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The effect of whitening toothpastes on the color stability and surface roughness of stained resin composite

Seda Gömleksiz^{1*} and Ömer Faruk Okumuş²

Abstract

Background This study aimed to investigate the effect of whitening toothpastes on the color stability and surface roughness of resin composites stained with coffee and cigarette smoke.

Methods Seventy-two disk-shaped specimens (6×2 mm) of supranano hybrid resin composite were randomly divided into two groups and exposed to coffee and cigarette smoke ($n=36$). After staining, the samples randomly divided into four groups according to whitening toothpastes and were brushed for 4 min: Opalescence Whitening (OW); Colgate Optic White (COW); Curaprox Black is White (CPX) and, distilled water (control) ($n=9$). Color was measured with spectrophotometer at the initial, after staining, and after brushing, and surface roughness was measured with profilometer at the initial and after brushing. A surface morphology analysis was examined using scanning electron microscopy and atomic force microscopy. The obtained data were statistically analyzed. ($p < 0.05$).

Results Cigarette smoke caused a significantly higher color change than coffee in the resin composite ($p < 0.05$). Brushing with hydrogen peroxide and silica-containing whitening toothpaste showed significant differences in color change ($p < 0.05$). The lowest whitening effect was found in activated charcoal-containing toothpaste. While all toothpastes increased the degree of surface roughness of resin composites, the highest roughness was caused by whitening toothpastes containing activated charcoal. ($p < 0.05$).

Conclusions The color stability and surface properties of resin composites can be affected by brushing them with whitening toothpaste. The utilization of whitening toothpaste containing hydrogen peroxide can be considered a safe method for increasing the whiteness of discolored resin composites.

Keywords Activated charcoal, Color stability, Resin composite, Surface roughness, Whitening toothpaste

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Introduction

In modern dentistry procedures, resin composites are frequently used in both anterior and posterior restorations because they provide natural esthetics with a conservative approach and adequate bonding to the tooth structure (1). Color stability is one of the leading factors determining clinical prognosis [2]. Resin composite restorations are sensitive to color change when exposed to various foods and beverages [3, 4]. Tobacco products use is also known as one of the high risk factors for discoloration [5]. Thousands of compounds, including tar, nickel, arsenic, carbon monoxide, ammonia, and heavy metals like cadmium and lead, are found in cigarette smoke [6]. This smoke causes yellowing and even darkening on the surfaces it comes into contact with [7]. Studies in the literature show that cigarette smoke causes clinically unacceptable discoloration of resin composites [8–12].

Patients' desire for a whiter, brighter, and healthier smile constantly increases the demand for esthetic dentistry. One of the approaches to achieving high esthetic results is whitening treatment, which is considered a non-invasive method. Whitening treatments, which are an effective method for removing or reducing stains on teeth, include many techniques and approaches such as different whitening agent contents, concentrations, and applications [13]. Nowadays, there is an increase in the usage of over-the-counter (OTC) whitening products that patients can apply themselves. Although there are many OTC products such as dental floss, gum, and mouthwash, the highest proportion is whitening toothpaste [14]. The abrasive qualities or specific chemical ingredients like aluminum oxide, silica, sodium bicarbonate, carbamidoxperoxide (CP), and hydrogen peroxide (HP) allow whitening toothpastes to more effectively clean surfaces [15]. It has been stated that toothpastes containing activated charcoal, which have recently been launched as a new product, are effective in removing external stains thanks to their high adsorption capacity [16].

Surface roughness is one of the factors affecting color stability [17, 18]. Abrasion from brushing and the abrasive particles in toothpaste can degrade the resin composite's appearance, increase surface roughness and decrease polishing, and alter plaque buildup, which can discolor it [19]. Based on this information; in this *in vitro* study it is aimed to comparatively evaluate the effect of whitening toothpastes with various active ingredients on the color change and surface roughness of supranano-hybrid resin composite stained with coffee and cigarette smoke. In this research, three following null hypotheses are investigated:

1. There would be no difference in color change between staining with coffee and with cigarette smoke.

2. Whitening toothpastes would not affect the color change and surface roughness of the stained resin composite.
3. There would be no difference between whitening toothpastes in terms of whitening effectiveness and roughness.

Materials and methods

Sample size calculation

The power of the sample size was calculated by G*Power software (G*Power Ver. 3.1.9.4, Heinrich-Heine Dusseldorf University, Dusseldorf, Germany) with a 95% confidence interval, an 80% power, and 0.50 effect size values for 72 samples according to one-way ANOVA-type power analysis. Nine samples per group were calculated as minimum sample size.

Preparation of sample

The composition of the resin composite used is given in Table 1. In the research, seventy-two composite samples (Shade A2) were fabricated in disk-shaped plastic mold (6×2 mm). After covering transparent mylar strip on samples, they were light cured under a glass slab by using the a LED light cure device (Valo Cordless, Ultradent, South Jordan, UT, USA) with 1000 mW/cm² of power intensity for 20 s. After polishing the samples' upper surfaces using discs covered in aluminum oxide (Sof-Lex, 3 M ESPE, USA), they were stored at 37 °C in distilled water for 24 h [20].

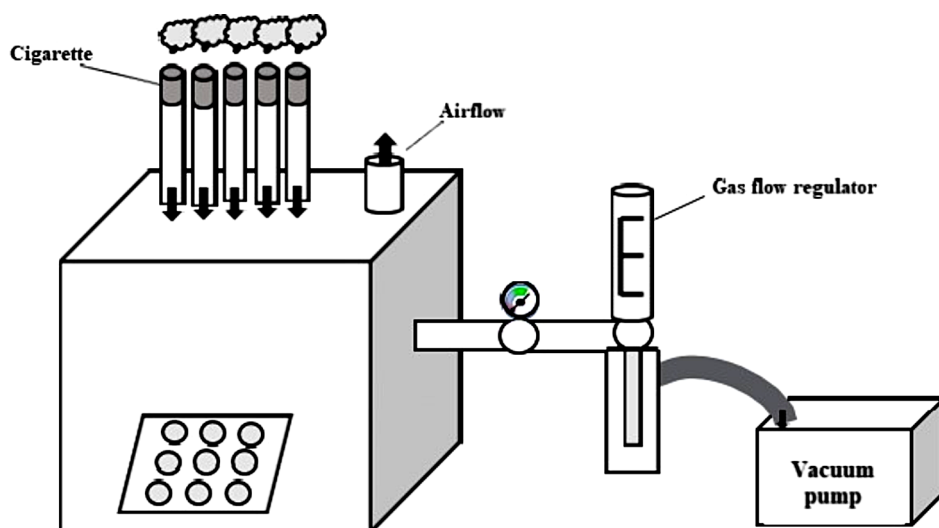
Staining of the samples

Based on the coffee and cigarette smoke process utilized in the study for staining process, two groups were randomly formed from the prepared samples. ($n=36$) As directed by the manufacturer, 2 g of coffee powder (Nescafe Classic, Nestlé; Turkey) and 200 milliliters of boiling distilled water were dissolved to create the coffee solution. A 24-hour immersion simulates around 30 days of consistent coffee drinking [21]. To simulate a year's worth of intake, all samples stored in coffee solution that renewed after every 24 h for 14 days [22].

A special machine, similar to a previous study, was designed to expose the samples in the cigarette smoke group (Fig. 1) [23]. For this purpose, 5 holes were drilled at equal distances from each other in the lid of a 500 ml plastic box. A cigarette holder with the filter parts removed was placed in each hole. A sixth hole was drilled in the lid, and a cigarette smoke evacuation mechanism was placed in this hole. A vacuum pipe was placed on the side of the box, and a flow meter that controlled the vacuum machine was connected to this pipe. The samples were placed in groups of nine into a storage container, and the cigarettes placed in all mouthpieces (Marlboro,

Table 1 Whitening toothpastes and resin composite used in the study

Product	Manufacturer	Composition
Opalescence Whitening (OW)	Ultradent Products, South Jordan, Utah, USA	Sodium Fluoride, Glycerin, Water (aqua), Silica, Sorbitol, Xylitol, Flavor (aroma), Poloxamer 407, Sodium Lauryl Sulfate, Carbomer, Sodium Benzoate, Sodium Hydroxide, Sucralose, Xanthan Gum, CI19140, CI77019, CI77891.
Colgate Optic White (COW)	Colgate-Palmolive Company NY, USA	Sodium Fluoride 0.24% (0.15% w/v fluoride ion), Water, Hydrated Silica, Sorbitol, Glycerin, PEG-12, Pentasodium Triphosphate, Tetrapotassium Pyrophosphate, Sodium Lauryl Sulfate, Flavor, Cellulose Gum, Cocamidopropyl Betaine, Sodium Saccharin, Xanthan Gum, Charcoal Powder, Sodium Hydroxide, Blue 1, Red 40, Titanium Dioxide
Curaprox Black is White (CPX)	Curaprox, CURADEN AG Kimbolton, Switzerland	Sodium Monofluorophosphate (0.723%), Potassium Thiocyanate (0.02%), Aqua, Sorbitol, Glycerin, Hydrated Silica, Charcoal Powder, Aroma, Argilla, Decyl Glucoside, Cocamidopropyl Betaine, Sodium Monofluorophosphate, Tocopherol, Mica, Xanthan gum, Hydroxyapatite (nano), Titanium Dioxide, Microcrystalline Cellulose, Maltodextrin, Potassium Acesulfame, Sodium Benzoate, Potassium Chloride, Potassium Sorbate, Menthyl Lactate, Methyl Diisopropyl Propionamide, Ethyl Menthane Carboxamide, Zea Mays Starch, Stearic Acid, Cetearyl Alcohol, Citrus Limon Peel Oil, Citric Acid, Lactoperoxidase, Glucose Oxidase, Amyloglucosidase, Tin Oxide, Sodium Bisulfite, Hydrogenated Lecithin, Limonen, CI75810, CI77289.
Estelite Sigma Quick	Tokuyama Dental Corporation, Japan	82% by weight (71% by volume) of silicazirconia filler and composite filler, BISGMA, TEGDMA

**Fig. 1** Diagram of smoke chamber. Direction of air flow for intake depicted with black arrows. At the bottom, circular shapes show disc specimens

RedLong, Philsa A.Ş., Izmir, Turkey) were lit. The vacuum machine was started with the vacuum speed set at 1 L/min, the vacuum machine was stopped every 60 s, and the evacuation mechanism was operated for 2 s. The process continued until we reached the filter part of the cigarettes. In total, one cycle lasted 10 min. Each group cycled four times.

Brushing procedures

After the staining process was completed, samples in both groups were divided into four test subgroups, each containing nine randomly selected composite samples, to test the following whitening toothpastes ($n_a = 9$). Except for the control group, each stained composite specimens was brushed manually with whitening toothpaste prepared with distilled water indicated in Table 1 in a 1:1 ratio using an electric toothbrush (Oral B Genius 8000, Braun, Germany) according to manufacturer's instructions

[24]. For the same amount of time, the samples in the control group were just brushed with distilled water. For a total of 240 s per day, people spend two minutes brushing their teeth twice a day. An individual with thirty-two teeth brushes each tooth for eight seconds on average each day [22]. Consequently, samples were brushed for four minutes to replicate a month of brushing.

Color change (ΔE_{00}) measurements

The color measurements were done utilizing a spectrophotometer (VITA Easyshade V, VITA Zahnfabrik) with a standard light source (D65) at the beginning (T_0), after staining (T_1), and after brushing (T_2). Three successive measurements were taken in the central areas, and the mean values for the L^* , a^* , and b^* parameters were applied into the CIEDE2000 formula. While the color change that occurs after the initial and staining was considered $\Delta E_{001} (T_0-T_1)$, the color change that occurs

Table 2 Means (standard deviations) of color change (ΔE_{001}) values according to staining agents

Staining agent	ΔE_{001}	Test statistics	P-value
Coffee	7.3 (1.4) ^A	-6.395	<0.001
Cigarette smoke	9.5 (1.51) ^B		

Note Different letters (A, B) indicate a statistically significant difference between the groups. ($p < 0.05$)

between staining and brushing was ΔE_{002} ($T_1 - T_2$). The following formulation was used to calculate ΔE_{00} :

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L}{K_L S_L}\right)^2 + \left(\frac{\Delta C}{K_C S_C}\right)^2 + \left(\frac{\Delta H}{K_H S_H}\right)^2} + R_T \left(\frac{\Delta C}{K_C S_C}\right) \left(\frac{\Delta H}{K_H S_H}\right)$$

In this research, the CIEDE2000 formula's parametric factors were set to 1. $\Delta E_{00} > 0.8$ was the threshold for perceptibility, while $\Delta E_{00} < 1.8$ was the criterion for clinical acceptability [25, 26].

Surface roughness (R_a) measurements

R_a measurements of samples were performed at the initial and after brushing through a surface profilometer (Mitutoyo SurfTest/SJ-301, Tokyo, Japan). Using a 0.8 mm tracing length, a 0.1 mm/s stylus speed, and a 0.25 mm cutoff length, three measurements were made for each specimen at different locations and orientations. The mean of three readings was used to determine the average R_a value for each specimen.

Surface topography analyzes

One specimen randomly selected from each group was analyzed by scanning electron microscopy (SEM) and atomic force microscopy (AFM) at the initial and after brushing. For SEM analysis, after gold sputtering, the specimens were examined under 500x magnification and at a speed of 15kv (SEM, FEI Quanta 450 FEG, Hillsboro, OR, USA).

With AFM analysis (Park System XE-100, Santa Clara, CA, USA), the surface topography of the samples was examined in areas of 10 $\mu\text{m} \times 10 \mu\text{m}$ with a tip operating in contact mode with an average scanning speed of 1 Hz. Images with a resolution of 512 \times 512 pixels were obtained from the samples.

Statistical analysis

Data were examined via IBM SPSS V23 and JAMOVI V28. Shapiro-Wilk and Kolmogorov-Smirnov tests were implemented to confirm the homoscedasticity and distribution of the data. The independent sample T-test and two-way ANOVA were used for the statistical analysis of the ΔE_{00} values, and multiple comparisons took place through implementing the Turkey post hoc test. The R_a values were compared using the Bonferroni correction and the robust ANOVA test ($p < 0.05$).

Results

Regardless of the whitening toothpaste groups, means and standard deviations of ΔE_{001} values after staining are given in Table 2. According to the results, all samples after both staining agents exhibited a color change above the clinically acceptable threshold ($\Delta E_{001} \geq 1.8$) [26]. However, independent sample t-test results showed that cigarette smoke caused significantly more coloration than coffee ($p < 0.001$).

The means and standard deviations of ΔE_{002} values are given in Table 3. The results of ANOVA test results showed that the staining agents ($p = 0.018$), whitening toothpastes ($p < 0.001$), and their interaction were statistically noteworthy ($p = 0.006$). When the results were examined, all whitening toothpastes except the CPX group exhibited clinically acceptable color improvement in both coloring media. According to the Tukey test results, the highest color improvement was observed in COW in the cigarette group, and this value showed a statistically significant difference from the other toothpaste groups ($p < 0.05$). The lowest color change value was again seen in CPX in the cigarette smoke group, and compared to the control group, this value was noticeably lower ($p < 0.05$). The OW group showed similar color improvement on samples in both the coffee and cigarette smoke groups ($p > 0.05$).

The mean R_a values and standard deviations of the whitening toothpastes depending on staining agent and time are given in Table 4. The robust ANOVA test results revealed that surface roughness values in all groups increased after brushing with whitening toothpaste and that there was a significant difference between time-dependent surface roughness values ($p = 0.001$). When the results were examined, it was observed that the whitening toothpaste groups after brushing showed higher roughness values than the control group ($p < 0.05$). In

Table 3 Means (standard deviations) of color change (ΔE_{002}) of resin composites after brushing

Staining agent	Whitening toothpaste				P-value
	OW	COW	CPX	Control	
Coffee	1.74 (0.33) ^{AB}	1.46 (0.16) ^{ABC}	1.23 (0.58) ^{BC}	1.26 (0.25) ^{BC}	0.006
Cigarette smoke	1.85 (0.42) ^{AB}	1.9 (0.6) ^A	0.95 (0.43) ^C	1.99 (0.5) ^A	

Note Different letters indicate a statistically significant difference between the groups. ($p < 0.05$)

Table 4 Means (standard deviations) of surface roughness (Ra) of resin composites at initial and after brushing

Staining agent	Whitening toothpaste	Initial	After brushing	P-value
Coffee	OW	0.13 (0.02) ^{AB}	0.26 (0.03) ^{ABC}	0.04
	COW	0.10 (0.01) ^A	0.14 (0.01) ^{AB}	
	CPX	0.14 (0.02) ^{AB}	0.26 (0.02) ^C	
	Control	0.10 (0.01) ^A	0.13 (0.02) ^{AB}	
Cigarette smoke	OW	0.15 (0.02) ^{ABC}	0.29 (0.06) ^{ABC}	
	COW	0.12 (0) ^A	0.21 (0.02) ^{BC}	
	CPX	0.15 (0.03) ^{ABC}	0.28 (0.04) ^{ABC}	
	Control	0.10 (0.01) ^A	0.10 (0.01) ^A	

Note Different letters indicate a statistically significant difference between the groups. ($p < 0.05$)

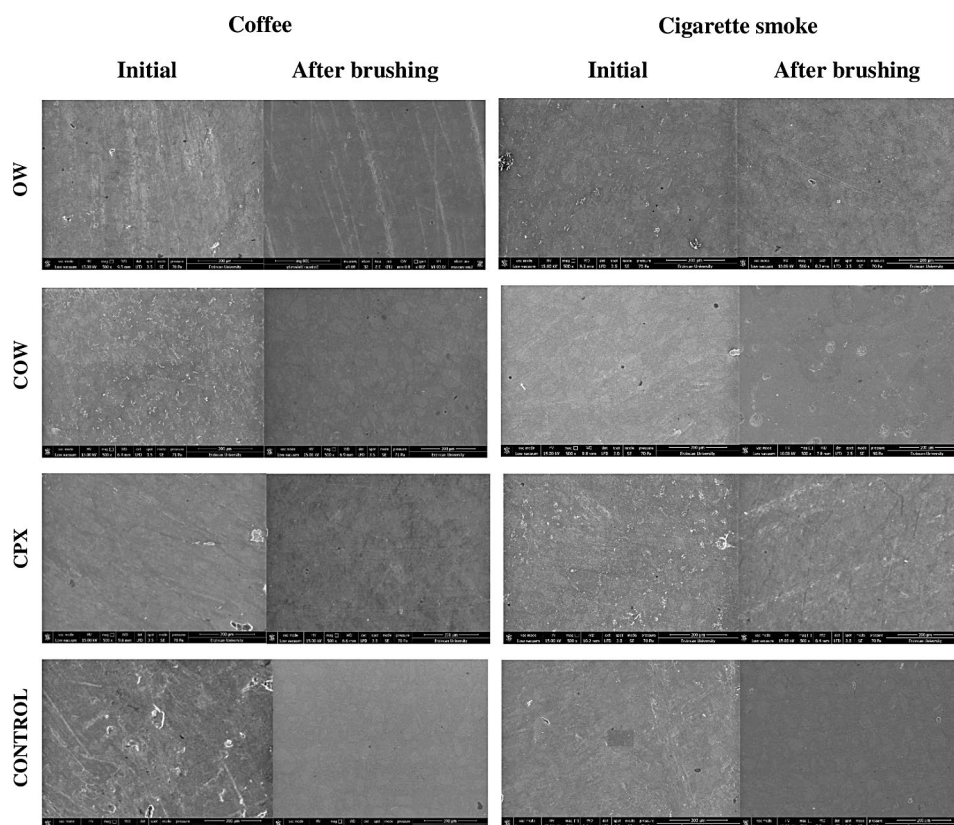


Fig. 2 Representative scanning electron microscope (SEM) images of resin composite surfaces at initial and after brushing with distilled water and whitening toothpastes on coffee and cigarette smoke groups. (x500 magnification)

both coloring environments, the highest surface roughness value after brushing was seen in the OW group ($p < 0.05$); CPX exhibited similar roughness behavior in the cigarette smoke group to the OW group. ($p > 0.05$) The lowest surface roughness value was found in the control group ($p < 0.05$). COW gave similar roughness values as the control group in the coffee group. ($p > 0.05$).

Surface topography evaluation

The SEM and AFM images of the changes occurring on the sample surfaces at the initial and after brushing are shown in Figs. 2 and 3, respectively. A qualitative analysis of the SEM micrographs presented that the brushing

protocol with whitening toothpaste produced surface changes in the form of lines and scratches on the tested surfaces compared to the baseline micrographs (Fig. 2). Unlike the control group, rough surfaces were more evident on the sample surfaces in the toothpaste-applied groups. More frequent and deeper scratches and grooves were detected on the surface of the OW applied samples compared to other toothpaste groups. In the 3D examination, more irregular areas, distinct peaks, and deep valleys were observed on the surface in the OW and CPX groups in comparison to the control group (Fig. 3). The SEM images and three-dimensional surface topographies

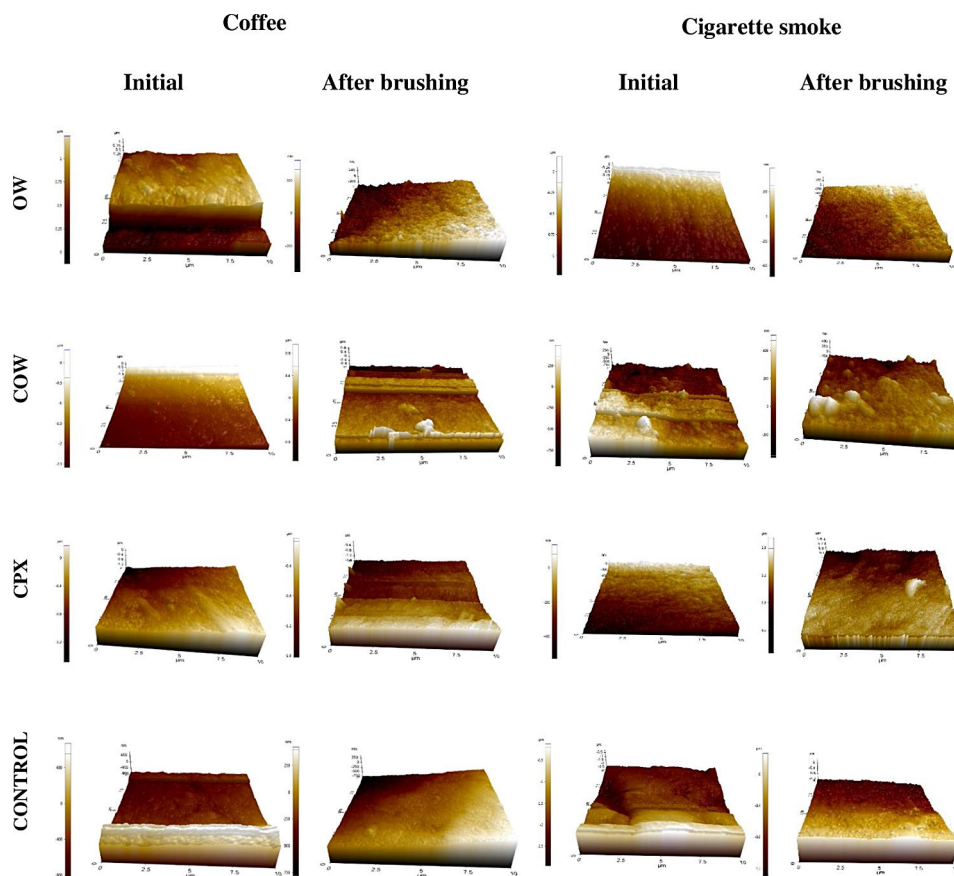


Fig. 3 Representative atomic force microscopy (AFM) images of resin composite surfaces at initial and after brushing with distilled water and whitening toothpastes on coffee and cigarette smoke groups

via AFM were compatible with the statistical evaluation of Ra values (Table 4).

Discussion

Ensuring color harmony and preserving the color of the restorative material during clinical use is critical to achieving esthetic results [4]. In the study, the effect of whitening toothpastes on the color change and surface roughness of resin composite stained with coffee and cigarette smoke was examined. The results obtained showed that coffee and cigarette smoke caused discoloration of the resin composite above the clinically acceptable threshold and that cigarette smoke caused more color change than coffee discoloration. Therefore, the first null hypothesis of the study was rejected.

It is well known that smoking stains teeth and restorations [5, 8, 10, 11]. Tar in cigarette smoke is considered a substance that causes discoloration of teeth and restorations due to its color and adhesion properties [11]. When tobacco is burned, additional compounds are produced that end up in cigarette smoke or are transferred from the tobacco to the smoke by heating. Some of these ingredients, such as sugar and cocoa, can be responsible

for discoloration [10]. While there are various studies in the literature investigating the impacts of staining agents on resin composites, number of studies comparing cigarette smoke and staining agents together are very few [8, 10–12]. A previous study made a comparison regarding the impacts of different coloring agents on color change in resin composites and results was attributed the higher color change caused by cigarette smoking than coffee to the pigmentation of the tar contained in the cigarette [11]. In a similar study where coffee, cigarette smoke and various coloring agents were evaluated, high cigarette coloration on resin composites was attributed to the dark color resulting from the oxidation of nicotine in the structure (12). Considering previous studies, in this study, the pigmentation and adhesive properties of the components in the structure of cigarette smoke may explain the high coloration caused by cigarette smoke.

In the study, the second null hypothesis was rejected due to the increase in whitening effect and roughness after brushing in resin composites. When ΔE_{002} was evaluated, has shown in Table 3 color change values were higher than 0.8 hence exceeding the perceptibility threshold [25]. However, acceptability values of whitening

toothpastes varied. The results showed a significant color change in the cigarette smoke group after brushing. At the end of brushing, the most effective whitening was seen in the COW group while CPX could not improve the color in the coffee and cigarette smoke groups. When surface roughness was evaluated, high roughness values were observed in the OW and CPX groups after brushing while the COW roughness increase was seen to be lower than the other paste groups. Consequently, the study's third null hypothesis was also rejected.

The primary whitening effect of toothpastes is determined by the interaction of peroxide compounds with abrasive materials, surfactants, polyphosphates, and enzymes [27]. To benefit from the oxidative function of HP, which is a peroxide compound, some whitening toothpastes contain trace amounts of this ingredient. The findings of this study indicated that brushing with COW was effective in improving the color of the resin composite and caused the highest color change in comparison to other toothpastes tested. The COW whitening toothpaste tested in the study contains HP. Previous studies have reported that toothpastes containing HP provide adequate whitening [28, 29]. COW toothpaste contains abrasive substances (silica, calcium, and pyrophosphate) in addition to the chemical component in its formulation [28]. The synergistic effect of these abrasives and chemicals may have contributed to COW's more effective removal of stains from resin composites. The OW tested in the study contained only silica as a whitening ingredient. The information obtained can only explain the lower colorant effect of OW containing silica than COW containing silica and HP.

Activated charcoal has recently been widely used in toothpastes because of its purported whitening effect. Activated charcoal-based toothpastes work by using the adsorption capacity of charcoal to remove pigments, chromophores, or extrinsic stains that cause teeth to naturally change color [16]. Activated charcoal has a very large surface area and quite porosity that enables effective and gradual cleaning. CPX, a charcoal-based toothpaste examined in the study, showed little color improvement compared to other whitening toothpastes. A previous study claimed that toothpaste containing activated charcoal exhibited a lower whitening impact than toothpaste with HP content [28]. Similarly, a recent study evaluated the whitening effectiveness of whitening toothpastes on colored resin composite and found that activated charcoal showed significantly lower color change than HP and silica-containing toothpastes [30]. On the other hand, there are contradictory results in the literature. A published study reported that there was no difference between HP and activated charcoal toothpastes [16]. In another study examining the color stability of resin composites, it was reported that toothpaste containing

activated charcoal caused high color change [31]. There are few studies on the possible effects of activated charcoal on resin composites [28, 30, 32]. Therefore, the differences between existing studies are attributed to factors such as the type of resin composite tested, the brand of toothpaste used, the brushing procedure, and its duration. Furthermore, a systematic review reported that the efficacy of whitening toothpaste with a charcoal component is still debatable and uncertain, as well as the fact that it has possible side effects [33].

In this research, it was observed that the surface roughness increased in all whitening toothpaste groups after brushing compared to the initial values. Previous studies have shown that resin composites wear out as due to brushing, and the remaining filler particles create a rough surface [29, 33]. However, the changes seen in the surface in the toothpaste groups after brushing in the AFM images confirm the findings of surface roughness.

Any restoration's surface roughness is clinically interpreted as encouraging the creation of oral biofilm and bacterial adherence to the surface, both of which have a direct impact on periodontal health [34]. A study has shown that surface roughness above 0.2 μm facilitates bacterial colonization on composite surfaces [35]. In addition, a high level of roughness disrupts the esthetic appearance of composite restorations by changing their color and brightness [18]. The study shows that OW and CPX toothpastes cause a surface roughness of over 0.2 μm . The structure of the resin composite, the type of brush, and the content of the toothpaste are effective in the abrasion of toothbrushes and toothpastes on resin composites [36]. It has been discovered that silica and hydrated-silica toothpastes can result in surface roughness above roughness threshold value after brushing [29, 33]. A similar study confirmed that silica-containing toothpastes create a rough surface structure on resin composites [26]. In parallel with these results, in this study, it is thought that the high roughness created by OW, a silica-containing whitening toothpaste, in resin composites may be due to the high abrasiveness of silica particles.

Although activated charcoal has been reported to have a high binding capacity, including pigments and chromophores with great color changing potential, there is still a lack of information regarding its shape, composition, and particle sizes. In a recent research examining the surface impacts of toothpastes on resin composites, it was reported that high roughness values were obtained in toothpaste containing activated charcoal [37]. In this study, examination of the resin surface after brushing in the CPX group revealed an irregular surface, which was consistent with high surface roughness values. To the contrary, One study stated that toothpaste containing activated charcoal created lower surface roughness as

opposed to toothpaste containing silica [32]. There are few studies in the literature on the effectiveness of activated charcoal on the surface roughness of resin composites. Therefore, it can be assumed that the different findings regarding activated charcoal-based toothpaste are a result of differences in application and materials, possibly combined with the size, shape, and abrasiveness degree of the charcoal particles used.

HP has oxidation and reduction abilities and shows its effect by creating free radical species. Therefore, it has the potential to damage the resin-filler interface and increase surface roughness [38]. However, an earlier study stated that the surface roughness of the resin composite is not significantly affected by low concentrations of HP in toothpaste [39, 40]. Therefore, in this study, COW containing low concentration of HP did not result in a significantly increase in surface roughness in comparison to other whitening toothpastes, which is compatible with other studies.

The proposed in vitro research presents a few limitations. The fact that the study is an in vitro study causes factors such as thermal fluctuations in the oral environment, saliva cleaning, and biofilm adhesion to not be reflected. Another limitation of the study is that tooth brushing was done with toothpaste diluted with distilled water. Clinically, the existence of ions and enzymes in saliva may reduce the impact on samples. However, it should be noted that the spectrophotometer device used in color measurements is a clinical device and is not recommended for in-vitro tests [41]. Future investigations are required to examine the long-term effects of whitening toothpaste and to test results with clinical studies.

Conclusions

Within the limitations of current research, cigarette smoke caused more discoloration of resin composites than coffee. Hydrogen peroxide-based toothpaste was shown to reduce discoloration and cause less surface roughness in resin composites. Activated charcoal-based toothpaste failed regarding color improvement and surface roughness.

Abbreviations

OTC	Over-the-counter
HP	Hydrogenperoxide
CP	Carbamidexperoxide
SEM	Scanning electron microscopy
AFM	Atomic force microscopy
SPSS	Statistical package for the social sciences

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Not applicable.

Author contributions

Research idea: S.G. Design of the study: S.G. and Ö.F.O. Acquisition of data for the study: S.G. Analysis of data for the study: S.G. and Ö.F.O. Interpretation of data for the study: S.G. Drafting the manuscript: S.G. and Ö.F.O. Revising it

critically for important intellectual content: S.G. and Ö.F.O. Final approval of the version to be published: S.G. and Ö.F.O.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request due to privacy reasons and large data size.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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