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Original research

Does hot coffee or cold coffee cause more discoloration on resin based composite materials?

Purpose
This study aimed to examine the effect of beverages at different temperatures on the coloring of composites.

Materials and Methods
A total of 48 cylindrical samples, 24 of which were prepared from 2 composite materials (G'aenial; Estelite Σ Quick), were included in the study. The sample dimensions were standardized at 2 10 mm^2. After the polishing, the initial color measurements were performed using a spectrophotometer. The samples were divided into 3 subgroups as distilled water, hot coffee (60 °C) and cold coffee (0 °C) (n=8). During the 7th and 30th days, the samples were immersed in the solutions for 15 min every day. Color measurements were repeated on the 7^{th} and 30^{th} days. Data were analyzed using a two-way analysis of variance, followed by the Tukey post-hoc test ($p<0.05$).

Results
The highest color change was detected on the 7^{th} and 30^{th} days in the G-aenial anterior microhybrid composite immersed in hot coffee ($p<0.001$). The application of hot and cold coffee applications did not make a statistically significant difference in the coloration of the Estelite Σ Quick composite samples at the end of the 7^{th} ($p=0.346$) and 30th ($p=910$) days.

Conclusion
Hot drinks had a more coloring effect on restorations. This coloration was quite evident in the microhybrid composite.

Keywords: *Coffee, cold coffee, discoloration, hot coffee, spectrophotometer*

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Introduction

Dental composite materials, which are frequently used in the clinic, are highly developed in terms of mechanical, physical, and esthetic properties. In addition to physical and mechanical properties, it is desirable for composites to maintain optical color stability as a result of long-term water absorption, which is one of the critical factors for clinical success (1, 2). Composite resins can be classified according to their properties such as size, content, filler type, and physical and mechanical properties of the material (3). Most microfilled composites contain particles ranging in size from 0.4 to 0.2 µm, while nanofilled composites contain filler particles smaller than 0.1 µm (4).

The discoloration that develops over time in composite restorations is the most important factor for the renewal of these restorations. A discoloration caused by extrinsic reasons can be removed by polishing, while intrinsic discolorations that reach the depths of the restoration may cause the renewal of the restoration (5). The intrinsic factors may result from the surface properties of the material, water absorption, diet consumption,

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and oral hygiene. However, these factors are affected by the polymerization time, polymer composition of the matrix, and fillers (6, 7).

Beverages with high coloring pigment contents such as tea and coffee, which are frequently consumed foods, are an important factor in the coloring of composite materials (8). Coffee consumption is seen as an indispensable habit for most individuals. Around two billion cups of coffee are consumed every day around the world (9). Although coffee is traditionally a hot beverage, the popularity and place of cold coffee in the global market have increased considerably with the increasing popularity of coffee varieties and coffee culture (10). Although the color changes in the materials can be perceived visually, using various color measurement devices is recommended for an objective evaluation. During the calculation of color changes in composites, the formula in the formula CIEDE2000 (ΔE00) was used over the parameters L*, a*, and b* (11). In the coloring of materials, studies and data examining the effect of the temperature of the solution in contact with the material on the coloration are few (12, 13).

This *in vitro* study investigated the degree of the color change of two different composite resins as a result of keeping them in hot (60°C) and cold coffee (0°C) (initially, on the 7th day, and on the 30th day). The first null hypothesis of our study is that the application of hot and cold coffee will cause similar color changes in the microhybrid composite on the 7th and 30th days. The second null hypothesis is that the application of hot and cold coffee will cause a similar color change in the nanofilled composite on the 7th and 30th days.

Materials and Methods

Sample preparation

A total of 48 cylindrical composite specimens of 2 × 10 mm^2 were prepared, 24 each from two different light-cured composite resin materials (G-aenial, GC Dental Products, Tokyo, Japan; Estelite Σ Quick, Tokuyama Dental, Tokyo, Japan). The type, color, content, and manufacturer's information of the composites are given in Table 1.

While the samples were polymerized, a 1-mm glass coverslip was placed over the mylar strip after the composite resin material was placed into in the Teflon mold with a metal hand instrument. Samples were polymerized for 20 s with a 1000 mW/cm^2 light emitting diode source (DTE LUX E, Stuttgart, Germany) with the tip of the light device in contact with the glass coverslip. The light output power of the LED light device was checked at regular intervals (in each group) on the control unit (PRIMA DB685-SUPER-DUAL, COXO, China). Sample preparation and color measurements were performed by the same experienced operator (BE). After the samples were prepared, they were polished with 3M Soflex (3M ESPE, MN, USA) discs at 10,000 rpm, under water cooling, from coarse to fine grains for 20 s. Afterward, the samples were cleaned by washing them with a compressed air–water spray. The composite samples were then placed in an incubator (FN 500, Nüve, Turkey) for 24 h in distilled water at 37°C.

Colorimetric measurements

Initial color measurements of the samples were made with the help of a spectrophotometer device (VITA Easyshade V 4.0; VITA Zahnfabrik, Bad Säckingen, Germany) in a specially prepared color measurement cabinet to ensure standardization. The light power in the color-measuring cabinet was set to 6500K according to CIE standards (Master TL-D 90 Graphica 18W/965, Philips, Poland). The interior of the cabin was covered with a gray floor, and the measurements were made on a white background. The colorimeter was calibrated before each measurement. Three measurements were made for each sample, and the mean values of the L*, a*, and b* data were calculated. L*, a*, and b* color differences on the initial day, 7th day, and 30th days were calculated as three-dimensional (ΔE_{00}) in the color space, with the formula CIEDE2000 (14) where *L** is the lightness; *a** is the red (+)/green (–) color coordinate; *b** is the yellow (+)/blue (–) color coordinate.

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{k_C S_C}\right)\left(\frac{\Delta H'}{k_H S_H}\right)}$$

For this study, K_L, K_C, and K_H were set to 1.0. The clinically accepted 50%:50% color change threshold was determined at ΔE_{00} = 1.8 (15). After the initial color measurement, 48 disk-shaped samples, 24 from each of the two composite materials, were randomly divided into three subgroups according to the type of solution (*n* = 8). Hot coffee (60°C) and cold coffee (0°C) solutions were prepared as standard in the

Table 1. *Composition of materials used in the study UDMA; urethane dimethacrylate, Bis-GMA; bisphenol A-glycidyl methacrylate, TEGDMA; tetraethylene glycol dimethyl ether.*

Composite	Brand	Material type	Filler	Matrix	Filler content (wt %)	Particle Size	Lot number
G-aenial anterior (A2)	GC Dental Product, Tokyo, Japan	Microhybrid	Pre-polymerized (silica, strontium, lanthanoid) silica, fumed silica, fluoroaluminosilicate, UDMA, dimethacrylate co-monomers	UDMA, dimethacrylate co-monomers	76	0,1-17 µm	210323C
Estelite Σ Quick (A2)	Tokuyama Dental, Tokyo, Japan)	Nanofilled	Silica-zirconia supra-nano-monodispersing spherical	Bis-GMA, TEGDMA, UDMA	78	0,1-0,3 µm	208E51

same coffee machine (Franke A800, Switzerland), with 44 mL (14 g) of coffee (Starbucks Espresso Roast, Fairtrade, USA) mixed with 311 mL of water. Before the composite samples were immersed in coffee solutions, their temperature was measured with the help of a digital thermometer (BENETECH GM1311, Shenzhen Jumaoyuan Science and Technology Co., Ltd., Shenzen, China) and the experimental procedure started when they reached the determined average consumption temperatures (0°C and 60°C). The average consumption time of one cup of coffee was 15 min (16). The samples were kept in hot coffee at 60°C, cold coffee at 0°C, and distilled water at room temperature for 15 min every day during the same time interval. After each holding, the samples were washed with distilled water and placed in fresh distilled water at room temperature for 24 h. At the end of the 7th and the 30th days, the initial color measurement procedure was repeated. ΔE values below 1.8 were considered clinically undetectable during evaluations ($\Delta E_{00} < 1.8$) (15). The color change values of the composite samples on the 7th and 30th days were calculated with the CIEDE2000 formula.

Statistical analysis

Kolmogorov–Smirnov test was used to determine whether the data had a normal distribution. A two-way analysis of variance (ANOVA) was used to examine the color change of the different materials tested. Tukey post hoc test was used for pairwise comparisons. The significance level was set to $p < 0.05$.

Results

When the results were evaluated, the most statistically significant color change on the 7th and 30th days was detected in the G-aenial anterior microhybrid composite soaked in hot coffee ($p < 0.01$) (Table 2). Hot and cold coffee applications did not make a statistically significant difference in the coloration of the nano-filled Estelite Σ Quick composite samples at the end of the 7th (p = 0.346) and 30th (p = 0.910) days (Table 2).

At the end of the 7th and 30th days, the samples kept in distilled water were significantly less colored than the samples kept in hot and cold coffee ($p < 0.01$). At the end of the 30th days, the coloration of the samples kept in distilled water, hot coffee, and cold coffee was significantly higher than the coloration at the end of the 7th day ($p < 0.01$).

At the end of the 7th day, G-aenial anterior composite specimens showed a color change below the detectable threshold in cold coffee ($\Delta E_{00} = 1.34$), while they showed a color change above the detectable threshold value in hot coffee ($\Delta E_{00} = 2.64$) (Table 2). Estelite Σ Quick composite samples showed a color change below the detectable threshold ($\Delta E_{00} \leq 1.8$) at the end of the 7th day after being kept in both hot ($\Delta E_{00} = 1.37$) and cold coffee ($\Delta E_{00} = 0.95$). G-aenial anterior and Estelite Σ Quick composite specimens showed a color change above the acceptable threshold value ($\Delta E_{00} > 1.8$) after the application of hot and cold coffee at the end of the 30th day (Table 2). At the end of the 30th day, G-aenial anterior samples ($\Delta E_{00} = 4.37$) immersed in hot coffee were significantly more colored than Estelite Σ Quick samples ($\Delta E_{00} = 2.04$) ($p < 0.01$) (Table 2).

Despite no significant difference in the coloration of the composites kept in cold coffee at the end of the 30th day, G-aenial anterior samples ($\Delta E_{00} = 2.48$) showed more coloration than Estelite Σ Quick samples ($\Delta E_{00} = 2.3$) (Table 2). Although color changes were observed in the distilled water samples at the end of the 7th and 30th days, the color changes were within the acceptable threshold ($\Delta E_{00} \leq 1.8$) (Table 2).

Discussion

The microhybrid composite was significantly more colored in hot coffee than in cold coffee at the end of the 7th and 30th days. Therefore, the first null hypothesis of our study was rejected. The nanofilled composite showed similar discoloration in hot and cold coffee at the end of the 7th and 30th days, therefore the second null hypothesis of our study was accepted.

Although dental composites are the most commonly used restorative materials in the clinic, the discoloration of these materials is still a major problem for patients and physicians. Advanced discoloration in composites is seen as a sign that the restoration needs to be renewed (17). Although intermittent polishing is recommended to remove intrinsic colorations, the main purpose is to make the composites less colored and to preserve their esthetic properties for a long time despite the consumption of coloring foods with high pigment content (18, 19).

Studies, examining the color change of composite restorative materials by keeping them in different beverages for different periods, are available in the literature (20-23). However, studies on the coloring of composite materials until today have focused on the coloration that occurs as a result of keeping colorants such as coffee, tea, wine, etc. at room temperature at usually 37°C. However, the daily consumption temperatures of these beverages are generally very different from the room temperature (37°C) and vary according to the type of beverage and the consumption. Hot beverages such as tea, hot chocolate, and coffee are often served at temperatures between 71.1°C and 85°C. However, consumers often consume their hot beverages at 60°C, which is lower than the

Table 2. *Coloration values of the composites on the 7th and 30th days. (Lower case letters a–c show statistically significant differences between rows. Upper case letters A and B show statistically significant differences between columns (p < 0.05).*

	Estelite Σ Quick 7th day	G-aenial anterior 7th day	p	Estelite Σ Quick 30th day	G-aenial anterior 30th day	p
Distilled Water	0.59a,A ± 0.1	0.49a,A ± 0.2	0.997	1.08a,A ± 0.2	0.89a,A ± 0.4	0.977
Hot Coffee	1.37b,A ± 0.6	2.64c,B ± 0.5	0.000	2.04b,A ± 0.2	4.37b,B ± 0.7	0.000
Cold Coffee	0.95ab,A ± 0.2	1.34b,A ± 0.4	0.450	2.3b,A ± 0.6	2.48c,A ± 0.6	0.984
p	0.000	0.000		0.000	0.000	

recommended serving temperature (24). Therefore, in this study, the immersion temperature of the samples in the hot coffee solution was determined as 60°C (24). Since the average consumption temperature of cold drinks was 0°C, this was determined as the holding temperature of the samples in cold coffee (25). Since the average consumption time of one glass of beverage is 15 min, the waiting time in the coloring solution was determined as 15 min per day. Thus, in the present study, the 15 min consumption time of real coffee and the temperature change at room temperature during the consumption period were also simulated, instead of keeping it at the same and constant temperature (16).

Estelite Σ Quick composite chosen for this study had nanosized fillers, while the G-aenial anterior composite consisted of microhybrid fillers. Thanks to the smaller size and better distribution of particles in the resin matrix of composite restorations, smoother surfaces were obtained (25). Studies have shown that the smaller size of nanofilled composite resin particles results in less staining (5, 26). In this study, G-aenial anterior composite samples with larger particle sizes were more colored than Estelite Σ Quick composite samples with smaller particle sizes during all time periods. However, contrary to these results, other researchers have also reported that increasing particle size causes less coloration in composites (5, 27). Another study showed that smooth surfaces were not always the most resistant to discoloring and that the staining ability was affected by the monomer and filler particles from which the composite was formed (28). In the study of Nasim *et al.* (5) which investigated the discoloration of different composite materials, the most discoloration was observed in nanofilled composite resin (Filtek Z350), followed by microfilled composite resin (Heliomolar), while the least discoloration was observed in Spectrum TPH, which is microhybrid composite resin (5). Similarly in the study of Villata *et al.* (29); nanofilled Filtek Supreme showed more discoloration than microfilled Esthet X composite.

According to the results of a study evaluating the effect of different temperatures (4^0C, 37^0C, and 60^0C) on the color stability of 5 different composite resins (Aelite LS Posterior, Point 4, Tetric EvoCeram, Vit-l-escence, Filtek Z350), different temperatures did not make a significant difference on the discoloration of these composites (12). In an another study on the discoloration of microhybrid composite (Filtek Z250) at different temperatures; coffee at 70°C showed significantly more discoloration than coffee at 37°C. It has been reported that high temperatures can weaken the floating properties of composite materials, reduce their microhardness and lead to more discoloration (13). In our study, G-aenial anterior composite samples kept in hot coffee on the 7^{th} and 30^{th} days were significantly more colored than those kept in cold coffee. Similar to the study of Tuncer *et al.* (13), in our study, coffee at 70°C may have reduced the surface hardness of the microhybrid composite and may have caused more staining. Estelite Σ Quick samples were more colored when kept in hot solutions at the end of the 7^{th} day, similar to G-aenial samples; however, this discoloration was not statistically significant for the Estelite Σ Quick samples (7^{th} day). The reason for the not significant difference could be the more resistance of Estelite Σ Quick to discoloration due to its nanofilled structure and small particle size.

The present study had some limitations. Oral foods are diluted with saliva under normal conditions, but this diluting effect could not be simulated in this study. In addition, as mentioned previously, further studies are needed to examine the effect of longer retention times and temperature on surface properties. Two composite types were investigated in this study. Further studies should be carried out by increasing the variety of materials. Despite all the limitations, it can be mentioned that this study was one of the limited numbers of studies examining the effect of storage conditions at different temperatures on the discoloration of composite resins.

Conclusion

Microhybrid composite resin was more colored than nanofilled composite resin. No significant differences were found in the discoloration of nanofilled composite samples kept in hot coffee and cold coffee for both the 7^{th} and 30^{th} days. Microhybrid composite samples kept in hot coffee were more colored than microhybrid composite samples kept in cold coffee for both the 7^{th} and 30^{th} days. If many composite resin restorations will be done for a person who likes to consume hot drinks, it is better to use nanofilled composite materials.

Türkçe özet: *Sıcak kahve mi yoksa soğuk kahve mi rezin esaslı kompozit materyallerde daha fazla renklenmeye neden olur? Amaç: Bu in-vitro çalışmanın amacı, farklı sıcaklık derecelerindeki içeceklerin kompozit restorasyonların renklenmesine olan etkisini incelemektir. Gereç ve yöntem: 2 kompozit materyalden (G'aenial, GC; Estelite Σ Quick, Tokuyama) 24'er adet olmak üzere toplamda 48 adet silindirik örnek hazırlandı. Örnek büyüklükleri teflon kalıp yardımıyla 2x10 mm^2 büyüklüğünde olacak şekilde standardize edildi. Örneklerin polisaj işlemi sonrası başlangıç renk ölçümleri spektrofotometre ile yapıldı. Örnekler bekletildikleri solüsyonlara göre; distile su, sıcak kahve (60 C^o) ve soğuk kahve (0 C^o) olarak 3 alt gruba bölündü (n=8). 7 ve 30 günlük boyunca örnekler her gün 15 dk boyunca solüsyonlara daldırıldı. 7. ve 30. günde spektrofotometre ile renk ölçümleri tekrarlandı. Veriler, iki yönlü ANOVA ve ardından Tukey post-hoc testi kullanılarak analiz edildi ($p <0.05$). Bulgular: Deneyin 30.günündeki materyaller üzerindeki renk değişim miktarı, 7.gündeki renk değişim miktarından anlamlı derecede fazlaydı ($p>0.05$). 7. ve 30. günde istatistiksel olarak en fazla renk değişimi, sıcak kahvede bekletilen G-aenial anterior micro-hibrit kompozitte tespit edildi ($p<0.05$). Estelite Σ Quick nano dolduruculu kompozit üzerinde sıcak ve soğuk kahve uygulaması istatiksel olarak anlamlı farklılık oluşturmadı. Sonuç: Sıcak içecekler, soğuk içeceklere göre restorasyonlar üzerinde daha fazla boyayıcı etkiye sahiptir. Mikrohibrit yapıdaki kompozitte bu renklenmenin oldukça belirgin olduğu gözlenmiştir. Anahtar Kelimeler: Sıcak Kahve, Soğuk Kahve, Spektrofotometre, Kahve, Renklenme.*

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