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Original article

Effects of whitening toothpastes on the esthetic properties and surface roughness of a composite resin

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Abstract

Purpose: The aim of this study was to investigate and compare the effects of some whitening toothpastes on the surface roughness and coloration susceptibility of a composite resin, as well as their whitening effectiveness.
Methods: This study was carried out in two different stages. In experiment A, samples were divided into 7 subgroups to compare the surface roughness and coloration susceptibility of the composite resin: distilled water, conventional toothpaste, and 5 different whitening toothpastes. In experiment B, samples were divided into 8 subgroups to compare the whitening effectiveness of the whitening toothpastes: conventional toothpaste, 5 other whitening toothpastes, and two bleaching groups. After toothbrushing simulation, the color and surface roughness of the samples were measured. Data were subjected to one-way analysis of variance, paired *t*-test and Tukey *post-hoc* test ($\alpha = 0.05$).
Results: There were no statistically significant differences among the surface roughness values for the groups for any period before and after brushing ($P > 0.05$). In terms of the coloration susceptibility of the composite resin and the whitening effects of the toothpastes, no statistically significant differences were evident among the groups for any period before and after brushing ($P > 0.05$).
Conclusion: The results of this study indicate that effective toothbrushing is more important than the type of toothpaste employed.

Keywords; coloration, composite resin, surface roughness, toothbrushing, whitening toothpaste

Introduction

Whiter teeth have always been considered basic to an esthetic smile and healthy appearance. Therefore, any visible discoloration or staining of teeth tends to negatively impact their esthetic appearance and increases the desire of individuals to have whiter teeth [1]. Tooth color is affected by both internal and external factors. The main internal causes of discoloration are congenital defects, progressive tooth aging, a history of trauma, or exposure to drugs such as tetracycline in early childhood or during the fetal period. Internal discoloration can also occur as a result of endodontic treatment, or tooth decay and fluorosis. External discoloration can be due to dietary habits, smoking or dental plaque [2]. In order to eliminate these color changes, individual demand for tooth whitening has increased. This increasing demand for better tooth esthetics has led to the development of whitening products, which offer a non-invasive solution for better tooth coloring [3]. Many methods for tooth whitening have been described, including a number of different bleaching agents, concentrations, application modes and activation methods [4,5]. In addition to the bleaching procedures that dentists can apply in their clinics, the use of bleaching products that patients can apply themselves has also increased. Toothpastes produced for this purpose are among these products. Whitening toothpastes exert a whitening effect on teeth through higher surface cleaning effectiveness resulting from the abrasive properties of the paste or specific chemical components, such as silica, aluminum oxide, sodium bicarbonate, carbamide peroxide and hydrogen peroxide [6].

It has been reported that tooth brushing affects not only teeth, but also the surface properties of composite resins. The soft polymer matrix of composite resin becomes worn by brushing, exposing the underlying inorganic structure. For this reason, the restoration surface may become rough and its susceptibility to coloration may increase [7]. Previous studies have shown that whitening toothpastes containing abrasive materials, special enzymes or materials can provide optical effects and bring about changes to the surfaces of teeth and filling materials [6,8]. Restorative materials should be able to maintain their surface properties and color stability after bleaching. Color stability and surface roughness are important factors affecting the longevity of any restorative material, as a rough surface structure can lead to staining and discoloration. Therefore, it is very important to clarify the effects of whitening toothpastes on restorative materials [9].

The present study was conducted to investigate the effects of some commercially available whitening toothpastes on the surface roughness and coloration susceptibility of a composite resin and to compare their whitening effectiveness.

The null hypotheses of the study were as follows:
1. Whitening toothpastes would have no effect on the surface roughness of composite resin.
2. Whitening toothpastes would not increase the coloration susceptibility of composite resin.
3. There would be no difference between toothpastes in terms of whitening effectiveness.

Materials and Methods

Sample preparation

The present study used a nano-hybrid composite material, Tetric Evo Ceram (Ivoclar Vivadent, Schaan, Liechtenstein, color A2, lot U23115). The composition of the composite resin, as stipulated by the manufacturer, was: bisphenol A glycidyl methacrylate (Bis-GMA), ethoxylated bisphenol A dimethacrylate (Bis-EMA), urethane dimethacrylate (UDMA), barium glass, ytterbium trifluoride, and mixed oxide prepolymer. A total of 150 samples were prepared from composite material. The composite resin (A2 shade) was placed in the metal mold (2 mm thickness and 8 mm diameter) then were covered with transparent tape (Mylar strips). Resin was polymerized for 20 s between two glass plates using a visible blue LED light device (Elipar Freelight II, 3M Oral Care, St. Paul, MN, USA) at a wavelength of 430-480 nm (light intensity: 1,200 mW/cm^2, dimensions: 28 mm diameter, 270 mm length). The tip diameter of the curing unit was 8 mm. The light intensity of the light curing unit used for the polymerization process was checked using a radiometer (Hilux UltraPlus Curing Units, Benlioglu Dental, Istanbul, Turkey). For polymerization, the surfaces of the restorative material in contact with the mold were illuminated by a light-emitting diode (LED) for an additional 20 s. For standardization of the sample surfaces, the restoration surfaces were polished with 600, 800, and 1,200 grit sandpaper, respectively [10]. All prepared samples were kept in distilled water for 24 h at room temperature.

This study was carried out in two different stages. Information about

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Table 1 Toothpastes used in the study

Toothpaste	Composition
Colgate Optic White (Colgate-Palmolive Co., New York, NY, USA)	sodium monofluorophosphate (0.76%), calcium pyrophosphate, propylene glycol, PEG / PPG 116/66 copolymer, PEG-12, glycerin, PVP, flavor, sodium lauryl sulfate, tetrasodium pyrophosphate silica, hydrogen peroxide, sodium saccharin, phosphoric acid, sucralose, butylated hydroxytoluene and water
Sensodyne Whitening (NeoCosMed Co., Ltd., Ladlumkaew, Thailand)	potassium nitrate, sodium fluoride w/v fluoride ion, aqua, hydrated silica, sorbitol, glycerin, pentasodium triphosphate, PEG-6, flavor, titanium dioxide, cocamidopropyl betaine, sodium methyl cocoyl taurate, xanthan gum, sodium hydroxide, sodium saccharin
ROCS Sensation Whitening (EuroCosMed, Moscow, Russia)	sorbitol, silica, glycerine, aqua, xylitol, cocamidopropyl betaine, aroma, xanthan gum, calcium glycerophosphate, bromelain, magnesium chloride, sodium saccharin, sodium benzoate, O-Cymen-5-Ol, titanum dioxide
Procsin Active Carbon (PRS Cosmetic Co., Gebze, Turkey)	sorbitol, aqua, hydrated silica, carbon black, cocamidopropyl betaine, cellulose gum, sodium saccharin, propolis extract aroma, menthl, citric acid, sodium benzoate
Signal White Now (Unilever Co., Rueil-Malmaison, France)	fluoride (1,450 ppm F), aqua, hydrogenated starch hydrolyzate, hydrated silica, PEG-32, zinc citrate, sodium lauryl sulfate, aroma, cellulose gum, sodium fluoride, sodium saccharin, PVM / MA copolymer, trisodium phosphate, sodium hydroxide, glycerin sodium lauryl sulfate, lecithin, limonene, CI 74160, CI 77891
Colgate Max Fresh (Colgate-Palmolive Co.)	sodium fluoride, sorbitol, water, hydrated cilica, PEG-12, sodium laurel sulfate, flavor, cellulose gum, tetrasodium pyrophosphate, cocamidopropyl betaine, sodium saccharin, methylcellulose

CI, color index; NA, not applicable; PEG, polyethylene glycol; PPG, polypropylene glycol; PVP, polyvinylpyrrolidone

the toothpastes used and their compositions is given in Table 1.

Experiment A

The effects of whitening toothpastes on the surface roughness of the composite material and its susceptibility to coloration were investigated. The samples were divided into 7 subgroups: distilled water (control), Colgate Max Fresh (Colgate-Palmolive Co., New York, NY, USA) (conventional toothpaste), and 5 whitening toothpastes (Colgate Optic White, Procsin Active Carbon [PRS Cosmetic Co., Gebze, Turkey], Signal White Now [Unilever Co., Rueil-Malmaison, France], ROCS Sensation Whitening [EuroCosMed, Moscow, Russia] and Sensodyne Whitening [NeoCosMed, Ladlumkaew, Thailand]) (n = 10). The baseline surface roughnesses and color values of all the samples were measured, and then toothbrushing simulation was applied.

Surface roughness measurement

The surface roughness of each composite sample was measured with a three-dimensional (3D) optical noncontact surface profilometer (Bruker Contour GT, Tucson, AZ, USA). This optical profilometer works on the principle of contact scanning white light interferometry to determined the surface roughness. The profilometer includes a Nanolens Atomic Force Microscopy module with a fully automated turret and programmable X, Y, Z movements controlled by Vision 64 application software. The standard ×1 camera has a magnification of ×5, thereby providing high resolution of the composite surface. The simple vision 64 application software transforms these high-resolution data into accurate 3D images. The measurement area for Ra is 9.46 × 1,261 μm^2. Each sample was scanned in five selected areas and the mean of the values was taken as the surface roughness (Ra). The first measurement of Ra was made from the center of the sample and the other 4 were made at a distance of 2,000 µm from the center.

Color measurement

The color of the samples was measured using a spectrophotometer (Spectro ShadeTM MICRO, MHT Optic Research AG, Milan, Italy). The calibration of the device was carried out in accordance with the manufacturer's instructions before the color measurements were conducted. The ΔE values between composite samples were determined as follows:

ΔE=[(ΔL)2+(Δa)2+(Δb)2] ½

where ΔL* is lightness and Δa* and Δb* are the differences in the green-red and blue-yellow axes, respectively.

Toothbrushing simulation

All samples were brushed using a toothbrushing simulation device, MF-100 (MOD Dental, Ankara, Turkey). Samples were embedded in molds (35 mm height and 25 mm diameter) using acrylic resin to make them ready for brushing simulation. The brushing simulator used in this study was a device facilitating forward and backward brushing movements with six independent plastic sample containers and six plastic toothbrush holder arms parallel to each other, thus allowing six samples to be subjected to the brushing process simultaneously. In experiment A, 10,000 cycles were applied, considering that 10,000 cycles are equivalent to 1 year of tooth brushing [11]. The brushing process involved a 10-mm back and forth movement at a speed of 30 mm per minute. Soft bristle Classic Colgate (Colgate-Palmolive, São Bernardo do Campo, SP, Brazil) toothbrushes were used with a load of 200 g. A distilled water/paste mixture was obtained by homogeneous mixing of 1,200 mL distilled water/300 mL paste according to ISO 11609.2010 standards [12]. The toothpastes and toothbrushes were changed after every brushing cycle, and then the samples were washed in running water and ultrasonically cleaned in distilled water for 10 min.

After the toothbrushing simulation, surface roughness and color values were determined again and then all samples were subjected to a staining process to determine their suspectibility to coloration.

Staining process

For the staining process, the samples were kept for 24 h in a solution prepared with 24 gr coffee (Nescafe 3 in 1; Karacabey, Bursa, Turkey) in 100 mL of water [13]. The samples were then removed from the solution, washed with deionized water and air dried. After the staining process, color measurements were repeated.

Scanning electron microscopy (SEM)

The changes to the composite surfaces resulting from the toothbrushing simulation and staining process were examined using a scanning electron microscope, FEI Quanta FEG 250 (FEI Co., Hillsboro, OR, USA) at various magnifications (×5,000, ×10,000, and ×20,000). A separate sample was prepared for each group to obtain the SEM images.

Experiment B

The effectiveness of whitening toothpastes on colored restorative material was examined by dividing the samples into 8 subgroups: Colgate Max Fresh (control) and 5 whitening toothpaste groups (Colgate Optic White, Procsin Active Carbon, Signal White Now, ROCS Sensation and Sensodyne). Two bleaching groups (Opalescence Boost 40% office bleaching gel and Opalescence PF 16% home bleaching gel; Ultradent Products Inc., South Jordan, UT, USA) were also included (n = 10). After baseline color measurements, all samples were subjected to the staining process described for experiment A and color measurements were repeated.

Experiment B samples (except for the Opalescence Boost and Opalescence PF groups) were brushed using the MF-100 toothbrushing simulation device described in experiment A employing a cycle equivalent to 14 days of brushing. For the bleaching groups, the hydrogen peroxide-containing office-type bleaching agent was applied for 80 min (equivalent to four applications for 20 min) and the carbamide peroxide-containing home-type bleaching agent was applied for 56 h (4 h per day for 14 days) to the composite surfaces. The samples were then washed with deionized water and air dried. After toothbrushing simulation, color measurements of all samples were repeated.

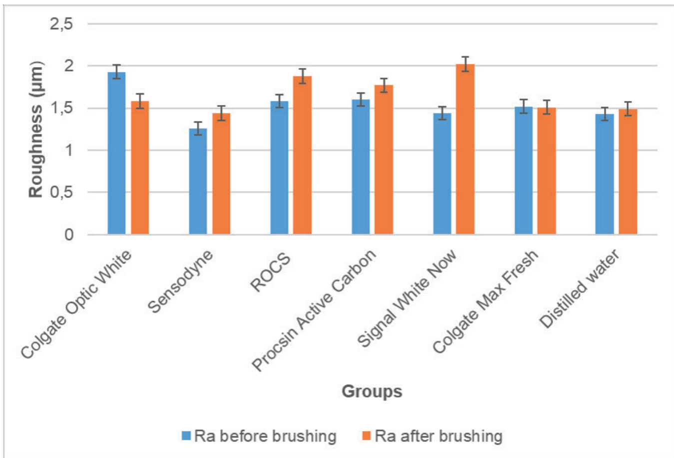

Fig. 1 The mean roughness values of the groups before and after brushing

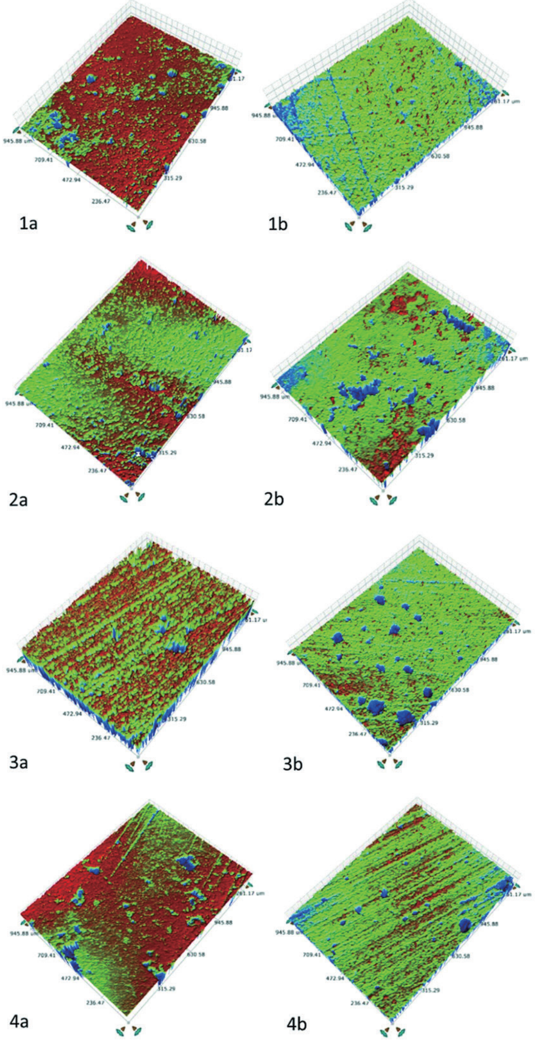

Fig. 2 3D surface images of groups 1-4 before and after brushing. 1: Colgate Optic White, 2: Sensodyne, 3: ROCS, 4: Procsin Active Carbon, a: Before brushing, b: After brushing

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) 20 (IBM, Chicago, IL, USA) software package was used for data analysis. The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to determine the distribution of the data. In addition, normality verification (equality of variances) of the data was performed using Levene's test. Paired *t*-test was used for comparisons of samples before and after toothbrushing for each group in terms of roughness, color susceptibility and whitening effect. Furthermore, one-way analysis of variance and Tukey *post-hoc* tests were used to determine

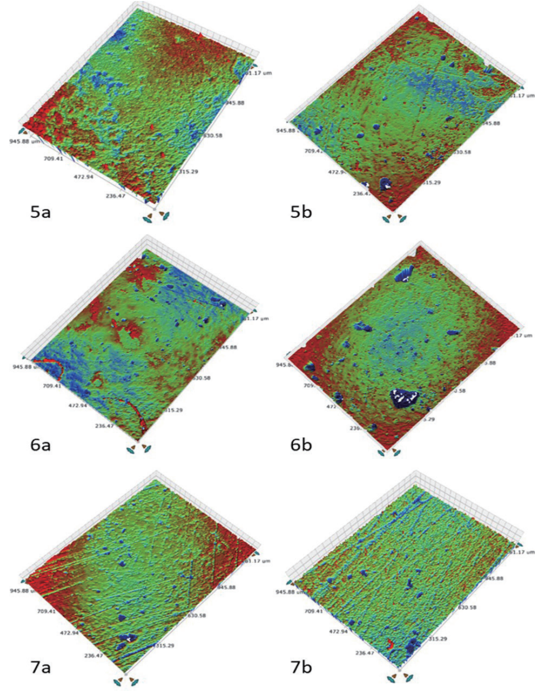

Fig. 3 3D surface images of groups 5-7 before and after brushing. 5: Signal White Now, 6: Colgate Max Fresh, 7: Distilled Water, a: Before brushing, b: After brushing

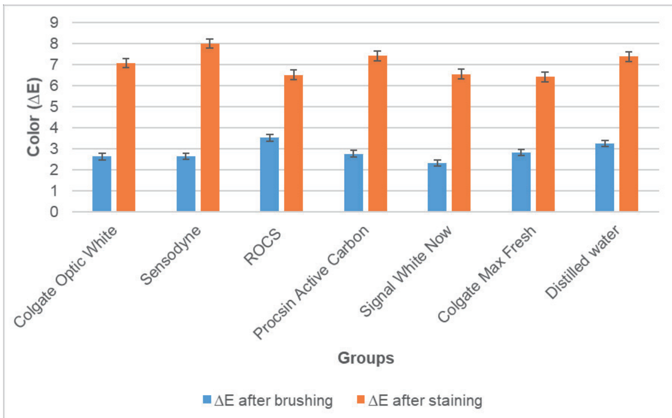

Fig. 4 Mean ΔE values reflecting color susceptibility of the composite resin after brushing and staining in each group

any significant differences within the groups for each period before and after brushing ($\alpha = 0.05$).

Results

Experiment A

The average roughness values obtained are shown in Fig. 1. Although these values generally increased after brushing, paired *t*-test demonstrated no statistically significant difference before and after brushing in each group ($P > 0.05$). One-way ANOVA also revealed no statistically significant differences among any of the groups for each period before and after brushing ($P > 0.05$). 3D surface images of the groups are shown in Figs. 2 and 3. There were no inter-group differences in surface roughness.

The average ΔE values for the color susceptibility of the composite resin are shown in Fig. 4. In each group, paired *t*-test demonstrated a statistically significant difference in ΔE values after brushing and staining ($P < 0.05$). The ΔE values obtained after staining in all groups exceeded the clinically acceptable limit of 3.3. One-way ANOVA demonstrated no statistically significant differences among any of the groups after brushing and staining for each period ($P > 0.05$).

The changes to the composite surfaces resulting from the toothbrushing simulation and staining are shown in Fig. 5. Except for partial deterioration

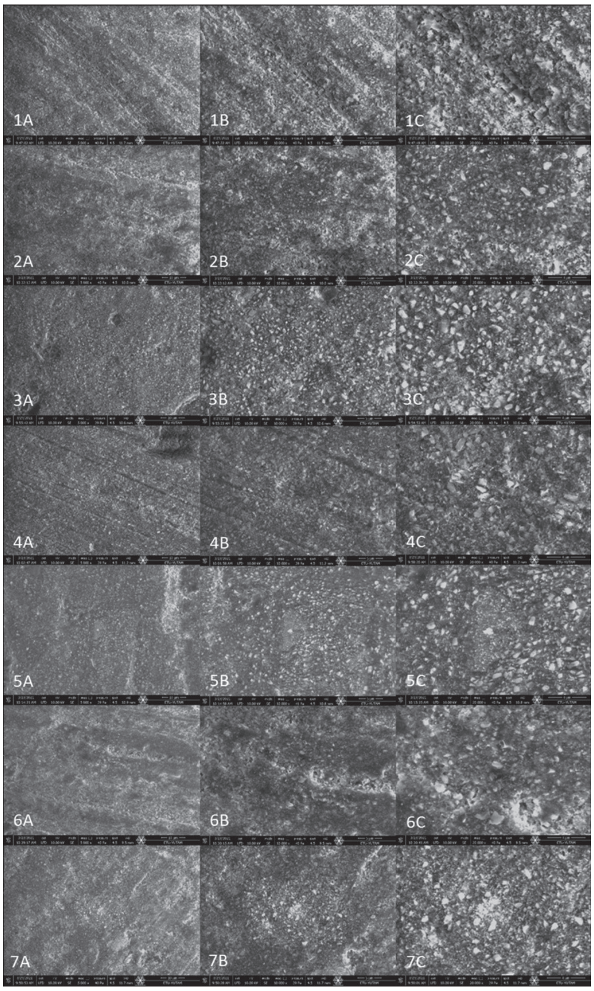

Fig. 5 SEM images of the samples. 1: Distilled water (Control), 2: Colgate Max Fresh, 3: Colgate Optic White, 4: Sensodyne, 5: ROCS Sensation, 6: Procsin Active Carbon, 7: Signal White Now, A: ×5,000 magnification, B: ×10,000 magnification, C: ×20,000 magnification

of the surface in terms of roughness, no marked morphologic alterations were detected on the composite resin, and in the toothpaste groups abrasive particles were also evident on the sample surfaces, unlike the control group.

Experiment B

The average ΔE values indicative of the whitening effectiveness of toothpastes are shown in Fig. 6. Paired *t*-test revealed a statistically significant difference in terms of ΔE values as a result of brushing for brands other than Opalescence PF and Opalescence Boost ($P < 0.05$). Although the ΔE values were decreased after brushing in all groups, these values did not fall below the clinically acceptable limit of 3.3. One-way ANOVA demonstrated a significant difference between Opalescence PF and Colgate Max Fresh in the period before brushing, but there were no significant differences among the other groups. After brushing, no statistically significant differences were evident among the groups as a whole ($P > 0.05$).

Discussion

The surface roughness of composite materials has clinical significance in terms of the susceptibility of those materials to coloration, resistance to abrasion, plaque accumulation and, subsequently, periodontal problems [14]. Profilometry is generally used for measurement of surface roughness. In this study, an optical laser profilometer was used because the sensor tip of a mechanical profilometer is unable to penetrate into all irregularities and there is also a risk of damaging the sample. As optical laser profilometers do not come into contact with the sample, the possibility of damage is reduced, and changes to the surface can be revealed in more detail by areal scanning of the sample surface through light emitted from the optical tip [15].

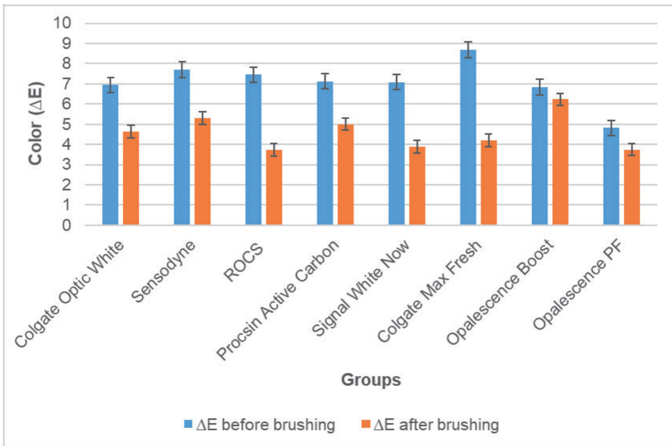

Fig. 6 Mean ΔE values obtained for each group reflecting the whitening effectiveness on the colored composite

Tooth brushing is mostly performed manually using toothbrushes and thus the brushing force can vary from person to person. A studies of materials subjected to brushing concluded that a load of 0.5-2.5 N should be applied in brushing tests in accordance with ISO standards [16]. In this study, a 200-gram (1.96 N) load was used for brushing. A study investigating the effect of toothbrushes and toothpastes on composite resins concluded that the type of brush, toothpaste content and the structure of the composite resin all affected the surface properties of the composite [17]. In the present study, the MF-100 toothbrushing simulation device was used to apply a standard force.

A previous study has shown that the polymer matrix of a composite material wears as a result of brushing, and that the remaining filling particles form a rough surface [7]. In contrast, Roselino et al. [18] brushed composite samples with two different toothpastes containing different amounts of abrasive, and found that the latter had no effect on the surface roughness. Similarly, in the present study, although the roughness values of the samples subjected to brushing with both distilled water and toothpaste increased after brushing, the difference was not significant ($P > 0.05$). Therefore, the increase in roughness values caused by brushing appeared to be only minimal, and accordingly the first hypothesis – that there would be no significant inter-group differences in the effects of whitening toothpastes on the surface roughness of the composite resin – was accepted.

The abrasivity of a toothtpaste formulation is most commonly represented in terms of its relative dentin abrasivity (RDA). This value is determined *in vitro* by examining the ability of a toothpaste slurry to remove radioactive dentine during a brushing protocol relative to a standard abrasive or toothpaste formulation. The International Standards Organisation (ISO) has stated that for dentine, the abrasivity of a test formulation should not exceed 2.5 times that of the reference abrasive, i.e. the RDA must not exceed 250 [12,19].

Although data on the RDA values for all the toothpastes used in the present study could not be found in a literature research, comparison was made with similar products of the companies concerned. This revealed that the RDA values of whitening toothpastes vary between 98 and 120, being 50 for a toothpaste containing activated charcoal and 175 for Colgate Max Fresh [20-23]. When considered in terms of ISO standards, it appears that all of the examined toothpastes are safe in terms of RDA values. The fact that no significant difference in surface roughness was evident between any of the groups in the present study shows that deterioration in the surface properties of restorative materials caused by brushing may not be due to the abrasive particles in the paste alone.

Both internal and external factors may affect the coloring of composite resins. While external factors include adsorption and absorption of coloring agents, internal factors may include the presence of unreacted methacrylate groups, oxidation of the polymer matrix, and oxidation of amine accelerators [24]. In studies that have examined the color stability of various composite restorations, exposure to chromogenic beverages such as coffee has been shown to have an effect [25]. Coffee, which was also used as a staining solution in the present study, is consumed by a high proportion of the public and shows a high rate of tooth coloring.

The color change of a material is expressed in ΔE units. In this study, ΔE = 3.3 was taken as the clinically acceptable threshold [26,27]. Any color change exceeding this value is considered to be esthetically unacceptable. In the present study, regardless of the type of toothpaste used, it was found that the color change in all groups increased significantly after coloring ($P < 0.05$) and was above the clinically acceptable level. Comparison among the groups revealed no significant differences in coloration susceptibility between the various toothpastes and the control group ($P > 0.05$). This suggests that the brushing process rather than the toothpastes employed impact the susceptibility of composite resins to coloration. Therefore, although the susceptibility of the composite resin to coloration increased in this study, the second hypothesis was accepted since this increase was not due to toothpastes.

After bleaching, restorations of the anterior teeth are renewed in terms of color harmony. However, teeth with very deep cervical caries and fractures need to be restored before bleaching. Therefore, the effects of bleaching agents on restorative materials continue to be studied [28]. During the bleaching process, both restorative materials in the mouth as well as teeth are exposed to bleaching agents. However, the results of studies that have investigated the effects of bleaching agents, toothpastes and toothbrushes on restorative materials have been contradictory [29]. No study has shown clearly that restorations should be completely changed after bleaching. In the present study, although bleaching agents improved the color of stained composite material to some degree, no significant difference between the bleaching groups and toothpastes was evident ($P > 0.05$).

It has been reported that the whitening effectiveness of some whitening toothpastes is due to removal of superficial attachments as a result of their abrasive properties, as well as through chemical whitening with peroxide or similar components [30]. It has also been shown that changes in the surface properties of materials are not attributable to abrasives in the paste alone. Detergents (e.g., sodium lauryl sulfate) in toothpastes and their pH values are also thought to affect the surface properties of restorative materials [31].

The present study employed 5 different trademark whitening toothpastes containing silica or hydrated silica as an abrasive and chemical whitening agents such as activated carbon, enzymes, calcium pyrophosphate, tetrasodium pyrophosphate, blue pigment, hydrogen peroxide, and titanium dioxide. A yellow-to-blue tooth color shift (decrease in the b value) is one of the important factors underlying perception of teeth as being whiter, and represents a type of optical illusion [32]. The mechanism of action of blue pigment (blue covarine) includes its accumulation and retention on tooth surfaces, where it can change the optical properties of the tooth through a shift from yellow to blue. The overall color shift causes an increase in the measurement and perception of tooth whiteness. *In vitro* and *in vivo* studies have confirmed that toothpastes can provide both measurable and noticeable whiteness [33]. In their *in vitro* study, Tao et al. reported that blue covarine added to toothpastes achieved a significant reduction of dental yellowness and that a greater whitening effect could be achieved by increasing the amount of blue covarine [34]. On the other hand, some studies have reported that toothpastes with optically effective pigments do not achieve better whitening effects than conventional toothpastes [13]. In the present study, although bleaching was effective for samples that had been brushed with Signal White Now whitening toothpaste containing blue covarine and hydrated silica, no significant difference was evident among groups brushed with other whitening toothpastes and non-whitening toothpaste ($P > 0.05$). One of the materials affecting the optical properties of restorative material is titanium dioxide. Some attempts have been made to provide restorative materials with the fluorescence and opalescence of natural teeth. Titanium dioxide, an inorganic additive of composite resin, has shown very promising properties. Yu et al. have shown that small amounts of added titanium dioxide nanoparticles significantly increase the opacity of composite resins; although they have little effect on the fluorescence spectrum, they significantly reduce translucency and color change. It has also been reported that composite resins containing titanium dioxide nanoparticles can mimic the opacity of enamel [35]. The present findings suggest that Sensodyne Whitening toothpaste shows whitening effectiveness because of its titanium dioxide content, besides its abrasive properties. Recently, due to their high surface area of carbon, activated charcoal toothpastes have attracted attention because of their capacity to adsorb pigments, chromophores and stains responsible for tooth color change. Activated charcoal/carbon is added to the formulations of some whitening toothpastes [36]. Brooks et al. [36] have stated that no study has provided sufficient scientific evidence for the cosmetic and health benefits of commercially available activated charcoal toothpastes, and consider that more exhaustive laboratory studies are needed to examine their whitening effectiveness and possible side effects. In the present study, Procsin Active Carbon, which is an active charcoal toothpaste, also provided whitening, but no significant difference from other groups was evident ($P > 0.05$). By adding natural enzyme extracts from plants to toothpastes, whitening toothpastes with different whitening mechanisms have been launched on the market. Bromelain, which can be obtained from the roots and leaves of pineapple comosus fruit, is one of the enzymes frequently added to toothpastes for whitening. Bromelain is a proteolytic enzyme [37] that exerts a whitening effect by breaking down the organic part of the pellicle (biological film) layer from which staining on the outer tooth surface originates [38]. Although the enzyme-containing whitening toothpaste used in the present study also has a whitening effect, its whitening effectiveness was not significantly different from that of other whitening toothpastes ($P > 0.05$).

Several previous studies have investigated the effect of brushing on dental materials. These mostly *in vitro* studies evaluated the surface roughness, abrasion, surface deterioration and mass loss of dental materials after brushing [17,39]. The present study demonstrated significant differences in the whitening effect in all groups except for home and office bleaching agents, but no significant differences among toothpastes ($P > 0.05$). Therefore, the third hypothesis was also accepted. In the present study, all groups except the home and office bleaching agent groups were subjected to brushing cycles. Consequently, the fact that a whitening effect on composite resin was evident in all groups suggested that the contents of these materials were also effective at bleaching. However, as significant differences were evident among only the brushing groups, this effect on color was likely due mainly to brushing alone. Consequently it can be suggested that the surfaces of composite resins affected by coloration may be esthetically improved to a greater degree through brushing, which would complement the whitening effects of toothpaste.

Within the limits of this study, it has been shown that effective toothbrushing is more important than the toothpaste employed in terms of whitening effectiveness, and that the toothpastes investigated do not exert negative effects in terms of the surface roughness and susceptibility to coloration of composite resin. However, more studies using different types of product will be needed for further clarification.

Conflict of interest

The authors declare that they have no conflicts of interest in relation to this study.

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