ATATÜRK ÜNİVERSİTESİ YAYINLARI
ATATURK UNIVERSITY PUBLICATIONS

Current Research in Dental Sciences

Research Article Araştırma Makalesi

DOI: 10.5152/CRDS.2024.23215

Effect of Commercial Whitening Toothpastes on Color Stability and Surface Roughness of Two Different Composite Resins

Piyasada Bulunan Farklı Beyazlatıcı Diş Macunlarının İki Farklı Kompozit Rezinin Renk Stabilitesi ve Yüzey Pürüzlülüğü Üzerindeki Etkisi

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This study was presented as an oral presentation at the Turkish Society of Restorative Dentistry 23rd International Scientific Congress which was held between December 6 and 8, 2019.

Received/Geliş Tarihi: 26.05.2022
Accepted/Kabul Tarihi: 18.07.2023
Publication Date/Yayın Tarihi: 18.01.2024

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Cite this article as: Şeşen Uslu Y, Doğruer I, Ulukapı H. Effect of commercial whitening toothpastes on color stability and surface roughness of two different composite resins. *Curr Res Dent Sci.* 2024;34(1):9-17.

ABSTRACT

Objective: The aim of this in vitro study is to compare the effects of different whitening toothpastes on the color stability (CS) and surface roughness (SR) of 2 composite resins.

Methods: A hundred disc-shaped specimens were prepared from Filtek Z250 microhybrid and Charisma Topaz nanohybrid composite resins. The discs were divided into 5 subgroups: artificial saliva, Colgate Active Charcoal, Yotuel, Opalescence, and Sensodyne Promine toothpastes. The initial roughness and color values of the samples were measured. In order to evaluate the CS and SR, all specimens were subjected to coffee and brushing cycles. A three-way mixed analysis of variance was used to analyze the data. All analyses were performed considering $\alpha = 0.05$.

Results: While the Z250 composite showed higher ΔE values than the other composite ($P < .05$), no significant differences were observed between the composites regarding SR ($P > .05$). Among the whitening toothpaste groups, there were no significant differences in ΔE values ($P > .05$) except for the control group. After an 8-week cycle, the activated carbon-containing toothpaste group showed a higher SR than the control group ($P < .05$).

Conclusion: All toothpastes were effective in removing discoloration from composite resins, depending on the composite resin used. However, the whitening toothpastes tested (after 8 weeks of use) increased surface roughness regardless of the composite resins used, but not more than regular toothpaste (not containing a whitening ingredient).

Keywords: Composite resins, discoloration, surface roughness, toothpastes

ÖZ

Amaç: Bu in vitro çalışmanın amacı, farklı beyazlatıcı diş macunlarının iki kompozit reçinenin renk stabilitesi (CS) ve yüzey pürüzlülüğü (SR) üzerindeki etkilerini karşılaştırmaktır.

Yöntemler: Filtek Z250 mikrohibrit ve Charisma Topaz nanohibrit kompozit reçinelerinden yüz adet disk şeklinde örnek hazırlandı. Diskler beş alt gruba ayrıldı: yapay tükürük, Colgate Aktif Karbon, Yotuel, Opalescence ve Sensodyne Promine diş macunları. Örneklerin başlangıç pürüzlülük ve renk değerleri ölçüldü. CS ve SR'yi değerlendirmek için tüm örnekler kahve ve fırçalama döngülerine tabi tutuldu. Verilerin analizi için üç yönlü karma varyans analizi kullanıldı. Tüm analizler $\alpha = 0.05$ düzeyinde yapıldı.

Bulgular: Z250 kompoziti, diğer kompozite göre daha yüksek ΔE değerleri gösterirken ($P < .05$), kompozitler arasında SR açısından anlamlı bir fark gözlenmedi ($P > .05$). Beyazlatıcı diş macunu grupları arasında, kontrol grubu hariç ΔE değerlerinde anlamlı bir fark bulunmadı ($P > .05$). Sekiz haftalık döngü sonrasında, aktif karbon içeren diş macunu grubu, kontrol grubuna göre daha yüksek SR gösterdi ($P < .05$).

Sonuç: Tüm diş macunları, kullanılan kompozit reçineye bağlı olarak kompozit reçinelerden renklenmeyi gidermede etkiliydi. Test edilen beyazlatıcı diş macunları (sekiz haftalık kullanım sonrası), kullanılan kompozit reçinelere bakılmaksızın, ancak beyazlatıcı etkili olmayan diş macunundan daha fazla olmayacak şekilde yüzey pürüzlülüğünü artırdı.

Anahtar Kelimeler: Kompozit reçineler, renk değişimi, yüzey pürüzlülüğü, diş macunları

INTRODUCTION

Today, it is accepted as an integral part of esthetic beauty in modern societies, and a natural and bright smile is desired. It has been reported in the literature that most patients desire whiter teeth and are not glad about the color of their teeth. The demand for aesthetic and restorative needs has led to the development of varied treatment options. This desire for whiter teeth has increased the use of tooth-whitening products.[1-3] Tooth bleaching techniques are widely used, and effective methods are utilized to eliminate or lighten the stains on the teeth.[2] In modern dentistry, teeth whitening is applied by a dentist with whitening gels containing carbamide peroxide (CH_4 $N_2O.H_2O_2$) or hydrogen peroxide (H_2O_2) of home or office type, or with the removal and control of extrinsic stains.[1,3]

Alternatively, the desired aesthetic result can be achieved with the use of whitening toothpaste.[4] Whitening toothpastes are products containing specific abrasives and/or chemicals that optimize the removal of extrinsic stains.[1] It is thought that the use of whitening toothpaste is considered a less costly and more convenient option for teeth whitening.[3] Whitening toothpastes, in addition to the caries and gingivitis preventive properties of conventional toothpastes, also have a whitening feature thanks to the different active ingredients (peroxides, enzymes, abrasives, optical action agents, etc.) in their content.[4]

The most commonly used abrasives in whitening toothpastes are calcium carbonate, calcium phosphate, calcium pyrophosphate, hydrated silica, and sodium bicarbonate, which are mainly responsible for removing extrinsic stain. The efficiency of whitening toothpastes containing abrasives depends on the particle's hardness, form, distribution, and concentration in their content.[1,5] Whitening toothpastes containing oxidants and enzymes prevent discoloration by chemically changing the pigments that color the teeth.[6] A recent discovery on the market is whitening toothpastes containing activated charcoal, which is an extremely lightweight black carbon and ash residue hydrocarbon.[7] There are fluoride-containing products, as well as fluoride-free whitening toothpastes with activated charcoal. Currently, charcoal-containing products' popularity is increasing, and social media advertising may help to spread the use of this material. There is not yet scientific evidence of the safety or effectiveness of these products in the oral environment.[8,9]

The surface roughness (SR), gloss, and color stability (CS) of composite resins affect the aesthetic appearance of the teeth they are used to restore.[2] With the use of whitening toothpaste, it is aimed at minimizing the discoloration that occurs in composite restorations, which is an important aesthetic treatment option. Since it causes an increase in SR, whitening toothpastes have an important effect on the performance and quality of composite resins.

There are many investigations in the literature analyzing the effect of whitening toothpastes on the SR and CS of composite resins.[10-12] However, few studies have assessed how activated charcoal whitening toothpaste affects the change in CS and SR of composite resins with different contents. In addition, although whitening toothpastes are widely used, the cumulative effects they can have on teeth and restorations due to their different ingredients are a matter of concern.[13] Based on the aforementioned, the current study aimed to assess the impacts of whitening toothpaste on the CS and SR of different composite resins. The null hypotheses tested were as follows: (1) whitening toothpastes would not affect the discoloration of composite resins (2) whitening toothpastes would not affect the SR of composite resins, and (3) there would not be a significant difference in terms of color change and SR between the composite resins used, respectively.

MATERIAL AND METHODS

Since this study did not involve human/animal subjects, no ethical approval or informed consent was obtained.

Specimen Preparation

Z250 universal microhybrid composite (MH) (3M ESPE, USA) containing Bisphenol A glycidyldimethacrylate (bis-GMA) and Charisma Topaz nanohybrid composite (NH) (Heraeus Kulzer, Germany) without bis-GMA were used in the study. From each composite, 100 disc-shaped specimens with dimensions of 10 mm in diameter and 2 mm in thickness were produced in 1 increment. Each specimen's surface was covered with a transparent mylar strip, and the extra material was gently pushed out of the specimens using a microscope glass slide. The top surfaces of all specimens were polymerized for 20 seconds by applying a light-emitting diode polymerization light, 3M Elipar™ DeepCure-S (1470 mW/cm^2, 3 M ESPE, USA). Afterward, all samples were kept in distilled water for 24 hours at 37°C in order to complete their polymerization. The specimens were polished using serially (coarse, medium, fine, and superfine) aluminum oxide discs (Sof-Lex, 3 M ESPE, St. Paul, MN, USA) for 10 seconds per disc. Then, all specimens were stored in deionized water at 37° for 24 hours, in dark containers before any measurements were performed. Then, the initial color and surface roughness measurements were performed.

Experimental Groups

The composite samples were divided into 5 subgroups randomly (n=10/group) based on the toothpaste type (brand) used: group

Table 1. Composites Evaluated in the Study

Composite	Type	Matrix	Inorganic filler content (wt%/vol%)	Manufacturer
Z250 MH	Microhybrid	BisGMA, UDMA, BisEMA	Zirconium/silica, mean size of 0.6 mm; 60% vol., 82% wt.	3M ESPE, St. Paul, MN, USA
Charisma Topaz NH	Nanohybrid	TCD-DI-HEA, UDMA	Barium aluminum fluoride glass, pre-polymerized fillers 73% wt./58% vol.	Heraeus Kulzer, Wehrheim, Germany

Table 2. Toothpaste Ingredients and Artificial Saliva Formulation Used in the Study

Toothpaste	Manufacturer	Ingredient	Tooth Whitening Technology
Promine, Sensodyne	GlaxoSmithKline, Turkey	Sodium fluoride, aqua, sorbitol, hydrated silica, glycerin, potassium nitrate, PEG-6, sodium lactate, aroma, cocamidopropyl betaine, titanium dioxide, xanthan gum, sodium saccharin, sodium fluoride, PVM/MA copolymer, sodium hydroxide, and limonene.	Nil
Yotuel All in One Snowmint	Biocosmetics Madrid, Spain	Carbamide peroxide, aqua, sorbitol, hydrated silica, xylitol, glycerin, tetrapotassium pyrophosphate, papain, titanium dioxide, potassium phosphate, Xantham Gum, aroma, sodium fluoride, sodium saccharin, diazolidinyl urea, and CI 42090.	Carbamide peroxide
Opalescence Whitening	Ultradent Products, Inc., USA	Sodium fluoride 0.25%, w/w, glycerin, water (aqua), silica, sorbitol xylitol, flavor (aroma), poloxamer, sodium lauryl sulfate, carbomer, (Cl 42090), (Cl 19140), sodium benzoate, sodium hydroxide, (Cl 77019 Cl 77891), sucralose, and xanthan gum.	Abrasives
Colgate Optic White Active Charcoal	Colgate Palmolive, Poland	Aqua, sorbitol, hydrated silica, PEG-12, tetrapotassium pyrophosphate, sodium lauryl sulfate, aroma, potassium hydroxide, cellulose gum, phosphoric acid, cocamidopropyl betaine, sodium fluoride, sodium saccharin, xanthan gum, charcoal powder, mica, limonene, and CI 77891.	Activated charcoal and enzymes
Artificial saliva		KCl 624.73 mg/L, KH_2PO_4 326.620 mg/L, K_2HPO_4 804.712 mg/L, $CaCl_2.2H_2O$ 166.130 mg/L, $C_8H_8O_3$ 2.000 mg/L, $MgCl_2.6H_2O$ 58.96 mg/L, CMC-Na 10.000 mg/L, deionized water 1000 mL	Nil

1 with artificial saliva (AS) (negative control group), group 2 with fluoride content toothpaste (Sensodyne Promine) (positive control group), group 3 with carbamide peroxide content (Yotuel All in One Snowmint), group 4 with abrasive particle content (Opalescence), and group 5 with active carbon content toothpaste (Colgate Optical White Active Charcoal). The positive control group was Promine Sensodyne toothpaste, which has no whitening component in its formulation. The negative control group was artificial saliva. The experimental groups, the characteristics of the composite materials, toothpastes applied, and a formulation of artificial saliva are presented in Tables 1 and 2.

Toothbrushing and Coffee Cycle

Initial color and SR measurements were performed. In this cycle, the samples were first brushed for 5 seconds with an electric toothbrush (Triumph Professional Care 5000, Oral B Braun GmbH, Kronberg/Ts., Germany) in continuous mode. Then the samples were stored in a coffee solution 3 times a day for 15 minutes. At the end of the cycle, the samples were again brushed for 5 seconds and subsequently stored in artificial saliva throughout the night. All specimens were subjected to brushing and a coffee cycle (for 4 weeks and 8 weeks) to better imitate the daily routine (Figure 1).

A custom-made experimental set-up was prepared, and both the samples and electric toothbrush were fixed. The toothpastes were mixed with artificial saliva in a ratio of 1 : 3 and the samples were brushed with this slurry mixture with a standard force of 2 N.[14] For the coloring process of the samples, 15 g of instant coffee powder (Nescafé Classic; Switzerland; pH 5.56) was mixed with 200 mL of hot water and then allowed to cool to room temperature.

To complete a 24-hour cycle, samples were stored in artificial saliva between the brushing and coffee cycles. The toothpaste slurry was freshly prepared each time, and the artificial saliva was replaced daily. Considering the 2 minutes of brushing time per day, each specimen was brushed for 10 seconds (2 brush strokes per second).[14] At the end of this protocol, the specimens were rinsed with deionized water. Each sample was brushed by the same researcher, who was blind to all the prepared composite discs.

Color Change Measurement

Color measurements were made using a clinical spectrophotometer (VITA Easyshade V, Ivoclar Vivadent, Liechtenstein). During these measurements, the CIEDE2000 color system was used on a standard white background under D65 standard illumination. The spectrophotometer was calibrated each time using its calibration block according to the manufacturer's instructions. In order to obtain accurate measurements, care was taken to place the probe tip perpendicular to the center of the samples in each measurement.[15]

Color measurements were performed 3 times by a single operator, and then the mean value was calculated. Color measurements of the samples were conducted 3 times: initially (T0), after a 4-week cycle (T4), and after a 8-week cycle (T8). The color values of the samples were calculated through the L*, a*, and b*

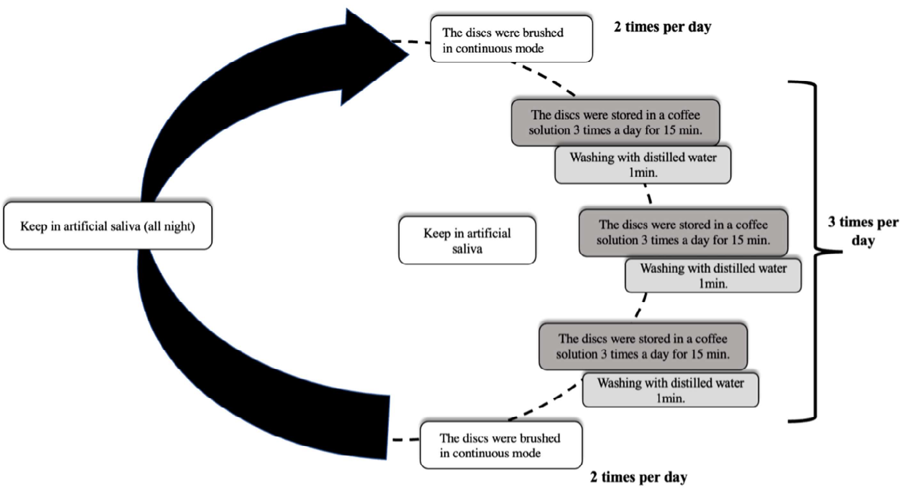

Figure 1. A schematic representation of the daily toothbrushing and coffee cycle.

parameters. The Obtained L*, a*, and b* parameters were entered into the CIEDE2000 formula (ΔE00) to detect coloring caused by the experimental conditions. The parameters KL, KC, and KH were all set to 1.

After 4 weeks, color measurement was performed, L_1*, a_1*, and b_1* values were recorded for each specimen, and ΔE1 values were calculated. The toothbrushing cycle was continued for another 4 weeks. After 4 weeks, the ΔE1 value was measured; 8 weeks after baseline L_2*, a_2*, and b_2* values were recorded for each specimen, and ΔE2 values were calculated. The formula below was used to calculate ΔE00 of the color change amounts between the obtained measurements.[16]

$$\Delta E_{00} = [(\frac{\Delta L}{k_L S_L})^2 + (\frac{\Delta C}{k_C S_C})^2 + (\frac{\Delta H}{k_H S_H})^2 + R_T (\frac{\Delta C}{k_C S_C})(\frac{\Delta H}{k_H S_H})]^{1/2}$$

According to the most recent guideline on color measurements issued by the International Organization for Standardization (ISO/TR 28642 2016), color stability should be based on the 50 : 50% acceptability (AT: ΔE_{00} = 1.77) and perceptibility (PT: ΔE_{00} = 0.8) thresholds.[15,16]

Surface Roughness Measurement

The SR was measured using a contact profilometer (Mahr Perthometer, Göttingen, Germany) with a tracing length of 5.6 mm and a cut-off value of 0.8 mm at the beginning and after the experimental period. In order to ensure repeatability, 2 lines were created on the samples with a marking (small drillings made with 1⁄4 burr) identifying the area. A reading was obtained by a diamond stylus moved at 0.5 mm/s, and then the arithmetic roughness (Ra) was recorded. This process was repeated in 3 positions on the same sample, and the average of these values was obtained. The measures were obtained by moving the diamond stylus across the sample surface and the reference areas perpendicularly to the direction of the movement of the toothbrush. The mean surface roughness values were calculated for each specimen.

Table 3. Color Change of Composite Materials, 4 and 8 Weeks After Exposure to Coffee and Brushing Cycles, According to Toothpaste Groups

Composite Resins	Group	Color Change After 4 Weeks: ΔE00 mean ± SD	Color Change After 8 Weeks: ΔE00 mean ± SD
3M Z250 (without Bis GMA)	Control	$3.31 \pm 0.22^{a,A}$	$3.25 \pm 0.23^{a,A}$
	Opalasense	$2.11 \pm 0.23^{b,A}$	$2.7 \pm 0.23^{b,A}$
	Yotuel	$2.08 \pm 0.41^{b,A}$	$2.01 \pm 0.34^{b,A}$
	Charcoal	$2.01 \pm 0.41^{b,A}$	$2.45 \pm 0.32^{b,A}$
	Promine	$2.58 \pm 0.29^{b,A}$	$2.55 \pm 0.32^{b,A}$
CharismaTopaz (with Bis GMA)	Control	$2.93 \pm 0.19^{a,B}$	$3.12 \pm 0.22^{a,B}$
	Opalasense	$1.61 \pm 0.24^{b,B}$	$1.63 \pm 0.3^{b,B}$
	Yotuel	$1.94 \pm 0.26^{b,B}$	$1.97 \pm 0.26^{b,B}$
	Charcoal	$1.72 \pm 0.28^{b,B}$	$1.52 \pm 0.28^{b,B}$
	Promine	$2.25 \pm 0.1^{b,B}$	$1.87 \pm 0.18^{b,B}$
Source of Variation		***P***	
Time		.521	
Composite resin		**.004**	
Toothpaste		**<.001**	
Time–composite resin		.154	
Time–toothpaste		.42	
Composite resin–toothpaste		.619	
Time–composite resin–toothpaste		.359	

Different lowercase letters (a, b) represent statistical differences among experimental groups for each composite resin ($P < .05$). Different uppercase letters (A, B) denote statistical differences among experimental toothpaste groups between brushing times ($P < .05$). In calculating the color difference of the samples, initial color values were taken as the baseline. It shows the statistically significant difference between rows (a-b) and columns (A-B) ($P < .05$). Only statistically significant effects were shown as bold values.

Scanning Electron Microscopy Analysis

After completing brushing and coffee cycles, 1 specimen from each group was randomly selected and analyzed via scanning electron microscopy. The specimen's surface was sputter coated with gold and palladium alloy in a vacuum evaporator, and photomicrographs of representative areas were obtained at ×1000 magnifications.

Statistical Analysis

Statistical Package for the Social Sciences Statistics software, version 21.0 software (IBM Corp.; Armonk, NY, USA), was used for the statistical analyses. The preliminary assessment of residuals' normal distribution and homogeneity of variances was checked by using Shapiro–Wilk's and Levene's tests. Roughness and color change were separately analyzed by a three-way mixed ANOVA (1 within-subjects factor, 2 between-subjects factors). To examine significant interactions, post hoc testing was performed using simple effect analysis with Bonferroni adjustment. All analyses were performed at a significance level of $\alpha = 0.05$.

RESULTS

Color Change Measurement (ΔE)

The effects of composite resin types, whitening toothpastes, and experiment time on the color change are given in Table 3. According to the results, the type of composite material and toothpaste were found to have an impact on color change ($P < .05$). However, no significant interactions were observed between "composite resin–time," "time–toothpaste," "composite resin–toothpaste," and "composite resin–time–toothpaste."

Regarding the color change on composite resins, MH showed higher ΔE00 values than NH ($P < .05$). Besides, all the toothpaste groups showed better results than the control group ($P < .05$). However, no significant differences in ΔE values were detected among the toothpaste groups ($P > .05$).

When the color change was evaluated for toothpaste groups and 2 composite materials over time, the color change on the MH composite and NH composite groups exceeded the established 50 : 50% perceptibility thresholds (ΔE00 > 0.81). Nevertheless, while the ΔE00 values of MH composite groups exceeded the determined 50 : 50% acceptability thresholds in all groups, only the NH composite + opalasence and NH + charcoal toothpaste groups did not exceed the 50 : 50% acceptability thresholds (ΔE00 < 1.77).

Surface Roughness Ra Measurement

The mean values of SR (ΔRa) with the respective standard deviations at different experiment times are illustrated in Table 4.

The results revealed that time ($P < .05$) and toothpaste ($P < .05$) affected surface roughness, while the type of composite material did not affect it ($P > .05$). Additionally, no significant interactions were detected between "composite resin–time," "composite resin–toothpaste," and composite resin–time-toothpaste.

While no significant difference was observed in the SR between the 2 composite materials ($P > 0.05$), the SR evaluation of toothpastes after 4 weeks showed no significant differences among them ($P > .05$). However, after an 8-week cycle, the activated carbon-containing toothpaste exhibited a higher SR than the control groups ($P < .05$).

Table 4. Surface Roughness of Composite Materials, 4 and 8 Weeks after Exposure to Coffee and Brushing Cycles, According to Toothpaste Groups

		Surface Roughness (initial)	Surface Roughness (After 4 Weeks)	Surface Roughness (After 8 Weeks)
Composite resins	**Group**	**SR mean ± SD**	**SR mean ± SD**	**SR mean ± SD**
3M Z250 (without Bis GMA)	Control	0.293 ± 0.025$^{a\ C}$	0.331 ± 0.025^{a,B}	0.948 ± 0.118^{b,A}
	Opalascense	0.286 ± 0.022^{a,B}	0.341 ± 0.017^{a,B}	1.45 ± 0.192^{ab,A}
	Yotuel	0.259 ± 0.016^{a,C}	0.415 ± 0.05^{a,B}	1.351 ± 0.253^{ab,A}
	Charcoal	0.325 ± 0.028^{a,B}	0.366 ± 0.029^{a,B}	1.672 ± 0.314^{a,A}
	Promine	0.283 ± 0.021^{a,B}	0.324 ± 0.019^{a,B}	1.614 ± 0.241^{ab,A}
CharismaTopaz (with Bis GMA)	Control	0.254 ± 0.011^{a,C}	0.331 ± 0.025^{a,B}	1.006 ± 0.187^{b,A}
	Opalascense	0.238 ± 0.014^{a,B}	0.281 ± 0.018^{a,B}	1.386 ± 0.184^{ab,A}
	Yotuel	0.239 ± 0.012^{a,C}	0.27 ± 0.021^{a,B}	1.509 ± 0.256^{ab,A}
	Charcoal	0.248 ± 0.013^{a,B}	0.304 ± 0.024^{a,B}	1.653 ± 0.265^{a,A}
	Promine	0.242 ± 0.015^{a,B}	0.274 ± 0.009^{a,B}	1.603 ± 0.207^{ab}
Source of Variation			***P***	
Time			**<.001**	
Composite resin			.575	
Toothpaste			**.044**	
Time–composite resin			.732	
Time–toothpaste			.005	
Composite resin–toothpaste			.992	
Time–composite resin–toothpaste			.998	

Different lowercase letters (a, b) represent statistical differences among experimental groups for each composite resin ($P < .05$). Different uppercase letters (A, B) denote statistical differences among experimental toothpaste groups between brushing times ($P < .05$). In calculating the SR of the samples, initial SR values were taken as the baseline. It shows the statistically significant difference between rows (a-c) and columns (A-C) ($P < .05$).

Scanning Electron Microscopy Results

Scanning electron microscope micrographs of both composite resins used in this study after the 4-week and 8-week coffee and brushing cycles are depicted in Figures 2 and 3. Topographical changes were observed on the sample surfaces regardless of the toothpaste used after the coffee and brushing cycle.

DISCUSSION

The main drawback of resin-based composite resins utilized in aesthetic restoration is the unpredictability of color change and staining that takes place over time. Nowadays, there is a vast choice of different toothpastes on the market that are used to eliminate the discoloration problem. The effects of whitening toothpaste with different contents on the color change and SR of 2 composites were evaluated in this in vitro study.

The findings of the present study revealed that the tested toothpaste groups had an impact on the color (ΔE) of resin-based restorative materials. While there was no significant difference among the toothpaste experimental groups, all toothpaste groups exhibited lower discoloration compared to the control group. The first null hypothesis that "whitening toothpastes would not affect the discoloration of composite resins" was rejected. Soateman GD et al[17] reported that almost all dentifrices formulated expressly for teeth whitening are efficient at removing discoloration, whether or not a chemical discoloring agent is added. The findings of the present study regarding color change are in line with this conclusion.

The observed color changes after all toothpaste groups for MH composite resin were above the 50 : 50% acceptability and perceptibility thresholds (AT: ΔE00 > 1.77 and PT: ΔE00 > 0.8). It indicates that the composite materials had unacceptable color changes, which are probably plainly visible to standard viewers. The recorded color changes after all toothpaste groups for NH composite resin were above the 50 : 50% perceptibility thresholds (PT: ΔE00 > 0.8). However, in the abrasive and activated carbon-containing toothpaste groups, the recorded color change was below the 50 : 50% acceptable threshold (ΔE00 < 1.77). It means that, despite color changes on the composite materials, it is likely that standard observers would not notice them.

In 2013, the CIEDE2000 (ΔE00) formula was adopted as the standard for detecting color differences. The number of parameters used in the CIEDE2000 (ΔE00) formula increased and became more complex compared to the CIELAB (ΔEab) formula. Additionally, the CIEDE2000 (ΔE00) includes an interaction term between chroma and hue differences in addition to lightness, chroma, and hue weighting functions. Nevertheless, the more recent CIEDE2000 formula, which outperforms CIELAB and better correlates with visual findings, is advised for use in detecting color differences (ΔE00).[18] Gómez-Polo et al[19] revealed that they found the (ΔE00) formula to be more effective than the (ΔEab) in the evaluation of coloration. The main clinical significance of comparing color differences in dentistry is to understand their relationship with perceptibility and acceptability thresholds, rather than merely detecting statistical differences.[20] In this study, all these factors were taken into account when evaluating the impact of whitening toothpastes on the color change of composite resins, and the CIEDE 2000 system was also used.

In this study, coffee solution was selected as a coloring agent not only because of its widespread consumption but also for its great effect on the coloring of both teeth and composite resins.[21,22] In the routine, there is a short-term contact of food and drinks with teeth and resin materials before washing with saliva or brushing teeth.[23] Moreover, according to coffee producers, a coffee consumer consumes an average of 3.2 cups of coffee a day, and the consumption of 1 cup of coffee also takes an average of 15 minutes.[24] In this study, the samples were subjected to a cycle of soaking in coffee for 15 minutes 3 times and brushing twice a day for periods of 4 weeks and 8 weeks. Mara da Silva et al[23] applied a coffee and brushing cycle for 30 days in their studies, in which they evaluated the color change and surface hardness of 2 different composite resins. In light of all this information, the reason why there was no statistical difference in 2 time periods in terms of preventing the color change between toothpaste groups in the current study may be due to the cycle times applied in this study.

The current study evaluated composites with different polymer networks. An MH composite is a bis-GMA-based material, whereas an NH composite contains UDMA and TCD in its organic matrix and is bis-GMA-free. The third null hypothesis was rejected due to the results of this study showing a difference in terms of color change between the composite resins.

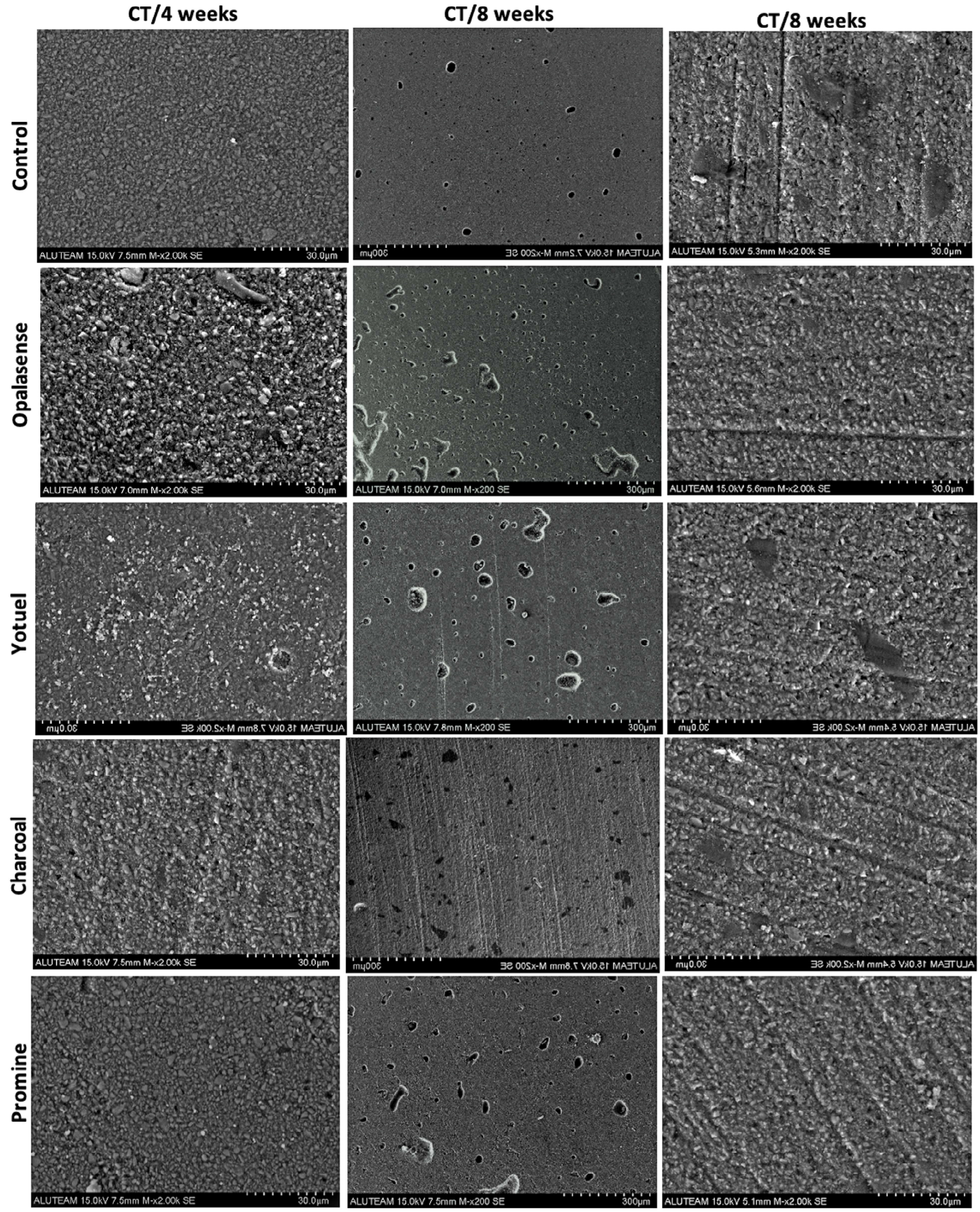

Figure 2. Representative scanning electron microscopy images of microhybrid composite resins.

The findings of the current study confirm that the color change of composite resins depends on the material used. Bis-GMA is the most widely used monomer in resin composites, showing less polymerization shrinkage than other monomers due to its large molecular weight. Hatipoglu et al[25] compared the color stability of composites with different monomer content in their study and found that the composite with bis-GMA content showed a higher discoloration. The discoloration of resin composites has been shown to be related to water absorption and solubility. Bis-GMA-based materials contain highly polar hydroxyl groups, resulting

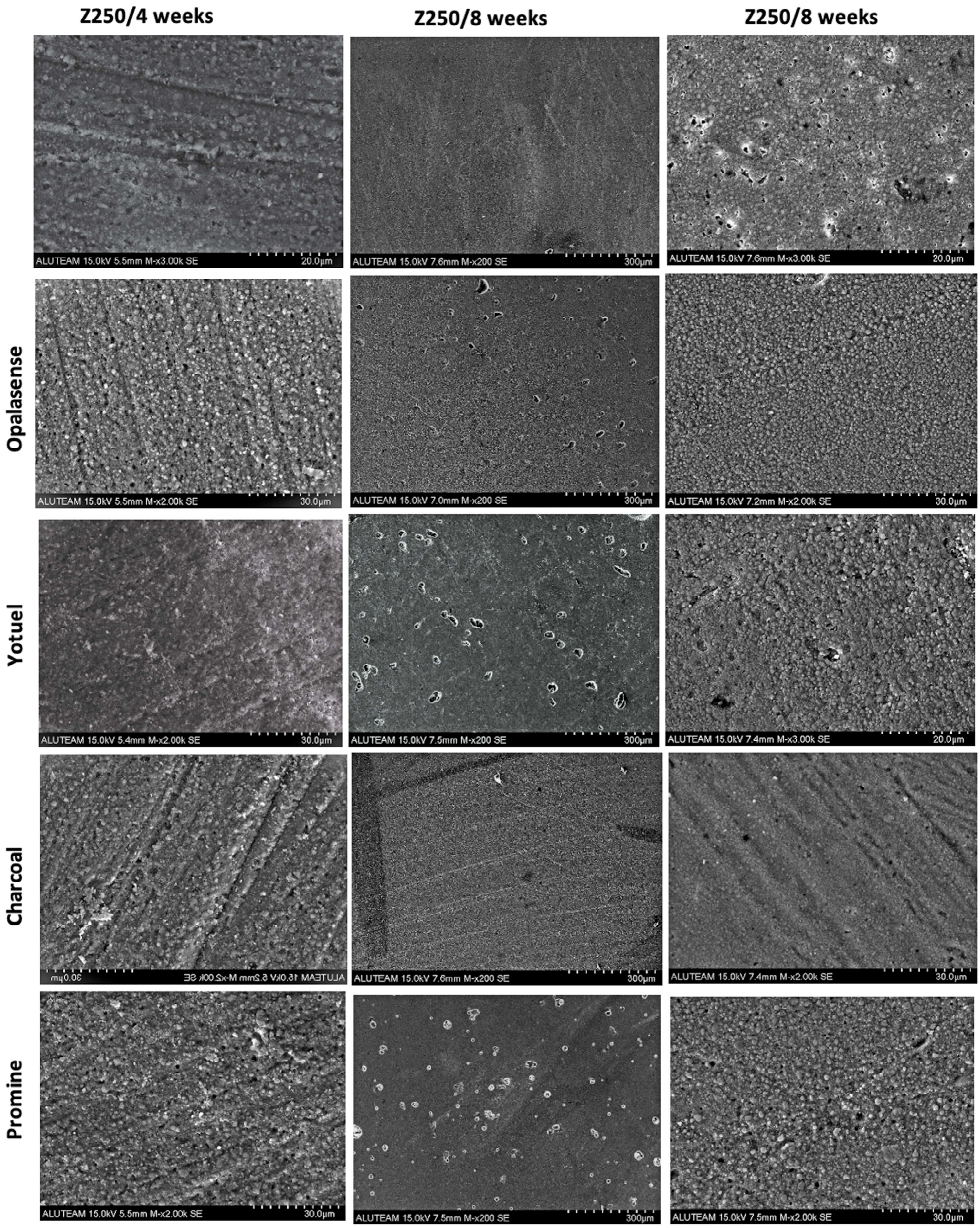

Figure 3. Representative scanning electron microscopy images of nanohybrid composite resins.

in high water absorption. In this study, it may have shown more color change due to Bis GMA in the MH content.[25]

A nanohybrid composite is a nanofilled resin-based composite with a smaller filler compared to the other composites examined in the study. After polishing, a smoother surface and a brighter appearance of this material were obtained. Composites become more sensitive to water absorption and color change as the filler particle size increases. This could be caused by the weakening of the bond between the matrix and the filler.[26] While the NH composite matrix is less hydrophilic, resulting in lower water absorption and water solubility, it consists of aliphatic chains; the matrix of the MH composite consists of hydrophilic hydroxide groups.[27] The difference between composite resins in terms of color change in this study may occur because of these reasons.

Both composite resins used in this study showed positive values for Ra, which means the roughening of the materials depends on the toothpaste used and the duration of exposure. There was no difference between composite resins in terms of surface roughness, and the null hypothesis 3 can be accepted partially. The more tooth brushing cycles and periods there are, the more composite resin deterioration and surface roughness there is; on the other hand, the brightness is lower.[23] This result could be attributed to the increase in roughness caused by the gradual removal of filler particles during the tooth brushing process.[23] Whitening toothpastes have caused an increase in the surface roughness of composite resins over time, thus causing the second null hypothesis to be rejected.

The abrasiveness of toothpastes affects the surfaces of the studied composites. The greater the abrasiveness of the toothpaste, the greater the surface roughness of the material.[28] In this study, the surface roughness of the samples brushed with activated carbon toothpaste increased statistically.

The theoretically detectable surface roughness by the patient in composite restorations was determined to be 0.50 µm.[29] In this study, the roughness values exceeded this threshold after prolonged brushing. However, Shimokawa et al[30] stated that all tested composites in their study exhibited an increase in roughness surpassing this threshold after brushing, but they noted that the relevant threshold was reported in terms of profile roughness rather than surface roughness.

According to the literature, a profile roughness threshold of 0.2 µm has been reported for bacterial adhesion and retention.[31] According to this threshold, it can be expected that bacterial adhesion would increase in all groups after toothbrushing, even though bacterial adhesion was not specifically assessed in this study. Furthermore, a recent systematic review has emphasized that using a threshold alone is insufficient for accurately predicting bacterial adhesion.[32] However, it should be noted that Shimokawa et al[30] reported that this threshold was based on profile roughness measurements rather than surface roughness, which may render it impractical to compare the results of this study with the aforementioned threshold.

In the study of Alofi et al,[33] it was stated that the surface roughness increased significantly after the use of whitening toothpaste and activated charcoal powder compared to baseline measurements. In this study, it was observed that as the brushing duration increased, there was a tendency for an increase in surface roughness when composites were brushed with toothpaste. Therefore, it can be stated that longer brushing durations have a negative impact on the surface smoothness of resin composites. This potential increase in roughness can ultimately diminish the material's surface gloss, contribute to heightened plaque accumulation, and elevate the risk of dental caries and periodontal inflammation.[34]

The composite resins used in this study were more easily worn out than their organic matrix after 8 weeks of brushing with activated carbon toothpaste and exposure to extensive time.[5] Therefore, the surface roughness may have increased more (Figures 2 and 3). The abrasive effect of charcoal-containing products depends on particle size and distribution, as well as the manufacturing process.[33] The activated carbon toothpaste used in this study also contains hydrated silica abrasive particles. In addition, tetrapotassium pyrophosphate and cocomidopropyl betaine (a thickening and foaming agent) may also have been effective in increasing the performance of the paste.[5] Heintze et al[35] demonstrated that the abrasive content of toothpaste is effective on the SR of composites. The relatively greater number of grooves seen in the scanning electron microscope images of activated carbon groups is consistent with the outcomes of the study (Figures 2 and 3).

In this study, the effect of brushing teeth with Sensodyne Promine with fluoride content, which was used as a positive control group, on color change and surface roughness for both composite resins was found to be statistically similar to other whitening toothpastes. As a result, the presence of hydrated silica in the content of this conventional toothpaste with fluoride may have been effective. Among various abrasive agents, hydrated silica serves as an intermediate abrasive agent and is fairly effective in stain removal.[1]

In this study, the color and SR of the samples were evaluated after 4-week and 8-week cycles in order to imitate routine oral hygiene procedures. Specimens were individually subjected to 4 and 8 weeks of brushing in a regular oral hygiene Practice.[36] Studies evaluating stain removal or prevention typically have durations ranging from 2 to 6 weeks, with few studies evaluating whitening effects for extended periods of 12 weeks or more.[1] For these reasons, the effectiveness of whitening toothpastes was evaluated after 4 and 8 weeks of use in this study.

The primary limitation of this study is that the results are obtained in vitro. Additionally, the types of movement or the impacts of salivary dilution and lubrication are limited by in vitro studies. Therefore, further in vivo studies are needed to confirm the results of this study and to understand the effect behavior of whitening toothpastes on different substrates.

Within the limits of this study, it can be concluded that whitening toothpastes were found to be effective in removing the discoloration in composite resins, depending on the used composite resin, but showed no difference from a regular toothpaste. Whitening toothpastes promoted an increased surface roughness, regardless of the composite resins used, but did not increase it more than a regular toothpaste. Furthermore, after the 8-week cycle, toothpaste containing activated carbon exhibited greater surface roughness compared to the control group.

Ethics Committee Approval: Since there was no human/animal substrate in this study, no ethical approval was obtained.

Informed Consent: Since there was no human/animal substrate in this study, no informed consent was obtained.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – Y.S.U., I.D., H.U.; Design – Y.S.U., I.D., H.U.; Supervision – H.U.; Resources – Y.S.U., I.D., H.U.; Materials – Y.S.U., I.D.; Data Collection – Y.S.U., I.D.; Analysis – Y.S.U., I.D., H.U.; Writing Manuscript – Y.S.U.; Writing and Editing – I.D., H.U.; Critical Review – Y.S.U., I.D., H.U.

Declaration of Interests: The authors declare that they have no competing interest.

Funding: The authors declared that this study has received no financial support.

Etik Komite Onayı: Bu çalışmada hiçbir insan/hayvan maddesi kullanılmadığından etik onay alınmamıştır.

Hasta Onamı: Bu çalışmada hiçbir insan/hayvan maddesi kullanılmadığından onam formu alınmamıştır.

Hakem Değerlendirmesi: Dış bağımsız.

Yazar Katkıları: Fikir – Y.S.U., I.D., H.U.; Tasarım – Y.S.U., I.D., H.U.; Denetleme – H.U.; Kaynaklar – Y.S.U., I.D., H.U.; Malzemeler – Y.S.U., I.D.; Veri Toplanması – Y.S.U., I.D.; Analiz – Y.S.U., I.D., H.U.; Yazıyı Yazan ve Düzenleyen – Y.S.U., I.D., H.U.; Eleştirel İnceleme – Y.S.U., I.D., H.U.

Çıkar Çatışması: Yazarlar çıkar çatışması bildirmemişlerdir.

Finansal Destek: Yazarlar bu çalışma için finansal destek almadıklarını beyan etmişlerdir.

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