ATATÜRK ÜNİVERSİTESİ YAYINLARI
ATATURK UNIVERSITY PUBLICATIONS

Research Article *Araştırma Makalesi* DOI: 10.17567/currresdentsci.1618999

Effect of Different Beverages and Polishing Systems on Color Stability and Surface Roughness of a Smart Chromatic Composite Resin and Methacrylate Composites

Farklı İçecek ve Parlatma Sistemlerinin Akıllı Kromatik Kompozit Rezin ve Metakrilat Kompozitlerin Renk Stabilitesi ve Yüzey Pürüzlülüğü Üzerine Etkisi

Semiha EKRİKAYA[1]

[1] Department of Restorative Dentistry, Nimet Bayraktar Oral and Dental Health Center, Kayseri, Türkiye

Özcan KARATAŞ[1]

[1] Department of Restorative Dentistry, Nuh Naci Yazgan University, Kayseri, Türkiye

ABSTRACT

Objective: The purpose of the study is to evaluate the color stability and surface roughness of smart chromatic composite resin and methacrylate composite resins with applying different polishing systems and stored in different solutions.

Methods: In the study, 120 disc-shaped specimens were prepared from a smart chromatic composite, a nanofill composite, and a nanohybrid composite. The specimens were separated into 12 groups with a specimen size of 10, and the two different polishing systems were utilized. The initial color values of the specimens were measured with a spectrophotometer and the surface roughness values were measured with a profilometer. Then, the specimens were stored in two different beverage solutions, and color and roughness measurements were repeated. The mean color change values of the specimens were calculated in ΔE, and the surface roughness values were recorded in Ra. Statistical analysis of the data was performed using One-way ANOVA and post hoc Tukey test (*P* =.05).

Results: Statistically significant variations were observed in the mean color change values among the groups, as a consequence of the utilization of various polishing systems and exposure to different solutions (*P*.05). Although no significant variations were observed in the mean surface roughness values of the specimens due to exposure to different solutions (*P* >.05), significant distinctions were identified among the groups to which different polishing systems were employed (*P* <.05).

Conclusion: The application of different polishing systems and exposure to various solutions can result in variations in color and surface roughness values for composite resins, owing to their inherent structural characteristics.

Keywords: Color Change, Composite Resin, Profilometer, Smart Chromatic Composite, Surface Roughness

ÖZ

Amaç: Çalışmanın amacı akıllı kromatik kompozit reçine ve metakrilat kompozit reçinelerin farklı cila sistemleri uygulanarak ve farklı solüsyonlarda saklanarak renk stabilitesi ve yüzey pürüzlülüğünün değerlendirilmesidir.

Yöntemler: Çalışmada akıllı kromatik kompozit, nano dolgu kompozit ve nano hibrit kompozitten 120 adet disk şeklinde örnek hazırlandı. Numuneler 10 numune büyüklüğünde 12 gruba ayrıldı ve iki farklı cilalama sistemi kullanıldı. Numunelerin başlangıç renk değerleri spektrofotometre ile, yüzey pürüzlülük değerleri ise profilometre ile ölçülmüştür. Daha sonra örnekler iki farklı içecek solüsyonunda saklanarak renk ve pürüzlülük ölçümleri tekrarlandı. Numunelerin ortalama renk değişim değerleri ΔE olarak hesaplandı ve yüzey pürüzlülük değerleri Ra olarak kaydedildi. Verilerin istatistiksel analizi One-way ANOVA ve post hoc Tukey testi kullanılarak yapıldı (*P* =,05).

Bulgular: Çeşitli cila sistemlerinin kullanılması ve farklı solüsyonlara maruz kalınması sonucunda gruplar arasında ortalama renk değişimi değerlerinde istatistiksel olarak anlamlı farklılıklar gözlendi (*P* <,05). Numunelerin ortalama yüzey pürüzlülük değerlerinde farklı solüsyonlara maruz kalmaya bağlı olarak anlamlı bir değişiklik görülmemekle birlikte (*P* >,05), farklı cila sistemlerinin kullanıldığı gruplar arasında anlamlı farklılıklar tespit edildi (*P* <,05).

Sonuç: Farklı cilalama sistemlerinin uygulanması ve çeşitli solüsyonlara maruz bırakılması, kompozit reçinelerin doğal yapısal özellikleri nedeniyle renk ve yüzey pürüzlülük değerlerinde farklılıklara neden olabilir.

Anahtar Kelimeler: Renk Değişimi, Kompozit Reçine, Profilometre, Akıllı Kromatik Kompozit, Yüzey Pürüzlülüğü

This study was presented orally at the 26th International Dentistry Congress of the Turkish Dental Association.

Geliş Tarihi/Received	13.01.2023
Revizyon Talebi/Revision Requested	19.01.2023
Son Revizyon/Last Revision	27.02.2023
Kabul Tarihi/Accepted	27.02.2023
Yayın Tarihi/Publication Date	20.01.2025

Sorumlu Yazar/Corresponding author: Özcan KARATAŞ
E-mail: ozcnkrts@gmail.com

Cite this article: Ekrikaya S, Karataş Ö. Effect of Different Beverages and Polishing Systems on Color Stability and Surface Roughness of a Smart Chromatic Composite Resin and Methacrylate Composites. *Curr Res Dent Sci* 2025;35(1): 41-47.

INTRODUCTION

The increasing demand for aesthetic dentistry has led to a rise in the popularity of cosmetic dentistry, as individuals seek to not only maintain oral health but also achieve a pleasing appearance of their teeth.[1] Composite resin restorations have become a popular choice among dental clinicians, as they can be used in a variety of indications and offer a more conservative alternative to traditional ceramic restorations.[2] To effectively imitate these properties, it is essential to have a comprehensive understanding of the optical, anatomical, and functional characteristics of natural teeth. Furthermore, the success of composite resin restorations in providing both function and aesthetics for prolonged periods of time is highly dependent on the clinician's expertise, the appropriate indication, and the use of high-quality materials.[3]

The replication of natural tooth aesthetics through composite resin restorations can be a challenging task due to the polychromatic and varied optical properties of natural teeth. The successful imitation of these properties is crucial for achieving optimal aesthetic outcomes in dental restorations. In addition, the development of layering techniques and the use of high-quality materials enable clinicians to perform complex restorations in a single session, utilizing direct techniques that result in superior aesthetic and clinical outcomes. However, it is important to note that the success of these restorations also depends on the practitioner's expertise and the appropriate indication for their use.[4,5]

The preservation of color stability in dental restorations is a crucial factor in achieving optimal aesthetic outcomes and ensuring the longevity of the restoration. Discoloration, which is a common cause of failure in anterior composite resin restorations, can be influenced by a variety of factors including personal oral hygiene habits, diet and oral habits. Additionally, the structural properties of the restoration, such as the degree of polymerization and surface roughness, can also impact the susceptibility to discoloration through water absorption.[6-8] Research has shown that the color stability of composite resins can be influenced by external factors, the composition of the material, and the shape and size of the filler particles. It has been demonstrated that efficient polishing and finishing techniques can reduce the surface roughness and discoloration of composite resins.[9]

The finishing and polishing of composite resin restorations is a critical aspect of achieving optimal aesthetic outcomes. A variety of tools and techniques are utilized in these processes, including the use of diamond or carbide burs, polishing discs, diamond-containing rubber spirals, silicon carbide brushes, and polishing pastes. These systems, which may involve one or multiple steps in the finishing and polishing process, vary in terms of composition, type, and abrasive particle hardness. The properties of the surface of composite resin restorations are directly impacted by the polishing systems used, and thus represent a significant factor in the overall success of the restoration.[10]

Recently, a new generation of smart chromatic composite resins has been developed that eliminates the need for color selection during composite resin restoration by mimicking the color of the dental tissues from which it is made.[11] While manufacturers claim that these composites exhibit good color compatibility, polishing and color stability with natural tooth tissues, there is a lack of research in the literature investigating the effect of different polishing systems on the surface properties and color of these composites. Furthermore, the effect of exposure to various beverages in the oral environment on the surface roughness and color of composite resins is an important topic that requires further investigation. To address these gaps in knowledge, the objective of this study is to examine the impact of two current polishing systems and different storage conditions on the surface roughness and coloration of a new generation smart chromatic composite and traditional methacrylate-based composites used in anterior restorations. The null hypothesis is that "different polishing systems and storage conditions have no effect on the color change (1) and surface roughness (2) of composite resin restorations."

METHODS

The materials utilized in this study are detailed in Table 1, which includes information on their composition, filler particle sizes and structures, and corresponding lot numbers.

Table 1. Resin-based composite materials and polishing materials used in the study.

Material/Manufacturer	Particle size	Content	Lot
Omnichroma Tokuyama Dental, Tokyo, Japan	260 nm spherical SiO_2-ZrO_2	UDMA, TEGDMA, Uniform size supra-nano spherical filler (spherical SiO_2-ZrO_2) Filling content by weight 70%	022E12
Filtek Ultimate (A2B) 3M ESPE, St. Paul, MN, USA	Silica particles (20 nm), zirconium particles (4–11 nm)	Bis-GMA, UDMA, TEGDMA, PEGDMA, Bis-EMA, silica, zirconium Filling content by weight 78.5%	645560
Estelite Asteria (A2B) Tokuyama Dental, Tokyo, Japan	200 nm spherical SiO_2-ZrO_2	Bis-GMA, UDMA, TEGDMA, Bis-MPEPP, supra-nano spherical filler (spherical SiO_2-ZrO_2) Filling content by weight 82%	W220
Material/Manufacturer	**Abrasive particle**	**Content**	**Lot**
Twist Dia Kuraray, Noritake, Germany	Pre-polisher: 25-35 µm High shine polisher: 4-8 µm	Diamond coated flexible silicone spirals	404817
3M Sof-lex 3M ESPE, St Paul, MN, USA	46 µm aluminum oxide particles 36 µm diamond particles	Spiral 1: Aluminum oxide coated spiral Spiral 2: Diamond elastomer coated spiral	N513708

Bis-GMA: *Bis-phenol A diglycidylmethacrylate,* ***Bis-MPEPP:*** *Bisphenol A polyethyl methacrylate,* ***Bis-EMA:*** *Bisphenol A ethoxylate dimethacrylate,* ***TEGDMA:*** *Triethylene glycol dimethacrylate,* ***UDMA:*** *Urethane dimethacrylate,* ***PEGDMA:*** *Polyethylene glycol.*

Preparation of Resin Specimens

In this study, three different composite resin materials were utilized (Omnichroma [smart chromatic composite; Tokuyama Dental, Tokyo, Japan], Filtek Ultimate [nanofill composite; 3M ESPE, St. Paul, MN, USA], Estelite Asteria [nanohybrid composite; Tokuyama Dental, Tokyo, Japan]). In total, 120 specimens were fabricated, each measuring 6 mm in diameter and 2 mm in thickness. Based on power analysis, it was determined that a minimum of 8 specimens per group should be prepared with 95% confidence (1-α), 80% test power (1-β) and f=0.4 effect size. Therefore, the number of specimens was set to 10. The 120 specimens were randomly divided into 12 subgroups based on the polishing system and staining solution. The composite resin was placed in a teflon mold (6 mm in diameter and 2 mm in height) between two cement glasses and polymerized by covering the composite surface with a transparent matrix tape, similar to a previous study on specimen preparation.[12] In the polymerization process of the specimens, a LED (light emitting diode) curing unit (Valo LCU; 1000 mW/cm^2, Ultradent Products Inc, South Jordan, USA) was utilized on the upper and lower surfaces of the specimens for a duration of 20 seconds. To ensure accuracy, the power of the light device was measured using a radiometer (Curing Radiometer; Kerr Corp., Orange, USA) and calibrated in all three specimens. The prepared specimens were then left to store in distilled water for 24 hours to complete the polymerization process. Subsequently, both surfaces of the specimens were polished five times

using 600-800 grit abrasive SIC (silicon carbide) abrasive papers to ensure initial surface standardization.

Study Groups

In the study, there are 6 different groups according to the composite resin and polishing spiral used in restorations, and they are divided into two subgroups according to the staining solutions (Figure 1).

Group 1: Omnichroma composite - Twist Dia spiral polishing disc (O-TD)
Group 2: Omnichroma composite - Soflex spiral polishing disc (O-S)
Group 3: Filtek Ultimate composite - Twist Dia spiral polishing disc (F-TD)
Group 4: Filtek Ultimate composite - Soflex spiral polishing disc (F-S)
Group 5: Estelite Asteria composite - Twist Dia spiral polishing disc (E-TD)
Group 6: Estelite Asteria composite - Soflex spiral polishing disc (E-S)

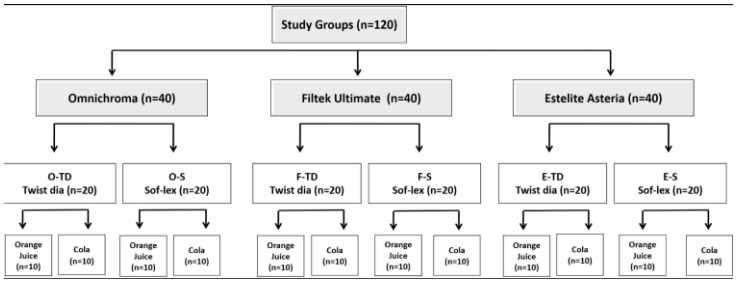

Figure 1. Systematic representation of study groups. **O-TD:** Omnichroma - Twist Dia, **O-S:** Omnichroma – Soflex, **F-TD:** Filtek Ultimate - Twist Dia, **F-S:** Filtek Ultimate – Soflex, **E-TD:** Estelite Asteria - Twist Dia, **E-S:** Estelite Asteria – Soflex

Polishing protocol

The surfaces of the composite specimens in the Twist Dia groups were polished using a 2-step diamond particle-impregnated polishing system (Twist Dia, Kuraray Noritake, Germany). The coarse-grained (14µ) spiral rubber was applied for 20 seconds in a counter-clockwise direction at 5.000 revolutions, followed by the fine-grained (10µ) spiral rubber applied to the composite resin surfaces for an additional 20 seconds in a counter-clockwise direction at 2.000 cycles.

The surfaces of the composite specimens in the groups using the Soflex Spiral Disk were polished using a 2- step polishing system (Soflex Spiral Disk, 3M ESPE, St. Paul, MN, USA). The system comprised the application of Al_2O_3-coated fine-grain polishing spirals followed by super fine-grain polishing spirals with diamond particles. Both were applied in a counter-clockwise direction for 20 seconds at a speed of 5.000 revolutions. Polishing systems were applied to the specimens under water.

Evaluation of Color Stability

After the polishing process, the specimens in all groups were exposed to staining solutions (orange juice [Dimes, Turkey], cola [Coca-Cola, Atlanta, USA]) to evaluate their color stability. According to previous in vitro studies using coffee as a staining solution, it was found that a cup of coffee is typically consumed within 15 minutes and the mean daily coffee consumption is 3.5 cups. Additionally, to replicate the oral environment, a constant temperature of 37°C was maintained during the study.[13,14] Before using the beverages for staining in this study, the pH of the beverages was measured using a pH meter (distilled water pH=5.56, orange juice pH=3.38, and cola pH=2.64). The specimens were immersed in the staining solutions at intervals of 8 hours, three times a day, and stored at 37°C. The staining solutions were renewed every 8 hours until the experimental period was completed. By maintaining this exposure regimen for a total of 12 days (288 hours), it approximated to a 12-month period of beverage consumption for an individual who consumes 2-3 cups of beverage daily, each consumed within 15 minutes.[7]

Color measurements of the prepared composite resin specimens were performed using a spectrophotometer device (SpectroShade Micro II, SpectroShade, CA, USA). The initial color measurements were taken after the specimens were stored in distilled water at 37°C for 24 hours and the data was recorded in the CIE L*a*b* color spectrum. Mean values were obtained by repeating the measurements three times on a standard white background. Before each measurement, the device was calibrated in accordance with the manufacturer's instructions. Subsequent color measurements were conducted after the specimens were removed from the staining solutions, washed with distilled water for 10 seconds, and dried slightly.[14] Color measurements of the specimens were taken at the initial step and after 288 hours of exposure to the staining solutions. All color measurements were repeated three times on a standard white background to obtain mean values, and the data was recorded. The color change (ΔE) values were calculated using the following formula:

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

The CIE L * a * b * values pertaining to the specimens after being immersed in the staining solutions are represented by the L1, a1, and b1 values, respectively. The CIE L * a * b * values measured during the initial step are represented by the L0, a0, and b0 values, respectively. A ΔE value of 3.3 was considered as a clinically acceptable level of color change.[14]

Evaluation of Surface Roughness

The initial surface roughness measurements of the composite resin specimens after polishing were conducted by measuring the specimen surfaces at three different points using a profilometer device (SJ-101 Mitutuyo Surfest, Kanagawa, Japan). The measuring length of the device was set at 0.8 mm and the working speed was set at 0.05 mm/s. The surfaces of the specimens on which the roughness measurements were made were marked and then exposed to staining solutions of orange juice and cola for 12 days. To determine the surface roughness values of the specimens after staining, three distinct points on the designated surface of each specimen were measured, and the average of these measurements was calculated. Additionally, surface roughness was evaluated qualitatively using a scanning electron microscope [SEM, (LEO-440, Zeiss, Cambridge, England)].

Statistical analysis

The collected data was analyzed using the SPSS statistical software to evaluate the results (SPSS 22, IBM, Chicago, Illinois, USA). The normality of the data was evaluated using the Shapiro-Wilks test to ensure the data met the assumptions of the statistical tests. Surface roughness and color stability assessments were performed using One Way ANOVA and the post hoc Tukey test (P=.05).

RESULTS

The findings of the CIE L*a*b* color spectrum for the resin composite resins and polishing systems evaluated in the study are presented in Table 2, and the color stability findings are presented in Table 3. A statistically significant variation was identified in the mean color change values between the groups exposed to different staining solutions (P<,05). Among the groups exposed to orange juice, the lowest color stability was observed in the O-S and E-S groups (P<,05). The lowest color stability was observed in the O-S, F-S, and E-S groups among the groups exposed to cola (P<,05). After storing in orange juice and cola, color change findings above the clinically acceptable threshold value were obtained in all resin composite resins. In general, the mean color change values were found to be higher in the specimens polished with the Soflex system.

The results of the surface roughness measurements for the composite resin specimens used in the study are presented in Table 4. An examination of the effect of the staining solutions on the surface roughness of the specimens indicated that the beverages that were tested did not significantly impact the surface roughness (*P*>,05). In general, it was observed that the mean surface roughness values of specimens stored in cola were higher than those stored in orange juice. Statistical significance was found between the application of different polishing systems to various composite resin specimens and the surface roughness values of the specimens (*P*<,05). The mean surface roughness values were found to be statistically significantly higher in the O-S and E-S groups (*P*<,05). Representative SEM images following exposure to the different beverages can be found in Figure 2.

Table 2. The mean L*, a*, b* values and standard deviation of the specimens at the initially and after the storing in the solutions

Group	Index	Initially (Distilled water)	Orange Juice	Cola
		Mean ± SD	Mean ± SD	Mean ± SD
O-TD	L*	82.81 ± 3.51	71.12 ± 3.64	62.24 ± 3.68
	a*	1.07 ± 1.37	1.03 ± 1.25	0.83 ± 1.11
	b*	21.36 ± 1.87	20.60 ± 1.30	20.31 ± 2.14
O-S	L*	83.14 ± 2.18	70.85 ± 3.14	59.26 ± 2.58
	a*	1.55 ± 0.81	1.47 ± 1.53	1.27 ± 1.36
	b*	22.931 ± 2.2	21.84 ± 1.75	21.60 ± 1.21
F-TD	L*	80.43 ± 2.45	71.31 ± 3.74	63.23 ± 2.75
	a*	1.29 ± 1.35	0.97 ± 0.84	1.12 ± 0.79
	b*	23.70 ± 2.57	21.21 ± 1.47	19.52 ± 3.28
F-S	L*	78.95 ± 2.78	70.73 ± 2.42	63.50 ± 3.71
	a*	1.18 ± 1.71	1.56 ± 1.62	1.58 ± 1.34
	b*	22.74 ± 2.51	21.41 ± 2.63	20.36 ± 2.98
E-TD	L*	81.42 ± 3.47	70.59 ± 2.72	65.42 ± 3.15
	a*	0.87 ± 1.63	1.23 ± 1.78	1.53 ± 1.46
	b*	19.59 ± 2.81	21.33 ± 2.18	22.41± 3.12
E-S	L*	82.75 ± 3.78	71.84 ± 2.36	60.42 ± 3.31
	a*	1.28 ± 1.51	2.06 ± 1.42	1.54 ± 1.13
	b*	21.51 ± 2.41	21.41 ± 1.67	20.33 ± 1.74

O-TD: *Omnichroma - Twist Dia,* ***O-S:*** *Omnichroma – Soflex,* ***F-TD:*** *Filtek Ultimate - Twist Dia,* ***F-S:*** *Filtek Ultimate – Soflex,* ***E-TD:*** *Estelite Asteria - Twist Dia,* ***E-S:*** *Estelite Asteria - Soflex*

Table 3. Mean ΔE values and standard deviation of specimens after storing in solutions

Group	ΔE-P	ΔE-K	*P*
	Mean ± SD	Mean ± SD	
O-TD	5.62 (± 1.06)^{Aa}	7.91 (± 1.37)^{Cb}	**<.001**
O-S	6.92 (± 1.37)^{Ba}	9.71 (± 1.48)^{Db}	**<.001**
F-TD	5.51 (± 0.95)^{Aa}	7.84 (± 1.05)^{Cb}	**<.001**
F-S	5.78 (± 1.04)^{Aa}	8.98 (± 1.16)^{Eb}	**<.001**
E-TD	5.73 (± 1.18)^{Aa}	8.19 (± 1.25)^{Cb}	**<.001**
E-S	6.23 (± 0.98)^{Ba}	9.45 (± 1.27)^{Db}	**<.001**
P	**<,001**	**<,001**	

** The same uppercase indicates statistical differences in the same column, same lowercase letters indicate statistical differences in the same row (P <,05).*

ΔE-P: *Initially – 12 days orange juice,* ***ΔE-K:*** *Initially – 12 days cola, O-****TD:*** *Omnichroma - Twist Dia,* ***O-S:*** *Omnichroma – Soflex,* ***F-TD:*** *Filtek Ultimate - Twist Dia,* ***F-S:*** *Filtek Ultimate – Soflex,* ***E-TD:*** *Estelite Asteria - Twist Dia,* ***E-S:*** *Estelite Asteria – Soflex*

Table 4. The mean Ra (μm) values and standard deviation of the specimens at the initially and after the storing in the solutions

Group	Initially (Distilled water)	Orange Juice	Cola	*P*
	Mean ± SD	Mean ± SD	Mean ± SD	
O-TD	0.19 (± 0.09)^{A}	0.19 (± 0.11)^{A}	0.21 (± 0.08)^{A}	.24
O-S	0.35 (± 0.11)^{B}	0.37 (± 0.09)^{B}	0.38 (± 0.11)^{B}	.93
F-TD	0.19 (± 0.10)^{A}	0.22 (± 0.07)^{A}	0.25 (± 0.13)^{A}	.37
F-S	0.16 (± 0.08)^{A}	0.17 (± 0.10)^{A}	0.19 (± 0.10)^{A}	.08
E-TD	0.18 (± 0.09)^{A}	0.18 (± 0.12)^{A}	0.19 (± 0.09)^{A}	.85
E-S	0.29 (± 0.11)^{C}	0.31 (± 0.09)^{C}	0.37 (±0.10)^{BC}	.42
p	**<0.001**	**<0.001**	**<0.001**	

** Same uppercase indicates statistical differences in the same column (P<,05).*

O-TD: *Omnichroma - Twist Dia,* ***O-S:*** *Omnichroma – Soflex,* ***F-TD:*** *Filtek Ultimate - Twist Dia,* ***F-S:*** *Filtek Ultimate – Soflex,* ***E-TD:*** *Estelite Asteria - Twist Dia,* ***E-S:*** *Estelite Asteria - Soflex*

DISCUSSION

In the present study, the color change and surface roughness of a smart chromatic composite resin and two different methacrylate-based composite resins were evaluated by exposing them to different polishing systems and solutions. The color of an object is defined as the reflection and absorption of light from the object and the sensation it creates in the eye, which is dependent on its own structure.[15] Color matching and color stability are critical parameters in aesthetic restorations. Different methods have been reported in the literature for assessing the color characteristics of restorative materials, however, spectrophotometers are commonly used due to their ease of use and ability to evaluate using different scales. In this study, we utilized a digital spectrophotometer for color measurement and recorded the data in the CIE L*a*b* color coordinates, which are widely used in the mathematical formulation of color values and are frequently preferred in dentistry with their ease of calculation and evaluation of data.[16] ΔE values were calculated by exposing the specimens to different polishing systems and solutions.

In the present study, the color change of composite resin specimens was evaluated by measuring their ΔE values after being stored in different polishing systems and staining solutions. Stober et al.[17] have shown that prolonged exposure to staining solutions can result in the discoloration of composite resins due to the penetration of color pigments into their surfaces. In this study, although keeping in orange juice caused a color change, it was determined that this effect was more in the specimens stored in cola. Similar to this study, Meenakshi et al. [18] found that the specimens stored in cola showed higher color change values than the specimens stored in orange juice. Researchers determined that cola caused more surface deterioration in composite resin specimens and stated that it could cause more color change with a high color-pigment ratio. This situation, which is stated in the literature, may cause more color changes in the specimens stored in cola in our study. In the present study, ΔE values in all specimens stored in different solutions were found to be higher than the clinically accepted value of 3.3. This is an indication that long-term exposure to both solutions may cause surface discoloration in composite resins.

In the current study, it was established that the polishing and structural characteristics of the resin have a significant impact on the composite resin's ability to resist discoloration. Specifically, it was observed that the better the surface of the composite resin is polished, the greater its resistance to discoloration. The use of polishing systems containing small-sized (10-14μm) diamond particles and flexible silicon structures, such as the Twist Dia system utilized in this study, was found to result in lower mean ΔE values for all composite resin specimens. These systems can improve surface brightness and, as a result, better resist discoloration.[19]

Studies in the literature have demonstrated that the organic matrix structure, filler content, and amount of composite resin play a role in resisting color change by influencing properties such as water absorption and degree of polymerization.[17,20] It was observed in the present study that the nanofill composite resin specimens (Filtek Ultimate) exhibited lower mean color change values than the smart chromatic composite resin and nanohybrid composite resin specimens. The small filler particle size (20 nm), filler content comprising zirconium particles, and the resin matrix structure of the nanofill composite resin may have contributed to the lower mean color change values observed.

The introduction of smart chromatic composite resins in dentistry has been met with great interest as they utilize an additive color mixing system to reflect the color of the supporting tooth tissues, mimicking the natural tooth appearance. This system aims to create a tooth- staining

image by reflecting light from natural tooth structures instead of relying on dominant color pigments, allowing for the imitation of various tooth shades with a single composite resin.[11,21] In this study, smart chromatic composite resin specimens displayed lower mean ΔE values than nanohybrid composite resin specimens, despite being exposed to solutions containing intense color pigments for an extended period. However, the mean color change values were higher than nanofill composites. Similar to our study, Aydın et al.[22] determined that smart chromatic composite resin specimens showed more color change than nanofill composites. Researchers claimed that this situation may be due to water absorption depending on the monomer content of the composite resin. The high color change in this study may be due to the matrix structure, monomer content of the composite resin, and water absorption during the storage process. These color change values were found to be above the clinically acceptable threshold. As a result, our first null hypothesis that "different polishing systems and storage conditions have no effect on the color change of composite resin restorations" was rejected.

In the present study, the surface roughness of composite resin restorations was evaluated using a profilometer device, which is widely used in dentistry due to its ease of use, suitability for the materials, and ability to provide sensitive results. The Ra value, which is calculated by averaging the absolute values of the positive and negative elevation and trough values of the line passing through the center of the specimen, was used as a measure of surface roughness. The higher the Ra value, the higher the surface roughness.[23] The clinically accepted threshold value for surface roughness, in terms of the absence of plaque retention and discoloration, is 0.2 µm. Additionally, a SEM was used in our study for qualitative evaluation of the surface roughness of the specimens. The findings of this study suggest that the finishing and polishing processes can influence the surface roughness of composite resin restorations, which may have an effect on the restoration's long-term clinical performance. Factors such as plaque and bacterial uptake, food accumulation, microleakage, and secondary caries formation, may be influenced by the surface roughness of the restoration.[24,25]

In this study, the mean surface roughness values of composite resin specimens maintained in various beverages showed no significant variation (*P*>,05). Storing composite resins in solutions with low pH values may result in an increase in surface roughness. Ertas et al.[26] also found that acidic beverages may increase the roughness of composite resin restorations by causing surface deterioration. In the present study, it was observed that the mean surface roughness values of the specimens stored in cola, which has a relatively lower pH compared to orange juice, were found to be higher. In spite of orange juice's acidic pH (pH=3.38), our study indicated that specimens stored in it had lower mean surface roughness values than specimens stored in cola (pH=2.64).

The results of this study indicate that the filler content and particle size, resin matrix structure, and degree of polymerization of composite resins can affect the surface roughness.[27] The smart chromatic composite resin specimens had the greatest mean surface roughness values, whereas nanofill composite resin specimens had the lowest mean values. In general, the mean surface roughness values of nanofill composite resin specimens were found to be below the clinically acceptable limit of 0.2 µm. The low particle size and high filler content (78.5% wt.) of the nanofill composite resin may have contributed to the smoothness of the restored surface. Aytaç et al.[28] found that composite resins with lower filler sizes showed lower surface roughness and color change. Similarly, Moda et al.[29] found that nanofill composites showed lower surface roughness values than hybrid composites. In this study, the higher filler particle size, lower filler volume, and resin matrix structure of the smart chromatic composite resin specimens may have led to higher surface roughness. The effectiveness of polishing procedures is a critical factor in determining surface roughness. Studies have reported that Twist Dia and Soflex spiral polishing discs, which are current and effective polishing systems for polishing, increase the success of composite resin restorations by decreasing the surface roughness of the composite resin and increasing the surface hardness.[30,31] According to the results of this study, the surface roughness values of the O-S and E-S groups polished with the Soflex spiral polishing disc were found to be higher than the other groups. The reason for these results may be that the particle sizes of the Soflex polishing spiral (46 - 36 µm) are larger than the Twist Dia polishing spiral (35 - 4 µm). Gömleksiz et al.[32] in their study with Bulk Fill composites, they found higher surface roughness in the groups polished with the Soflex spiral disc than in the groups polished with Twist dia. Similarly, Degirmenci et al.[33] obtained high roughness values in the Soflex polishing system group, depending on the composite type used in their studies using different composite resin and polish systems. The results of this study are consistent with similar studies in the literature. Based on the results, our second null hypothesis, which states that "different polishing systems and storage conditions have no effect on the surface roughness of composite resin restorations," was partially rejected.

The present study aimed to investigate the color change and surface roughness of composite resin restorations under different polishing systems and storage conditions. While the results revealed significant differences in color change and surface roughness between the composite resins and polishing systems tested, there are also limitations to the study. Firstly, the study was limited to a small number of composite resins, and further research could benefit from the inclusion of a wider range of composite resin types, such as microhybrid and microfill. Secondly, the study focused on color change and surface roughness as evaluation criteria; however, there are many other tests and parameters that could be used to assess the physical and mechanical properties of composite resins.[21] Thirdly, although the solutions were applied for a simulated period in an in vitro setting, further clinical studies are necessary to evaluate the color change and surface roughness of restorations under oral conditions. This study should be considered as a pilot study and further researches are needed to confirm the findings and to investigate the potential impact on clinical practice.

Despite the limitations of this study, the results indicate that storage in orange juice and cola may affect the color change and increase the surface roughness of smart chromatic composite resins and methacrylate composite resins. These effects may be influenced by factors such as the matrix structure of the composite resin, the filler particle structure and amount, the chemical composition, and the environment to which it is exposed. Clinicians should consider these factors, including the patient's diet, the structural characteristics of the applied composite resin, and the effectiveness of the polishing systems, in their treatment protocols. Further studies involving a larger number of composite resins and a broader range of parameters are needed to fully understand the impact of these variables on the long-term clinical success of composite resin restorations.

Etik Komite Onayı: Bu çalışma in vitro bir çalışma olduğundan etik kurul onayına tabi değildir.
Hasta Onamı: Bu çalışma in vitro bir çalışma olduğundan hasta onamı bulunmamaktadır.
Hakem Değerlendirmesi: Dış bağımsız.

Yazar Katkıları: Fikir – S.E., Ö.K.; Tasarım- S.E., Ö.K.; Denetleme - S.E., Ö.K.; Kaynaklar - S.E., Ö.K.; Malzemeler S.E., Ö.K.; Veri Toplanması ve/veya İşleme - S.E., Ö.K. Analiz ve/veya Yorum - S.E., Ö.K.; Literatür Taraması – S.E., Ö.K.; Makaleyi Yazan - S.E., Ö.K.; Eleştirel İnceleme; Diğer – S.E., Ö.K.
Çıkar Çatışması: Yazarların beyan edecekleri herhangi bir çıkar çatışması yoktur.
Finansal Destek: Yazarlar bu çalışmanın herhangi bir finansal destek almadığını beyan etmiştir.

Ethics Committee Approval: Since this study is an in-vitro study, it is not subject to ethics committee approval.
Informed Consent: Since this study is an in vitro study, patient consent is not required.
Peer-review: Externally peer-reviewed.
Author Contributions: Concept - S.E., O.K.; Design - S.E., O.K.; Supervision - S.E., O.K.; Resources - S.E., O.K.; Materials - S.E., O.K.; Data Collection and/or Processing - S.E., O.K.; Analysis and/or Interpretation - S.E., O.K.; Literature Search - S.E., O.K.; Writing Manuscript – S.E., O.K.; Critical Review; Other – S.E., O.K.
Conflict of Interest: The authors have no conflict of interest to declare.
Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Rekow ED. Digital dentistry: The new state of the art - Is it disruptive or destructive? *Dent Mater*. 2020; 36(1): 9-24. doi:10.1016/j.dental.2019.08.103
2. van de Sande FH, Moraes RR, Elias RV, et al. Is composite repair suitable for anterior restorations? A long-term practice-based clinical study. *Clin Oral Investig*. 2019; 23(6): 2795-2803. doi:10.1007/s00784-018-2722-5
3. Crins L, Opdam NJM, Kreulen CM, et al. Randomized controlled trial on the performance of direct and indirect composite restorations in patients with severe tooth wear. *Dent Mater*. 2021; 37(11): 1645-1654. doi:10.1016/j.dental.2021.08.018
4. de Abreu JLB, Sampaio CS, Benalcazar Jalkh EB, Hirata R. Analysis of the color matching of universal resin composites in anterior restorations. *J Esthet Restor Dent*. 2021; 33(2): 269-276. doi:10.1111/jerd.12659
5. Kanzow P, Krois J, Wiegand A, Schwendicke F. Long-term treatment costs and cost-effectiveness of restoration repair versus replacement. *Dent Mater*. 2021; 37(6): e375-e381. doi:10.1016/j.dental.2021.02.008
6. Frese C, Wohlrab T, Soliman S, et al. A Multicenter Trial on the Long-term Performance of Direct Composite Buildups in the Anterior Dentition - Survival and Quality Outcome. *J Adhes Dent*. 2020; 22(6): 573-580. doi:10.3290/j.jad.a45514
7. Schmidlin PR, Filli T, Imfeld C, Tepper S, Attin T. Three-year evaluation of posterior vertical bite reconstruction using direct resin composite--a case series. *Oper Dent*. 2009;34(1):102-108. doi:10.2341/08-11
8. Schneider LFJ, Ribeiro RB, Liberato WF, Salgado VE, Moraes RR, Cavalcante LM. Curing potential and color stability of different resin-based luting materials. *Dent Mater*. 2020; 36(10): e309-e315. doi:10.1016/j.dental.2020.07.003
9. Bagheri R, Burrow M, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. *J Dent*. 2005; 33(5): 389-398.
10. St-Pierre L, Martel C, Crépeau H, Vargas M. Influence of polishing systems on surface roughness of composite resins: polishability of composite resins. *Operative Dent*. 2019;44(3):E122-E132.
11. Lowe RA. OMNICHROMA: One Composite That Covers All Shades for an Anterior Tooth. *Compend Contin Educ Dent*. 2019; 40(suppl 1): 8-10.
12. Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging. *Dent Mater*. 2004; 20(6): 530-534. doi:10.1016/j.dental.2002.11.001
13. Rajkumar K, Kumar S, Mahalaxmi S, Ragavi P, Mageshwaran T. Colour stability of resin composites after emersing in coffee of different temperature-an in vitro study. *SRM Univ J Dent Sci*. 2011; 2(2): 92-95.
14. Ardu S, Rossier I, di Bella E, Krejci I, Dietschi D. Resin composite thickness' influence on L*a*b* coordinates and translucency. *Clin Oral Investig*. 2019; 23(4): 1583-1586. doi:10.1007/s00784-018-2585-9
15. Lee YK, Yu B, Lee SH, Cho MS, Lee CY, Lim HN. Shade compatibility of esthetic restorative materials--A review. *Dent Mater*. 2010; 26(12): 1119-1126. doi:10.1016/j.dental.2010.08.004
16. Kuzu T, Karatas O. The effects of mouthwashes and antiseptics on color stability of different composite resin. *J Dent Fac Atatürk Uni*. 2021; 31(1): 71-76. doi:10.17567/ataunidfd.806587
17. Stober T, Gilde H, Lenz P. Color stability of highly filled composite resin materials for facings. *Dent Mater*. 2001; 17(1): 87-94. doi:10.1016/s0109-5641(00)00065-8
18. Meenakshi CM, Sirisha K. Surface quality and color stability of posterior composites in acidic beverages. *J Conserv Dent*. 2020; 23(1): 57-61. doi:10.4103/JCD.JCD_291_19
19. El Gezawi M, Kaisarly D, Al-Saleh H, ArRejaie A, Al-Harbi F, Kunzelmann KH. Degradation Potential of Bulk Versus Incrementally Applied and Indirect Composites: Color, Microhardness, and Surface Deterioration. *Oper Dent*. 2016; 41(6): e195-e208. doi:10.2341/15-195-L
20. Miotti LL, Nicoloso GF, Durand LB, Susin AH, Rocha RO. Color stability of a resin composite: Effect of the immersion method and surface treatments. *Indian J Dent Res*. 2016; 27(2): 195-199. doi:10.4103/0970-9290.183137
21. Ahmed MA, Jouhar R, Khurshid Z. Smart Monochromatic Composite: A Literature Review. *Int J Dent*. 2022; 2022: 2445394. doi:10.1155/2022/2445394
22. Aydın N, Karaoglanoglu S, Oktay EA, Ersoz B. Investigation of Single Shade Composite Resin Surface Roughness and Color Stability. *J Dent Fac Atatürk Uni*. 2021; 31(2): 207-214.
23. Karatas O, Gul P, Akgul N, et al. Effect of staining and bleaching on the microhardness, surface roughness and color of different composite resins. *Dent Med Probl*. 2021; 58(3): 369-376. doi:10.17219/dmp/131022
24. Heintze S, Forjanic M, Ohmiti K, Rousson V. Surface deterioration of dental materials after simulated toothbrushing in relation to brushing time and load. *Dental Materials*. 2010; 26(4): 306-319.
25. Gaviria-Martinez A, Castro-Ramirez L, Ladera-Castaneda M, et al. Surface roughness and oxygen inhibited layer control in bulk-fill and conventional nanohybrid resin composites with and without polishing: in vitro study. *BMC Oral Health*. 26 2022; 22(1): 258. doi:10.1186/s12903-022-02297-w

26. Ertas E, Guler AU, Yucel AC, Koprulu H, Guler E. Color stability of resin composites after immersion in different drinks. *Dent Mater J*. 2006; 25(2): 371-376.
27. Berger SB, Palialol AR, Cavalli V, Giannini M. Surface roughness and staining susceptibility of composite resins after finishing and polishing. *J Esthet Restor Dent*. 2011; 23(1): 34-43. doi:10.1111/j.1708-8240.2010.00376.x
28. Aytac F, Karaarslan ES, Agaccioglu M, Tastan E, Buldur M, Kuyucu E. Effects of Novel Finishing and Polishing Systems on Surface Roughness and Morphology of Nanocomposites. *J Esthet Restor Dent*. 2016; 28(4): 247-261. doi:10.1111/jerd.12215
29. Moda MD, Godas AGL, Fernandes JC, et al. Comparison of different polishing methods on the surface roughness of microhybrid, microfill, and nanofill composite resins. *J Investig Clin Dent*. 2018; 9(1). doi:10.1111/jicd.12287
30. Aydın N, Karaoglanoglu S, Kılıçarslan M. Effect of Wet and Dry Polishing Conditions by Two Finishing and Polishing Systems on the Surface Roughness and Color Changes of Two Composite Resin Restoratives: An In Vitro Comparative Study. *J Adv Oral Res*. 2022; 13(1): 127-134. doi:10.1177/23202068221084448
31. Cazzaniga G, Ottobelli M, Ionescu A, Garcia-Godoy F, Brambilla E. Surface properties of resin-based composite materials and biofilm formation: A review of the current literature. Am J Dent. Dec 2015;28(6):311-320.
32. Gomleksiz S, Gomleksiz O. The effect of contemporary finishing and polishing systems on the surface roughness of bulk fill resin composite and nanocomposites. *J Esthet Restor Dent*. 2022; 34(6): 915-923. doi:10.1111/jerd.12874
33. Degirmenci A, Pehlivan IE, Degirmenci BU. Effects of polishing procedures on optical parameters and surface roughness of composite resins with different viscosities. *Dent Mater J*. 2023; 30: 199-210. doi:10.4012/dmj.2022-178