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EFFECTS OF COLORANT BEVERAGES ON SURFACE ROUGHNESS AND DISCOLORATION OF NANOHYBRIT AND GINGIVA-COLORED COMPOSITE

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ABSTRACT

Background and Aim: The aim of this study was to investigate changes in color and surface roughness on gingiva-colored and nanohybrid composite resins after immersion in various beverages.

Materials and Methods: A gingiva-colored composite, Amaris Gingiva (VAM), and a nanohybrid composite, 3M Filtek Z550 (Z550), were used in this study. A total of 80 specimens, 6 mm in diameter and 2 mm in thickness, were prepared as 40 pieces from each composite resin material. After the polishing processes, the specimens were divided into four subgroups (n=10): distilled water, Coca-Cola, Red Bull, and Nescafe Xpress Black Roast. After initial color and roughness measurements, all specimens were placed into the beverages for 30 days, and the measurements were repeated. Statistical analysis of the data was performed ($p<0.05$).

Results: The color changes of all composite specimens immersed in all beverages (with the exception of distilled water) were found to be above the clinically acceptable threshold level ($\Delta Eab>3.3$). The most color change occurred in specimens immersed in Nescafe, both in the Z550 and VAM composites ($p<0.05$). Coca-Cola and Nescafe made more color changes in the Z550 composite compared to VAM. All beverages increased the surface roughness of both composites ($p<0.05$). The highest ΔRa value was detected in the specimens immersed in Coca-Cola for both composites.

Conclusions: Gingiva-colored composite and nanohybrid composite resins were susceptible to color change, and this color change was above the clinically acceptable threshold level for all beverages, except for distilled water. Immersion of both composite specimens in Coca-Cola increased the surface roughness.

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Keywords: Beverages, Color Change, Composite Resin, Gingiva-Colored Composite, Nanohybrid, Roughness

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REKLENDİRİCİ İÇECEKLERİN NANO-HİBRİT VE DİŞETİ RENKLİ KOMPOZİTLERİN YÜZEY PÜRÜZLÜLÜĞÜNE VE RENK DEĞİŞİMİNE ETKİSİ

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ÖZ

Amaç: Bu çalışmanın amacı bir dişeti renginde ve bir nano-hibrit kompozit rezinin çeşitli içeceklerde bekletildikten sonra renk ve yüzey pürüzlülüğündeki değişikliklerin incelenmesidir.

Gereç ve Yöntem: Bu çalışmada bir gingiva renkli kompozit olan Amaris Gingiva (VAM) ve bir nano-hibrit kompozit olan 3M Filtek Z550 (Z550) kullanıldı. Çapı 6mm ve kalınlığı 2 mm olan toplamda 80 örnek her kompozit rezinden 40 tane olacak şekilde hazırlandı. Cilalama işleminden sonra, örnekler 4 alt gruba ayrıldı (n=10): distile su, Coca Cola, RedBull, NescafeXBR. Renk ve pürüzlülüğün başlangıç ölçümünden sonra bütün örnekler 30 gün içeceklerde bekletildi ve ölçümler tekrarlandı. Verilerin istatistiksel analizi yapıldı ($p<0.05$).

Bulgular: Bütün içeceklerde (distile su hariç) bekletilen kompozit örneklerin hepsindeki renk değişimi klinik olarak kabul edilebilen eşik seviyenin ($\Delta Eab>3.3$) üzerinde bulunmuştur. Hem Z550 hem de VAM kompozit örneklerinde en yüksek renk değişimi NescafeXBR'de bekletilen örneklerde meydana gelmiştir ($p<0.05$). Coca Cola ve NescafeXBR, VAM'a göre Z550 kompozitinde daha fazla renk değişimine neden olmuştur. İçeceklerin hepsi her iki kompozitin yüzey pürüzlülüğünü artırmıştır ($p<0.05$). Her iki kompozit için de en yüksek ΔRa değeri Coca-Cola'ya batırılmış örneklerde tespit edildi.

Sonuçlar: Dişeti renginde kompozit ve nano-hibrit kompozit rezin renk değişimine yatkındır ve bu renk değişimi distile su hariç bütün içecekler için klinik olarak kabul edilebilir eşik değerinin üzerindedir. Her iki kompozitin Coca Cola'da bekletilen örneklerinde yüzey pürüzlülüğü artmıştır.

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Anahtar Kelimeler: İçecekler, Renk Değişimi, Kompozit Rezin, Dişeti Renkli Kompozit, Nanohibrit, Pürüzlülük

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INTRODUCTION

Composite resins have become the materials most used by dentists because they are simple to use,[1] they can be used in both anterior and posterior restorations,[2] and, importantly, they meet patients' aesthetic expectations. The aesthetic success of tooth-colored composites, especially of anterior teeth, depends on the harmony of color, opacity, and transparency of the material within the tooth.[3] This increase in aesthetic expectations was not limited only to teeth; gingiva-colored composite resins have been developed to reconstruct cervical lesions and cover exposed, discolored, or hypersensitive cervical regions of teeth.[4] When cervical defects on teeth are restored with gingiva-colored materials, teeth that appear longer than normal can be masked, especially in cases of gingival recession.[5]

The basis for the success of composite restorations depends on surface properties and color stability.[6,7] The smooth surface of composite affects the clinical aesthetic quality and long-term success of the restoration.[8] The properties of the filler particles of composite resin may affect the quality of the polish and can determine the surface roughness of a restoration. The composite's resin matrix and filler have different hardness values, and they do not wear at the same rate. After the polishing process, porosities form around the quartz particles in conventional composites, and this porosity can cause the restoration surface to be rough.[9, 10] For this reason, the predisposition of the composite to external discoloration can be prevented by modifying the particle size of the composite resin filler.[11-13] Nanohybrid composites contain filler in micro and nano sizes.[14] The mechanical properties of nanocomposites, such as their ability to counteract occlusal forces, are as good as microhybrids', and they have a high polish as well as favorable optical and aesthetic properties.[15]

Additionally, the color stability of composite materials is affected by intrinsic factors such as the nature of the resin matrix,[16] filler content,[16,17] incomplete polymerization,[18] and water sorption.[19]. Hygroscopic absorption in the resin matrix may cause color changes in the material.[20] Extrinsic factors, including surface roughness,[21] colorant beverages, and foods,[6,21] are important when the material is colored as a result of adsorption and absorption of the outsourced colorants.[22] The increase in roughness may also cause an increase in external discoloration.[21] Polymer degradation in composites may occur as a result of thermal, mechanical, and passive hydrolysis,[23] and this process results in the chemical deterioration and wear of the composite.[24] Polymer degradation is related to composite resin erosion from acidic factors, which indicates the loss of material.[23]

Several studies examining the surface roughness and/or color change of composites have tested various beverages such as cola, beer, vodka, whisky, coffee, fruit juice, red wine, tea, and Red Bull.[6,20,25,26] Color changes and surface roughness of various restorative materials have also been investigated, but no studies so far have focused on gingiva-colored composites.

Thus, in this study, the aim was to investigate the effects of various drinks on color change and roughness of gingiva-colored and nanohybrid composites. The first null hypothesis was that the tested drinks would not affect the color of the composites. The second null hypothesis was that the tested drinks would not affect the surface roughness of the composites.

MATERIALS AND METHODS

Specimen preparation

The composite materials tested in this study and their ingredients are listed in Table 1. The specimens of each composite resin were randomly divided into four groups: distilled water (water); Coca-Cola (Coke) (Coca-Cola Company, Istanbul, Turkey); Red Bull (Red Bull Gmbh, Fuschl am See, Austria); Nescafe Xpress Black Roast (NescafeXBR) (Nestlé, Bursa, Turkey). Eighty specimens were prepared for each composite material and beverage tested (n=10) using a Teflon mold (6 mm in diameter and 2 mm in thickness). The composite materials were inserted into Teflon molds in a single increment and covered with a polyester strip and a hard glass microscope slide by applying finger pressure. Using a light curing device (3M ESPE Freelight S10, 3M ESPE, St. Paul, MN, USA), the composite material was polymerized in accordance with the manufacturer's recommendations. After keeping the samples in distilled water at 37 °C for 24 h, the finishing and polishing treatments of the specimens were performed with OptiDisc (KerrHawe, Switzerland). The specimens were then washed with distilled water and dried with paper napkins.

Before the staining cycle, the baseline Commission Internationale de l'éclairage (CIE) L* a* b* color coordinates of the specimens were measured with a spectrophotometer (VITA Easyshade Compact, VITA Zahnfabrik, Bad Säckingen, Germany), and baseline surface roughness was measured

Table 1. List of the material used in this study

Material / Code	Type	Composition	Manufacturer
Filtek Z-550 (Z550)	Nano-hybrid composite resin	Matrix: Bis-GMA, Bis-EMA TEGDMA, UDMA, PEGDMA Filler: Silica nano fillers (20 nm) zirconia/silica nanoclusters (0.1-10 mm) (82 wt.% filler)	3M ESPE
Amaris Gingiva (VAM)	Gingiva-colored composite resin	Matrix: BIS-GMA, UDMA, TEGDMA and 80 wt.% filler	VOCO

using a tactile profilometer (Surftest SJ 201, Mitutoyo, Tokyo, Japan) with a 0.25-mm cutoff value. The resolution of the profilometer was 0.01 mm with a transverse length of 4.0 mm, and the diamond recording pin stylus diameter was 5 µm. A constant measuring speed of 0.25 mm/sec was used to determine an average roughness profile. Five measurements were made with equal distances (1 mm) for each specimen. The measured roughness parameter was Ra (the average value of all absolute distances of the roughness profile). Before the specimens were measured, the profilometer was calibrated against a reference block.

After the initial measurements, all specimens were immersed in the tested beverages for 30 days, and the beverages were refreshed every other day. After the staining cycle, the composite specimens were gently rinsed with distilled water and immersed in distilled water. Changes in color coordinates were measured after the 30-day staining period. Any color differences, primarily evaluated by CIE LAB and ΔE*ab, were calculated. The second profiles were obtained with a profilometer after the staining cycle.

The Kolmogorov–Smirnov test was performed to analyze the normality of the ΔE and Ra values. The statistical analysis of color change (ΔE) after beverage immersion was done with one-way ANOVA and Tukey's post-hoc tests. Repeated measures ANOVA was used to evaluate the before and after surface roughness values. One-way ANOVA and Tukey's post-hoc tests were also used for the statistical analysis of surface roughness. IBM SPSS v.20 for Mac (SPSS Inc., Chicago, IL) was used for the analysis, and the significance level was set at α=0.05.

RESULTS

The mean ΔE and ΔRa values and standard deviations are shown in Figures 1 and 3. After 30 days of immersion, with the exception of distilled water, all of the beverages caused color changes that were higher than the acceptable threshold level (ΔE>3:3) in both restorative materials (Z550 and VAM). It was found that the effects of all of the beverages on the ΔE values of Z550 were statistically different ($p<0.05$). The discoloration in Z550 was the greatest for NescafeXBR, Red Bull, Coca-Cola, and distilled water, respectively ($p<0.05$). In the VAM specimens, while Coca-Cola and water had the same effect on the ΔE value, the differences for Red Bull and NescafeXBR between themselves and among the others were significant ($p<0.05$). The VAM specimens showed significantly ($p<0.05$) higher discoloration at 1 month, with the most in Red Bull (ΔE=15.176) and NescafeXBR (ΔE=18.085).

When the surface roughness was examined, it was determined that the difference between before and after 30 days of immersion in all of the beverages was significant in both composites. All beverages increased the surface roughness of both composites ($p<0.05$) (Table 2 and Figure 2), and there was a statistically significant difference between the ΔRa values of the Z550 composite formed by the water and by the other beverages. The highest ΔRa value was detected in specimens immersed in Coca-Cola for both composites (Figure 3). The differences in NescafeXBR, Red Bull, and Coca-Cola were not significant for Z550 ($p>0.05$). Immersion in Coca-Cola and Red Bull caused a rougher surface than water did ($p<0.05$) for VAM. When

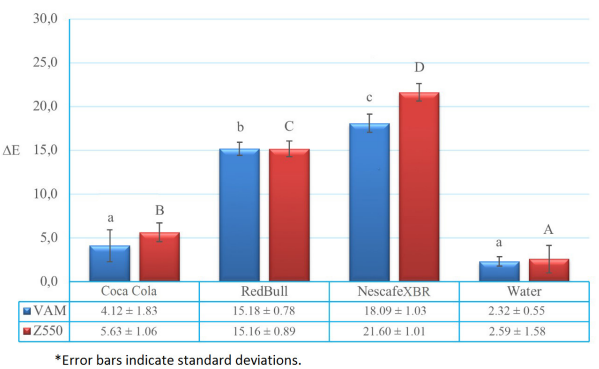
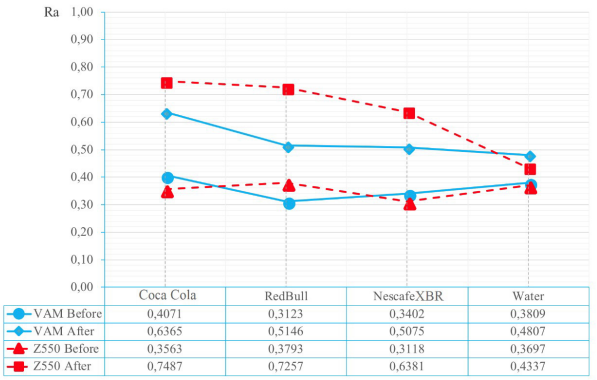


Figure 1. Mean ΔE values of the groups before and after immersion in the beverages

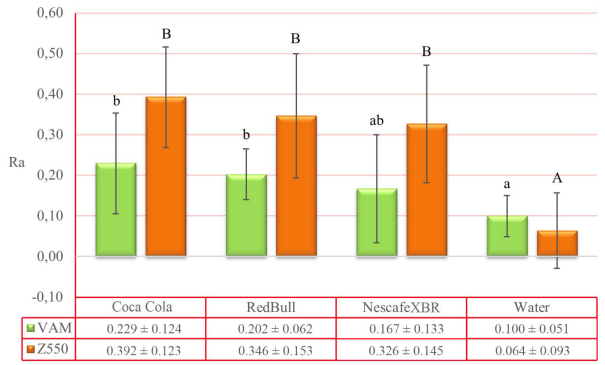
Table 2. Time dependent changes of surface roughness values (Ra) according to the Repeated Measurement ANOVA ($p<0.05$)

				Type III Sum of Squares	df	Mean Square	F	Sig.
Tests of Within-Subjects	VAM	Coca-Cola	Linear	.798	1	.798	76.319	.000
		Error(Coca-Cola)	Linear	.146	14	.010		
		Redbull	Linear	.307	1	.307	157.813	.000
		Error(Redbull)	Linear	.027	14	.002		
		Nescafe	Linear	.210	1	.210	23.690	.000
		Error(Nescafe)	Linear	.124	14	.009		
		Water	Linear	.075	1	.075	58.090	.000
		Error(Water)	Linear	.018	14	.001		
	Z550	Coca-Cola	Linear	1.154	1	1.154	150.538	.000
		Error(Coca-Cola)	Linear	.107	14	.008		
		Redbull	Linear	.900	1	.900	76.830	.000
		Error(Redbull)	Linear	.164	14	.012		
		Nescafe	Linear	.798	1	.798	76.319	.000
		Error(Nescafe)	Linear	.146	14	.010		
		Water	Linear	.031	1	.031	7.065	.019
		Error(Water)	Linear	.061	14	.004		
				Type III Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Tests of Between-Subjects Effects	VAM	Coca-Cola	Intercept	8.168	1	8.168	141.285	.000
			Error	.809	14	.058		
		Redbull	Intercept	5.129	1	5.129	95.083	.000
			Error	.755	14	.054		
		Nescafe	Intercept	5.390	1	5.390	121.010	.000
			Error	.624	14	.045		
		Water	Intercept	5.569	1	5.569	134.014	.000
			Error	.582	14	.042		
	Z550	Coca-Cola	Intercept	9.158	1	9.158	68.122	.000
			Error	1.882	14	.134		
		Redbull	Intercept	9.157	1	9.157	75.131	.000
			Error	1.706	14	.122		
		Nescafe	Intercept	6.767	1	6.767	81.197	.000
			Error	1.167	14	.083		
		Water	Intercept	4.841	1	4.841	107.860	.000
			Error	.628	14	.045		



	Coca Cola	RedBull	NescafeXBR	Water
VAM Before	0,4071	0,3123	0,3402	0,3809
VAM After	0,6365	0,5146	0,5075	0,4807
Z550 Before	0,3563	0,3793	0,3118	0,3697
Z550 After	0,7487	0,7257	0,6381	0,4337

Figure 2. Mean Ra values of the groups before and after immersion in the beverages



	Coca Cola	RedBull	NescafeXBR	Water
VAM	0.229 ± 0.124	0.202 ± 0.062	0.167 ± 0.133	0.100 ± 0.051
Z550	0.392 ± 0.123	0.346 ± 0.153	0.326 ± 0.145	0.064 ± 0.093

*Error bars indicates standard deviations.

Figure 3. Results of one-way ANOVA and Tukey's post-hoc comparison for surface roughness (Ra)

comparing the effects of NescafeXBR and distilled water on the roughness of VAM, the difference was not significant ($p>0.05$).

DISCUSSION

Staining in composite resins is a problem in aesthetic restorations. Many factors such as surface properties, filler content, water sorption and incomplete polymerization affect the staining of composite resins.[16-18,27] Exposure of the composite resins to staining beverages accelerates this even further.

There are many studies in the literature evaluating the susceptibility of composite resins to staining and roughness after immersion in beverages.[20-22,25] However, there are no studies in the literature investigating changes in the physical properties of gingiva-colored composite resin as a result of exposure to staining beverages.

Describing color differences using terms such as "match" or "mismatch" is usually subjective and generally based on conventionally accepted ΔE values.[28] However, delta E values lower than 1 cannot be determined by the human eye. If the values are higher than 1 and lower than 3.3, clinicians can detect them, but this is a clinically acceptable situation.[29] When the values exceed 3.3, the color change is more visibly noticeable. In this study, the color change in all of the composite specimens was found to be above the clinically acceptable threshold level ($\Delta E>3.3$) after immersion in beverages, with the exception of distilled water. Thus, the first null hypothesis, that the tested drinks would not affect the color of the composites, was rejected. Studies on color stability have shown that drinks such as coffee, tea, red wine, and cola cause extrinsic discoloration at various grades on dual cure and light cure composites.[30,31] For this reason, the effect of drinks[26,29] that have a high concentration of pigment on gingiva-colored composite was investigated in this study. The gingiva-colored composite specimens showed more color change after 30 days of immersion in NescafeXBR ($\Delta E=18.09$) and Red Bull ($\Delta E=15.18$) than distilled water ($\Delta E=2.32$) and Coca-Cola ($\Delta E=4.12$) ($p<0.05$). The difference between Coca-Cola and distilled water was not significant (Figure 1). Some possible reasons for the increase in discoloration caused by coffee are the water absorption in the polymer and the hydrophilic nature of the matrix.[16] Water absorption also indicates that the composite resin can also absorb various coloring agents. Um and Ruyter's findings on surface adsorption and absorption of colorants reinforce this conclusion.[22] Because of the compatibility of the colorants with the organic matrix of the composite resin materials, the less polar pigments in the coffee deeply penetrated into the composite.[22] Water absorption can cause softening and degradation of the resin matrix, thus reducing stain resistance and causing various changes in transparency.[32]

One of the most significant findings of this study was that the greatest color change for Z550 occurred in the specimens immersed in NescafeXBR, Red Bull, Coca-Cola and distilled water, respectively ($p<0.05$). The reason for the greater color change from coffee could be explained by the yellow pigments that were absorbed by the mass of resin material, which then penetrated into the organic matrix of the composite resin.[22] As in previous studies, coffee was found to be the most staining beverage in this study as well.[12,33-35]

According to the student's-t test results, NescafeXBR and Coca-Cola changed the color of the Z550 composite more than it did the VAM composite. Under low pH conditions, polymer degradation and material loss occurred on the

surface of the composite resin.[24,26] The lower pH value of the cola (pH ~1.57) may have caused the surface of the Z550 composite to become more deteriorated and made the color change more. Another study investigating surface roughness and micro-leakage in composite resins after exposure to different beverages concluded that cola and coffee change the surface roughness and increase micro-leakage in restorations.[36] As stated above, the colorants in the coffee may exhibit better penetration into the Z550 composite than into the VAM composite. The increased color change in the Z550 composite immersed into NescafeXBR can be explained with this insight.

The surface roughness of a restoration is associated with both aesthetic and biological properties, and these may cause secondary caries problems, including color change, wear, and easy plaque retention. The composition and the porosity of the material, as well as the polishing techniques used, can affect the quality of the composite surface, which can cause premature color change in the material.[9,37,38] Surface roughness value is considered to be acceptable below 0.2 mm. With this roughness level, the restoration surface is protected from accumulation of the most common bacterial species. In recent studies, it has been reported that the storage media can affect the surface roughness of composite resins via water sorption.[20,35] The resin matrix, filler, and interfacial bonding between particles and the matrix play an important role in water sorption.[39] and decreased filler loading has been shown to result in greater water absorption.[39] In this study, all of the beverages increased the surface roughness of both composites after immersion. According to the results of this study, it was determined that all of the drinks increased the surface roughness of both composites (Figure 2) after 30 days of immersion. The second null hypothesis, that the tested drinks would not affect the surface roughness of the composites, was rejected. This increase was significantly higher in the specimens immersed in Coca-Cola and Red Bull than those immersed in distilled water, and the highest ΔRa value was detected in the specimens immersed in Coca-Cola for both composites ($p<0.05$). The low pH of Coca-Cola may affect surface roughness. In a previous study, it was observed that a low-pH cycling regimen made the surface of restorative materials rougher.[40] This can be attributed to acid media's capacity to soften restorative materials. In this study, it can be concluded that low pH causes the chemical degradation of restorative materials, with the support of previous studies.[40-43] The surface roughness of both Z550 and VAM composite resins increased with all beverages, so the result is stronger because this increase was not dependent on the material.

Water uptake may cause the degradation of polymer materials such as composite. When water absorption occurs, coupling agents can cause hydrolysis and later, loss of bonding between filler particles and the organic phase.[44,45] In this study, water also increased the surface roughness of both composites after 30 days of immersion. This finding can be explained by the polymer degradation of composite materials as a result of water uptake. After de-bonding of the filler matrix, the surface roughness may increase because the filler particles are broken from the surface. Further imaging techniques and analysis are the next part of this study. As the water content in other beverages is high, water absorption may also have contributed to the increase in surface roughness of the specimens in these groups.

In vitro studies have several limitations for simulating clinical conditions. In this study, the specimens in the control group were immersed in distilled water instead of saliva. One of the limitations of this study was the lack of saliva, and the specimens were kept in drinks for 30 days without saliva's dilution effect. However, saliva has an acid buffering effect in the mouth. Additionally, coloring and roughness occurring over a 30-day period may require a longer period of time in clinical conditions.

CONCLUSIONS

In this study, a nanohybrid composite and a gingiva-colored composite were stored in distilled water, Coca-Cola, Red Bull, NescafeXBR for 30 days. Despite the limitations of the study, the following conclusions were reached:

- The gingiva-colored composite had a tendency to discolor as much as the nanohybrid composite did, and this color change was found to be above the clinically acceptable threshold level for all of the tested beverages, except for distilled water.
- Coffee caused the greatest color change in both of the resin composites.
- All beverages increased the surface roughness of both of the resin composites.
- The highest ΔRa value was detected in the specimens immersed in Coca-Cola for both of the resin composites.
- Increased surface roughness did not seem to depend on the material tested.

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None declared

CONFLICT OF INTEREST

None declared

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