite resins. This finding was in line with Domingos et al. (30), who indicated that coffee caused higher color change compared to tea and cola for nanofilled composite resins. Tavangar et al. (31), who evaluated the color change of nanohybrid and MH composites, indicated that coffee and tea caused more color change than cola. Besides, in this study, tea caused significantly higher color change than cola for MH and single-shade supra-nanohybrid composite resins. The sorption of yellow colorants of the coffee and tea may occur due to the organic phase of the restorative material (32). Silva et al. (32) reported that tea and coffee could produce water sorption and color degradation due to hot temperatures (65-80 ^{o}C), which might also cause to the surface degradation of the polymeric matrix. Besides, in this study, tea caused significantly higher color change than distilled water for all tested composite resins. However, no significant color changes were observed between cola and distilled water. Ertaş et al. (29) reported that coffee and tea had a greater influence on the staining of nanofilled composite than cola and water.

The contents of the restorative materials and the characteristics of the filler particles are notable in the tendency of discoloration (33). The hydrophilicity of the resin matrix and the degree of water absorption affect the susceptibility of the resin composites to staining. After immersion in coffee, single-shade supra-nanohybrid composite resin exhibited significantly higher color change than other composites. A previous study revealed that resins formulated with Bis-EMA tended to be less susceptible to dissolution when compared with those with Bis-GMA and UDMA (34). Bis-GMA is usually combined with low viscosity monomers like TEGDMA (35). However, the addition of TEGDMA increases water sorption and hinders color stability (36). Filtek Z250 contains three major components: Bis-GMA, UDMA, and Bis-EMA while Omnichroma consist of UDMA and TEGDMA. This finding can be contributed to the hydrophilic monomer, TEGDMA of this restorative material. Increased filler content could lead to lower water absorption and less surface degradation (37). This could explain why Filtek Z250 exhibited the best overall results. Besides, this composite contains Bis-EMA monomer with high molecular weight in its organic matrix and it is more resistant to degradation (19). Besides, parameters such as the amount, size, distribution and type of filler could affect the water absorption of the resin composite (38). In this study, single-shade supra-nanohybrid composite resin, which had a small filler size, had significantly higher color change than MH composite resin with a larger filler size after immersion in tea and coffee. This finding is in accordance with the results of the study by Gönülol and Yılmaz (39), who concluded that composites with smaller filler size showed higher discoloration. Besides, Villalta et al. (40) reported that nano-filled composite resin showed higher color change than micro-filled composite. In this study, after immersion in cola, nano-ceramic composite resin exhibited significantly higher color change than MH composite. No significant differences in terms of color change were found between nano-ceramic and single-shade supra-nanohybrid composite resin. Llena et al. (41) also reported that nano-ceramic composite resin showed similar color change to nano- hybrid composite after immersion in cola.

In this study, poorly polymerized resin-rich layer referred to as oxygen inhibition layer was not removed because the polishing procedures were not performed to the composite resin samples. In addition, the samples were not subjected to thermocycling aging. Consequently, these two factors might influence the color change of composite resin materials. Different parameters such as the properties of surface roughness and hardness were not investigated. Therefore, further studies should focus on the effects of these factors on color stability, surface roughness and microhardness change of single-shade composite resins. Besides, SEM images could be beneficial to determine the surface morphology of the composite resins.

Conclusion

Within the limitations of this study,

The following conclusions can be drawn:

1) For all tested composite resin, coffee caused the highest color change than other beverages. Besides, tea caused higher color change than distilled water. No significant differences in color change were found between cola and distilled water

2) After immersion in tea and coffee, single-shade supra-nanohybrid composite resin showed higher color change than MH composite.

3) After immersion in cola, nano-ceramic composite resin showed higher color change than MH composite resin.

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Ethics

Ethics Committee Approval: Ethics committee approval is not required.

Peer-review: Externally peer reviewed.

Authorship Contributions

Concept: B.O., Design: B.O., Z.C.Ö., Analysis or Interpretation: L.F., E.E.D., Literature Search: E.E.D., Writing: L.F.

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