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Effect of Brushing with Whitening Toothpaste on Color Stability and Surface Roughness of Color-Adjustment Resin-Based Composites

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Research Article

History

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ABSTRACT

Objectives: Aim of this study is to compare the color stability and surface roughness of four different color-adjustment composites produced using smart chromatic technology and a highly esthetic nano-hybrid composite after brushing with whitening toothpaste**.**

Materials and Methods*:* 4 different color adjustment composites and 1 nano hybrid composite are divided into 5 main groups according to their contents. A total of 120 disc-shaped specimens (8 x 2 mm) were prepared, 24 in each group. The prepared samples were sequentially kept in solutions (tea, coffee and cherry juice) for 12 days and randomly divided into 3 subgroups (n=8). Subgroup 1, brushing with distilled water; Subgroup 2, brushing with whitening toothpaste; Subgroup 3, home bleaching agent were applied (14 days). Color measurements were made with a spectrophotometer, ΔE values were calculated using the CIELAB formula. Surface roughness values were made using a profilometer device. Samples from each group were selected for SEM surface analysis.

Results: Among the composite groups, the highest coloration was observed in the Omnichroma, while the lowest ΔE values were observed in the Vittra composite group. Although the ΔE values on the 14th day were higher than the 7th day in all groups, the differences between them were statistically insignificant. In all composite groups (except Omnichroma), the ΔE values of brushing with whitening toothpaste at the end of the 14th day were higher than brushing with distilled water.

Conclusions*:* Although the application of home bleaching agent was found to be more effective in a short time in whitening color-adjustment composites; brushing with whitening toothpaste at the end of the 14th day was found to be as effective as the application of home bleaching agent. Coloring and bleaching procedures applied to color-adjustment restorative materials did not have a significant negative effect on surface roughness values.

Key words*:* Color Adjustment, Roughness, Color Stability, One Shade Composites.

Beyazlatıcı Diş Macunu ile Fırçalamanın Renk Uyumlu Rezin Bazlı Kompozitlerin Yüzey Pürüzlülüğüne ve Renk Stabilitesine Etkisi

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ÖZ

Amaç: Bu çalışmanın amacı yüksek estetiğe sahip bir nanofil kompozit ve akıllı kromatik teknoloji kullanılarak üretilen dört farklı renk uyumlu kompozitlerin beyazlatıcı diş macunu ile fırçalama sonrası renk stabilitesinin ve yüzey pürüzlülüğünün karşılaştırmalı olarak değerlendirilmesidir.

Yöntemler: Çalışmada 4 farklı renk uyumlu kompozitler ile bir supra nanofil (kontrol) kompozit içeriklerine göre 5 gruba ayrıldı. Her grupta 24 adet olmak üzere toplam 120 disk şeklinde örnek (8 x 2 mm) hazırlandı. Hazırlanan örnekler 12 gün boyunca sırayla solüsyonlarda (çay, kahve ve vişne suyu) bekletildi ve rastgele 3 alt gruba ayrıldı (n=8). 14 gün boyunca 1. alt gruba distile su ile fırçalama, 2. alt gruba diş macunu ile fırçalama, 3. alt gruba ise ev tipi beyazlatıcı ajan uygulaması yapıldı. Renk ölçümleri spektrofotometre ile yapıldı, ΔE değerleri CIELAB formülü kullanarak hesaplandı. Yüzey pürüzlülük değerleri profilometre cihazı kullanılarak yapıldı. SEM Analizi Yüzey analizinin yapılması için her gruptan seçilen örnekler incelendi.

Bulgular: Kompozit grupları arasında en fazla renklenme Omnichroma kompozit grubunda görülürken, en düşük ΔE değerleri Vittra kompozit grubunda görülmüştür. Tüm gruplarda 14. gün ΔE değerleri 7. güne göre yüksek çıkmasına rağmen, aralarındaki farklar istatistiksel olarak önemsiz bulunmuştur. Tüm kompozit gruplarda (Omnichroma hariç) 14. Gün sonunda beyazlatıcı diş macunu ile fırçalama ΔE değerleri, distile su ile fırçalamaya göre daha yüksek değerler elde edilmiştir.

Sonuçlar: Renk uyumlu kompozitlerin beyazlatılmasında, ev tipi beyazlatma ajanı uygulanması kısa sürede daha etkili bulunmasına karşın, 14. gün sonunda beyazlatıcı diş macunu ile fırçalama ev tipi beyazlatma ajanı uygulanması kadar etkili bulunmuştur. Renk uyumlu restoratif materyallere uygulanan renklendirme ve beyazlatma prosedürleri yüzey pürüzlülük değerlerinde kayda değer negatif bir etki yapmamıştır.

Anahtar Kelimeler: Renk Uyumlu, Pürüzlülük, Renk Stabilitesi, Tek Renk Kompozit.

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Introduction

Composite resins, which have a wide range of applications in Restorative Dentistry, are continuously being developed and updated according to the needs and demands of patients. Advances in composite resins have increased patients' interest in aesthetic dentistry by enabling the creation of aesthetically pleasing restorations that resemble natural teeth.[1] In recent years, color-adjustment resin-based composites, which can match all shades with a single shade, have been produced to facilitate the color selection procedure, reduce the time spent on the patient's chair, and minimize the variables that depend on the dentists.[1-4] Different methods are used to obtain various colors during the production of composites. In the chemical color matching method, color is obtained by adding dyes and pigments. In the structural color matching method, color is obtained using inorganic fillers of the same size without pigments or dyes. Besides in the blending method, there is an optical interaction of the dental materials used.[3,5,6] In restorative dentistry, it is based on the principle of imitating the colors of the surrounding structures of the material known as the "chameleon effect mixing effect" in the production of color-matched resin-based composites. Resin composites should be translucent character that transmits light in be able to have a blending effect with the surrounding tooth structure.[1,7,8]

In the development process of composite resins, the different properties they acquire can cause changes in the surface structure of the material and respond differently to aging factors. Discoloration may be due to intrinsic and extrinsic reasons causes as one of the most common aging factors in composite resins.[9-11] Factors causing intrinsic discoloration are related to the more chemical properties of the composite, such as the structure of the resin matrix, matrix-particle interface, size and volume of filler particles. External discoloration is associated with physical factors such as oral hygiene, occupational factors, smoking, and contact with food and drink.[12,13] Various studies examining the color stability of composite resins have reported that different beverages (such as coffee, tea, wine, cola, fruit juice, etc.) and mouthwash solutions have varying degrees of staining effects.[14,15] According to these studies, the highest discoloration was observed in samples immersed in coffee, followed by tea, red wine and cola.[16] A wide variety of methods are used to detect color changes, including visual methods and measurement methods using different instruments.

Currently, color measurement devices used in dentistry include colorimeters, spectroradiometers, spectrophotometers, and digital cameras.[17,18] Spectrophotometers or colorimeters, which provide numerical results with low error rates, are mainly used for color evaluation.[19] Colorimeters are low cost and easy to use color measurement devices, but they are not suitable for use in dental practice as they are designed to measure flat surfaces.[20] On the other hand, spectrophotometers are mainly used in more professional fields, such as scientific research, color identification, and quality control. In addition, spectrophotometers can discriminate and diagnose metamerism, distinct to colorimeters.[17] The two most commonly used systems for calculating color changes are reported to be the CIE L*a*b* and CIEDE 2000 systems. When examining studies related to dental materials, it is stated that the CIE L*a*b* system is preferred and is the most commonly used color measurement system in the literature for investigating the color differences of materials.[21]

Many whitening techniques have been proposed to remove discoloration and prevent aesthetic problems in teeth and composite restorations. In addition to applying whitening agents with different chemical compositions, mechanical methods such as tooth brushing can also be used to remove discoloration.[22, 23] Whitening toothpastes contain agents such as abrasives, surfactants, calcium chelators, enzymes, and polymers to clean teeth and remove discoloration. Depending on the mechanisms of action of the agents they contain, toothpastes can provide a whitening effect on teeth through physical, chemical, or optical means. Physical agents such as abrasives and chemical agents such as peroxides can be used together to achieve a synergistic effect.[24]

The surface properties of composite resin materials may be altered or compromised when brushed with toothpaste. Abrasive particle sizes in toothpaste are important factors in the deterioration of the type of toothbrush used and the composite resin used.[25] Studies have reported that brushing restorative materials with toothpaste can affect the surface roughness values of the materials.[26] In addition to quantitative methods such as mechanical (two-dimensional) and optical (three-dimensional) profilometry techniques that can measure surface roughness, qualitative methods such as AFM and SEM are also used to evaluate surface structures of composite resins. Many researchers recommend using multiple techniques to examine the surface structures of composite resins.[26]

The aim of this study is to investigate the effect of brushing with whitening toothpaste on the color stability and surface roughness of color-adjustment resin-based composites after staining due to beverage consumption. The null hypothesis of this study was that there would be no significant difference in color stability and surface roughness between brushing color-adjustment resin composites with whitening toothpaste and applying home bleaching agent.

Material and Methods

Preparation of Samples

Ethics Committee approval dated 17.11.2021 and numbered 2021-11/24 was obtained by Sivas Cumhuriyet University Non-Interventional Clinical Research Ethics Committee to start the study. A total of 120 disc-shaped samples with the dimensions of 8 mm × 2 mm were prepared by using teflon-molds. The tested composite resins increment by compressing between two glass slides and mylar strip types. Specimens were polymerized with a light-curing unit (Valo Cordless light device (Ultradent, USA) with a

wavelength of 395-480 and a power of 1000 mW/cm$_2$) for 40 s from both, upper and bottom surfaces. After removing the excess residues on the upper surfaces of the samples with arkansas stone, the Soflex Spiral Diamond (3M ESPE, St. Paul, USA) diamond polishing system in 2 stages; Beige spiral rubber for pre-polishing and pink spiral rubber for high gloss was applied by using a slow-speed handpiece (15.000-20.000 rpm) under wet condition for 15-20 seconds. The prepared samples were kept in distilled water at 37°C for 24 hours.

Experimental Groups

Four different color-adjustment resin based composites and one supra nano spherical filler content multishade composite were divided into 5 main groups according to their contents. The tested composite resins and their compositions are given in Table 1.

Omnichroma Group: Tokuyama Omnichroma Single-shade composite (Tokuyama Dental Tokyo, JAPAN) specimens were prepared using teflon-molds and subjected to processes as described above (n=24).

Vittra Group: Vittra Unique APS Single-shade composite (FGM Dental, BRAZIL) specimens were prepared using teflon-molds and subjected to processes as described above (n:24).

Charisma Group: Charisma Diamond Topaz One Single-shade composite (Kulzer, Tokyo, JAPAN) specimens were prepared using teflon-molds and subjected to processes as described above (n=24).

Zenchroma Group: Zenchroma Single-shade composite (President Dental, GERMANY) specimens were prepared using teflon-molds and subjected to processes as described above (n=24).

Asteria Group: Tokuyama Estelite Asteria multi-shade composite -A2 color preferred- (Tokuyama Dental, JAPAN) specimens were prepared using teflon-molds and subjected to processes as described above (n=24).

The main groups were randomly divided into 3 subgroups according to their bleaching procedures (n=8).

Sub-group 1: Brushing with Distilled Water: Oral-B Smart 4 (Braun Oral B Procter & Gamble / USA) electronic electric toothbrushes with pressure sensors were used for brushing the samples. The brushing simulator (HİYELLAB Makine Arge ve Inovasyon San.ve Tic.) we designed was prepared to ensure standardization in the use of electric toothbrushes and to eliminate the variables depending on the practitioner. In order to ensure that the brushes contact the samples and apply an equal amount of force, 200 N weights were attached to the samples and their positions were fixed. The prepared samples were subjected to a brushing procedure with the help of a brushing simulator for 10 seconds twice a day with distilled water for 14 days.

Sub-group 2: Brushing with Whitening Toothpaste: The prepared samples were subjected to a brushing procedure with the help of a brushing simulator for 10 seconds twice a day with whitening toothpaste (Colgate Optic White Expert, Palmolive, USA) for 14 days. The tested whitening toothpaste and its composition is given in Table 2. Toothpaste was mixed with distilled water at a ratio of 2:1 and applied on the samples by using an applicator. Distilled water was applied to the samples with the help of an applicator every 5 seconds during brushing.

Sub-group 3: Home Bleaching Agent: The home bleaching agent (Opalascence, Utradent, USA) was applied to the polished upper surface of the samples by using an applicator, without applying pressure, in accordance with the manufacturer's instructions. The tested home bleaching agents and its composition is given in Table 2. The samples were kept in a closed container with moist cotton pellets at room temperature for 8 hours. After the bleaching agent application, the samples were washed under running tap for 10 seconds and kept in distilled water. The whitening process was continued in the same way for 14 days.

Coloring Procedure

After the initial color and roughness measurements of the samples were made, they were kept in each solution for 4 days respectively tea (Lipton Yellow Label, Unilever, Turkey), coffee (Nescafe Classic, Nestle, Turkey) and cherry juice (DimesFruit Juice, Dimes, Turkey) for simulating 1 year coloring procedure. At the end of the coloring processes, the samples were placed in opaque containers after washing under running tap for 10 seconds. During the entire staining procedure, solutions were refreshed daily and samples were kept at room temperature.

Measuring Color Change Values (ΔE)

Color measurements were made with a Vita Easyshade Advanced 4 (Vita Zahnfabrik, Bad Sackingen, Germany) spectrophotometer. Measurements were repeated three times for each sample, their averages were recorded as L0*, a0* and b0* values, and the device was calibrated after all three measurements. Color measurements were made in 4 stages: beginning, post-colouring, 7th day end of bleaching procedure and 14th day end of bleaching procedure. The following formula was used to calculate the ΔE values according to the CIELAB color system:

$$\Delta E^* = [(L1^*-L0^*)^2+(a0^*-a1^*)^2+(b0^*-b1^*)^2]^{½}$$

Measuring Surface Roughness Values

In the measurement of the surface roughness values of the samples; a profilometer device (Mitutoyo, surftest SJ-301, JAPAN) was used with a scanning length of 4 mm and a surface cutting length of 0.25 mm. The arithmetic average of the values obtained by measuring the roughness from three different regions of each sample was taken and calculated as the Ra value; It was recorded in 3 stages: at the beginning, after the coloring procedure and after the bleaching procedures.

SEM Analysis

After the roughness measurements of the samples were made after the bleaching procedures, 1 sample from each of the 15 subgroups was coated with 90 A° gold-palladium in an airless environment using a coating device (Quorum Q150R ES, UK) and then SEM images were examined under 20.000x and 50.000x magnification.

Statistical Analysis

Variation data of were analyzed using the SPSS statistical software program (22.0 version, SPSS Inc., Chicago, USA). The data were subjected to statistical analysis with using two-way analysis of variance and Tukey's test to examine pairwise differences at a significance level of 0.05.

Results

Color changes in composite specimens after coloring procedures are given in Table 3. The highest level of color change among composite groups was observed in the Zenchroma group following the Omnichroma group, while the lowest color change was observed in the Vittra group (Table 3). The differences between the vittra, charisma and asteria groups were insignificant ($p>0.005$), on the contrary differences between the other groups were statistically significant ($p<0.005$).The color changes in the composite specimens at the end of the 7th and 14th day after the bleaching procedures are given in Table 4. Color change values after the bleaching procedures were found to be higher in all groups on the 7th day compared to the groups brushed with distilled water while only Charisma Groups color change values were significant ($p<0.05$). On the 14th day, the differences in ΔE values between groups brushed with whitening toothpaste and distilled water were statistically significant in all composites except for Omnichroma ($p<0.05$). As a result of brushing with whitening toothpaste; while the highest whitening effect was seen in Charisma group, the least whitening effect was seen in Omnichroma group.

In all groups in which home bleaching agents were applied, a greater whitening effect was observed at the end of the day compared to the groups brushed with distilled water. But only Asteria and Charisma groups' color change values were observed significant changes ($p<0.05$). At the end of the 14th day, color change values in all groups applied with home bleaching agents were statistically significant (except for Vittra Unique). The maximum ΔE value was observed in the Asteria group, while the minimum ΔE value was observed in the Zenchroma group, and the differences between them were statistically insignificant ($p>0.05$). Although coloration and bleaching procedures applied to composite resins caused some changes in surface roughness values, the differences between them were statistically insignificant ($p>0.05$). When the composite groups were compared among themselves, at the end of the 14th day, the least roughness was observed in the groups that applied home bleaching agent, in the Asteria and Zenchroma groups, and the difference between the Charisma group was significant ($p<0.05$). Home bleaching agent application provided greater whitening effects in 7th day follow-ups compared to brushing with a whitening toothpaste, but similar whitening effects were observed as the end of 14th day(except for Omnichroma). SEM images of all the groups after bleaching procedures are given in figure 2-6.

Table 1. The tested composite resins and their compositions

Groups	Type	Filler Contents
Estelite Asteria	Supra- nano sferical	Bisphenol A di(2-hydroxy propoxy) dimethacrylate (Bis-GMA), Bisphenol A polyethoxy methacrylate (Bis-MPEPP), 1,6-bis(methacrylethyloxycarbonylamine) timethyl hexane (UDMA), triethylene glycol dimethacrylate (TEGDMA), Mequinol, Dibutyl hydroxyltoluene, UV absorbers, 82% by weight (71% by volume) silica zirconia fillers
Omnichroma	Supra- nano sferical	79% by weight (68% by volume) spherical silica-zirconia fillers (average particle size: 0.3 µm, particle size range: 0.2 to 0.4 µm) and composite fillers, 1.6-bis (methacryl-ethyloxy) carbonyl amine), trimethyl hexane (UDMA), Triethylene glycol dimethacrylate (TEGDMA), Contains Mequinol, Dibutyl hydroxyl toluene and UV absorber.
Vittra Unique	Zirconium oxide glass particle	Methacrylate monomer mixture UDMA, TEGDMA, photoinitiator composition (APS), initiators, stabilizers, silane, boron-aluminum-silicate glasses. (72-80% by weight, 52-60% by volume)
CharismaDiamond Topaz One	TCD matrix	Urethane dimethacrylate (UDMA), TCD- DI-HEA, Triethylene glycol dimethacrylate (TEGDMA), barium, Aluminum, boron, fluorine, silicon glass, PPF, silicon oxide 75% by weight (59% by volume) inorganic filler
Zenchroma	Radio-opaque glass with filler microhybrid	Glass powder, diurethane dimethacrylate, silicon dioxide, Bisphenol A dimethacrylate (Bis-GMA), tetramethylene dimethacrylate. 75% by weight (by volume 53% inorganic filler (0.005-3.0μm)

Table 2. The tested whitening agents and their compositions

Trade Name	Type	Contents	Company
Colgate Optic White Expert	Whitening Toothpaste	Glycerin, propylene glycol, sodium monofluorophosphate, calcium pyrophosphate, PEG-12, PVP, PEG/PPG-116/66 Copolymer, disodium pyrophosphate, pentasodium triphosphate, sodium laurly sulfate, silica, flavor, sodium saccharin, hydrogen peroxide, lemon	Colgate/Palmolive Company, New York, NY, USA
Opalescence	Home Bleaching Agent	16% Carbamide Peroxide, Deionized Water, 0.5% Potassium Nitrate, 0.11% Sodium Fluoride, Carbopol, Glycerin	Ultradent Products Inc, South, Jordan, Utah, USA

Table 3. Color change values after staining procedure

Groups	ΔE (mean)	(SD)
Estelite Asteria	11.39[a]	2.92
Omnichroma	16.08	2.11
Vittra Unique	7.97[b]	2.81
Charisma Diamond One	9.75[a.b]	2.75
Zenchroma	13.39	1.80

F=37.561, P=0.000, p<0.05, [a,b] there is a statistical no difference between the groups shown with the same lower case letters.

Table 4. Color change values after bleaching procedures, Mean Values (Standard Deviasion)

Whitening Procedures	Time	Estelite Asteria	Omnichroma	Vittra Unique	Charisma DiamondOne	Zenchroma
Brushing with Distilled Water	7th day	2.20 (0.66)[a]	2.61 (1.67)	3.15 (2.11)	1.99(0.48)[f.g]	2.23 (0.88)
	14th day	2.99 (0.53)[b.c]	3.34 (1.45)[d]	3.46 (1.52)[e]	3.00(0.59)[h.i]	2.84 (0.66)[k.l]
Brushing with Whitening Toothpaste	7th day	4.20 (1.27)	3.19 (0.56)	4.13 (2.46)	4.65 (0.91)[f]	3.09 (0.46)
	14th day	5.75 (0.88)[b]	4.30 (0.96)	5.94 (1.11)[e]	5.95 (1.00)[h]	5.65 (1.57)[k]
Application of Home Bleaching agent	7thday	5.18 (1.83)[a]	3.84 (0.92)	4.32 (1.12)	4.63 (0.89)[g]	3.61 (0.53)
	14th day	6.79 (1.17)[c]	5.93 (0.64)[d]	5.37 (1.05)	6.04 (1.49)[i]	5.31 (1.06)[l]

F=10.248, P=0.000, p<0.05, [a,b,c,d,e,f,g,h,i,k,l] there is a statistical difference between the groups shown with the same lower case letters.

Figure 1: Brushing simulator used for brushing the samples.

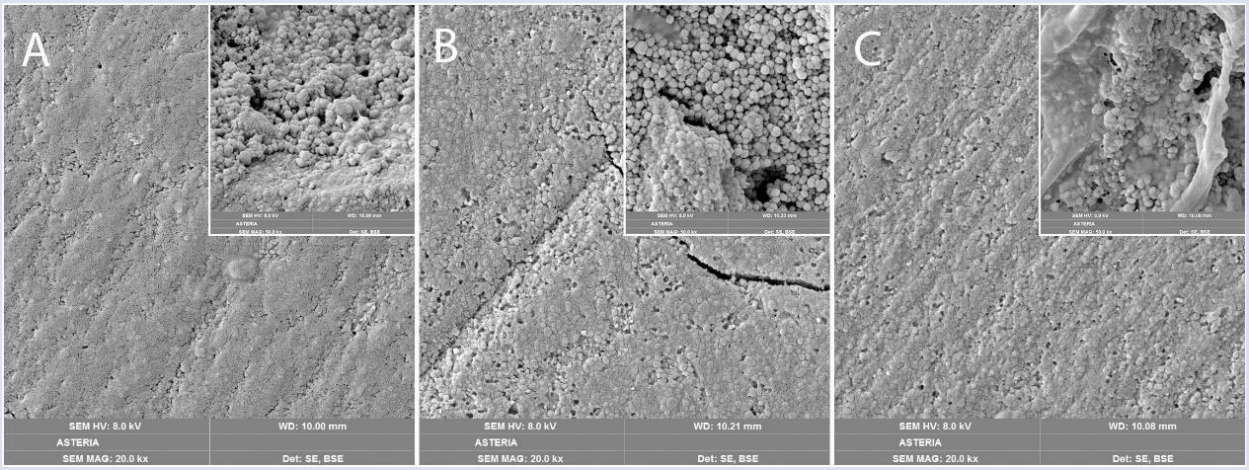

Figure 2: After bleaching procedures SEM images x20.000 x50.000 magnification respectively, Asteria Group, (A-Brushing Distiled Water, B- Brushing Whitening Toothpaste, C- Home Bleaching Agent Application).

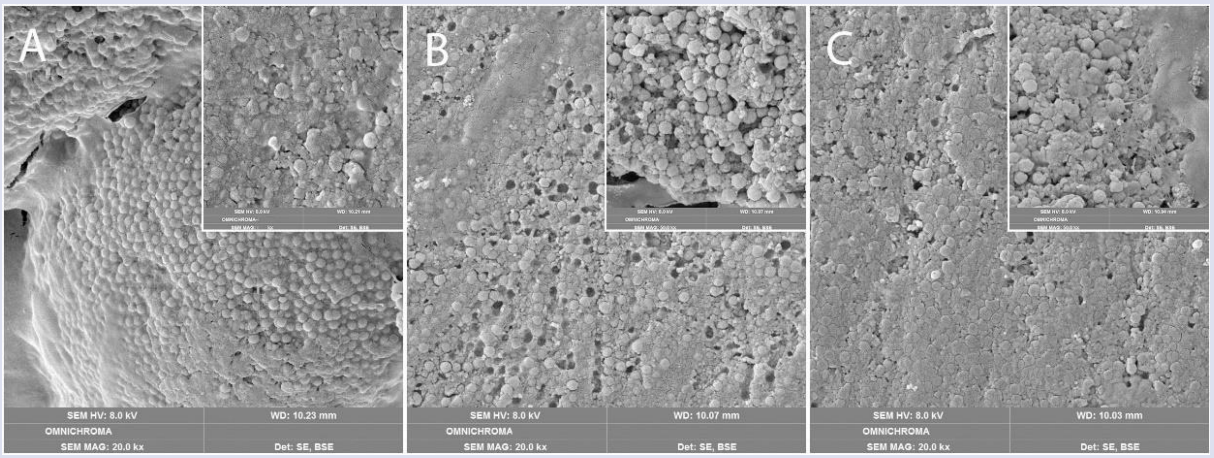

Figure 3: After bleaching procedures SEM images x20.000 x50.000 magnification respectively, Omnichroma Group, (A-Brushing Distiled Water, B- Brushing Whitening Toothpaste, C- Home Bleaching Agent Application).

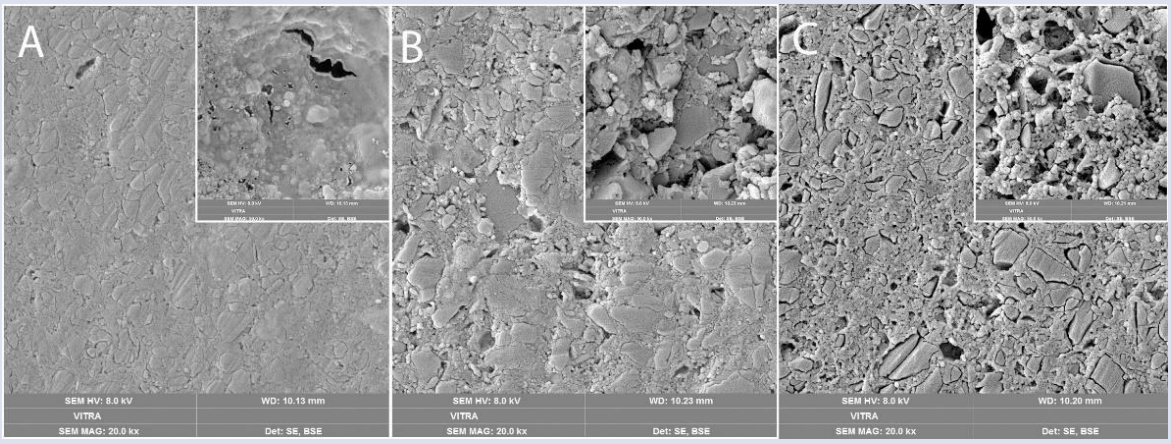

Figure 4: After bleaching procedures SEM images x20.000 x50.000 magnification respectively, Vittra Group, (A-Brushing Distiled Water, B- Brushing Whitening Toothpaste, C- Home Bleaching Agent Application).

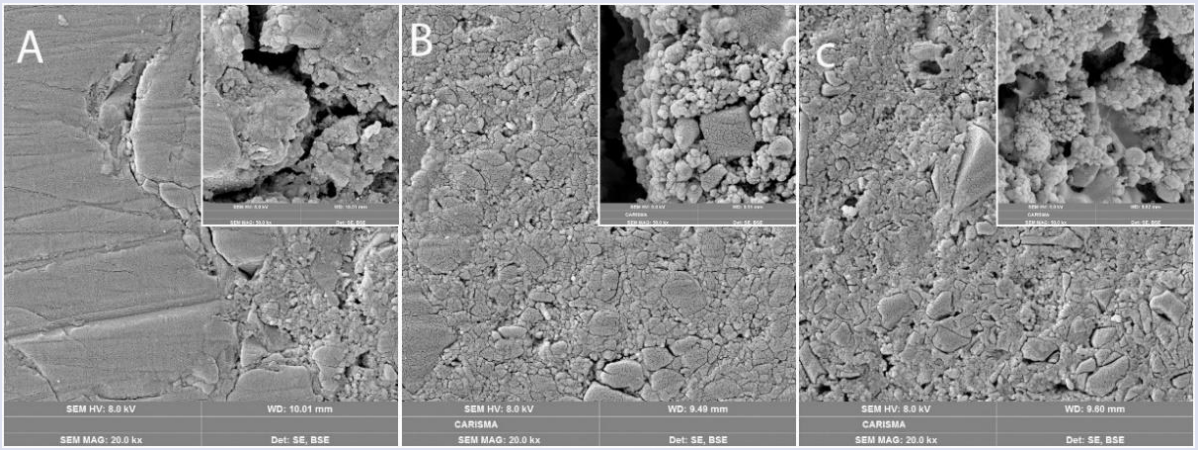

Figure 5: After bleaching procedures SEM images x20.000 x50.000 magnification respectively, Charisma Group, (A-Brushing Distiled Water, B- Brushing Whitening Toothpaste, C- Home Bleaching Agent Application).

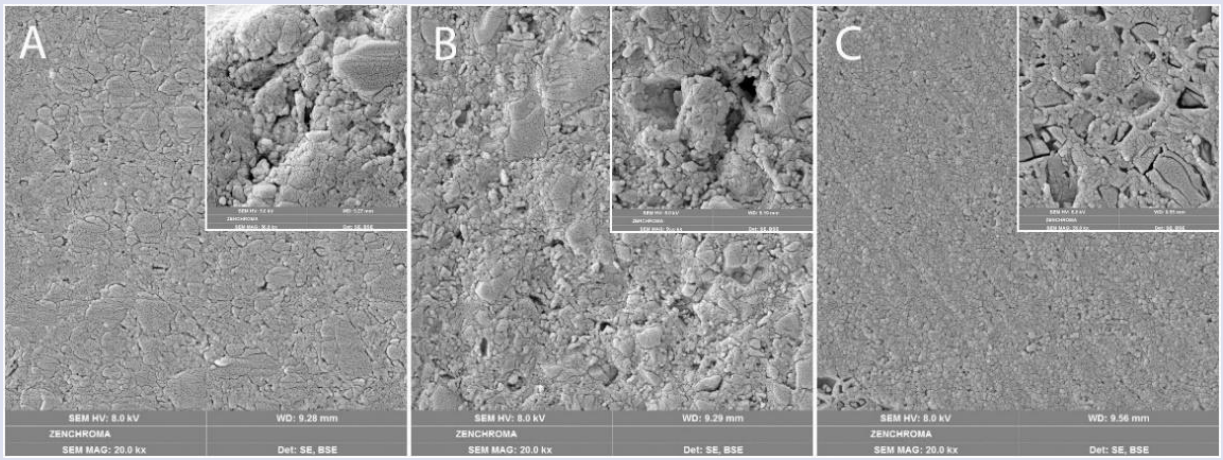

Figure 6: After bleaching procedures SEM images x20.000 x50.000 magnification respectively, Zenchroma Group, (A-Brushing Distiled Water, B- Brushing Whitening Toothpaste, C- Home Bleaching Agent Application).

Discussion

In clinical practice, multiple composites with different properties should be layered to create restorations compatible with the natural tooth structure, which entails a complex color selection process. To simplify this process, color adjustment resin-based composites that can match all shades with a single composite have been developed.[1,4] In De Abreu *et al.*[1]'s study examining restorations performed on teeth with different color properties, there was no significant difference in color harmony between single shade and multi shade composite resins.

Color is an important factor for optimum aesthetics in dental restorations. In addition to the initial color harmony, color stability is also one of the criteria that should be considered for the continuity of the optimum aesthetics of restorations. One of the main reasons for replacing composite resin restorations is the failure to achieve sufficient color stability.[25] Many factors such as the structure of the resin matrix, the amount of polymerization, oral hygiene, food and beverages, water absorption and surface roughness can affect the color change process of composite resin materials.[26]

In the literature review, although there are many studies on the color adjusting abilities of single shade composites, there is limited research on their color stability and mechanical properties. Therefore, in this study, we investigated the effect of brushing with whitening toothpaste on the color stability and surface roughness of four different single-shade resin-based composites after simulating 1-year coloring procedure.

Akgül *et al.*[29] investigated the color changes and surface roughness of different resin composites after immersing them in various solutions (distilled water, cola, coffee, and orange juice) for 12 days. All samples immersed in coffee showed significant color change. The least color change was observed in Filtek Universal composite while the highest color change was observed in Omnichroma composite. Fidan *et al.*[30] investigated the effect of coffee staining on color change and translucency

of different composite resins for 12 days in coffee. It was reported that both the highest color chance and highest translucency value were observed in the Omnichroma group. Aydin *et al.* [31] examined the effect of staining with coffee solution on surface roughness and color changes of a single shade composite (Omnichroma) and multiple shade composites. They reported that the highest coloration was observed in the Omnichroma group at all measurement times (1st, 7th, and 30th day) and this result may be related to the hydrophilic nature of TEGDMA monomer present in Omnichroma's organic structure.

In various studies[28-30], it has been reported that TEGDMA and Bis-GMA in the composite resin matrix structure exhibit more hydrophilic properties than UDMA and Bis-EMA, and the addition of TEGDMA to the matrix structure to dilute Bis-GMA and UDMA increases hydrophilicity, leading to more coloration in composite resins as hydrophilic character increases.

Ilie[32] investigated the aging behavior, quasi-static and viscoelastic behavior analyses of universal chromatic resin-based composites. As a result, they stated that the mechanical properties of the Omnichroma composite are lower than the Venüs Pearl One (≅ Charisma Diamond One) composite. The reason for the low stability of the Omnichroma against aging procedures; It has been reported that the production of inorganic fillers by clustering around an organic-inorganic core using by sol-gel method may be due to the observation of a more porous and weak structure in the interphase (Figure 3-A). In addition, the better mechanical properties of Venüs Pearl One composite might releated that the urethane groups in the TCD matrix structure facilitate the polymerization reaction, enabling the formation of multiple polymer chains and contributing to the color stability by reducing the amount of residual monomer.

In this study, the highest color change was observed in the Omnichroma composite group following the coloring procedure. The result of this study, Akgul et al.[29], Fidan et al.[30], Aydın et al.[31] and Ilie[32] consistent with the results of their study. Omnichroma's low color stability possibly be related to the effect of TEGDMA hydrophilic character however TEGDMA is also present in the structures of the other composites (except Zenchroma) in this study. Therefore color stability could be not only releated composite resins's hidrophilic characters but also differences in inorganic filler types and sizes, differences in photo initiators and the presence of pre-polymerized monomers.

Graf and Ilie[33] examined the long-term mechanical properties and translucency characteristics of color-matching resin-based composites. They found that the TCD matrix structure of the organic matrix in Charisma Diamond One improves the mechanical properties of the material and creates a structure that is more resistant to aging processes. Additionally, they reported that the presence of additional pre-polymerized monomer in the organic matrix structure of Charisma Diamond One may contribute to the long-term mechanical stability of the composite (Figure 4-B).

Pedrosa *et al*. [34] compared the color stability of different composite resins after polymerization and water storage (30 days). While Vittra APS showed the least color change after polymerization, the highest color change was observed after water storage. The least color change after water storage was observed in the Z350XT and Charisma Diamond One. They suggested that the minimal color change of Vittra APS after polymerization may be due to the different photoinitiator system.

Özara *et al.*[35] investigated the color stability of different resin materials after being stored in different beverages (coffee, tea, cola, and saliva) for 14 days. While Charisma Diamond One showed the highest color change in cola, it showed less color change in other beverages. They stated that the higher color stability of Charisma Diamond One may be due to its hydrophobic structure.

In literature review, we could not come across a study specifically focused on the color stability of Zenchroma composite. Atalı *et al.*[36] compared the physical and mechanical properties of different shade-matched resin-based composites. They stated that the composites with the highest conversion degree were Vittra APS Unique and Charisma Diamond One, followed by Zenchroma and Omnichroma. As the degree of conversion increased, the mechanical properties of the material improved and the color stability increased.

In this study, the least color change after the coloring process was in Vittra APS and Charisma, followed by Asteria and Zenchroma. The reason why the highest color stability was seen in the Vittra APS in the studies of Pedrosa *et al.* [34] was releated might be due to the composition, which is free of Bis-GMA and smaller quantities of campheroquinone. Researchers stated that the campheroquinone/amine and BisGMA/TEGDMA ratios play an important role in the coloring of the composites and that the a* and b* values from the color coordinates vary depending on these ratios. In this study, while a significant increase was observed in b* parameters in Charisma, Omnichroma and Zenchroma groups depending on the tea and coffee we used in the coloring procedure, while a very little change was observed in the b* parameter in the Vittra Unique.

In the literature, there is no direct study on brushing with whitening toothpaste and the application of home bleaching agent to color-adjustment resin-based composites. In their study, Mehrgan *et al.*[38] investigated the effects of brushing with different whitening toothpastes on coffee-stained Spectrum TPH composite samples over a period of two weeks. According to their results, the whitening toothpaste containing 2% hydrogen peroxide (Colgate Optic White) was more effective than abrasive-containing and charcoal-containing whitening toothpastes.

Similarly, Al-Shalan *et al.*[39] investigated the effect of brushing with different whitening toothpastes on the color stability of cylindrical samples prepared using different restorative materials. The samples were subjected to brushing with the whitening toothpastes for 1 hour, twice daily for 15 days to simulate brushing habits. They reported that the glass ionomer cement group brushed with Colgate Optic White Expert toothpaste showed important color change.

In various studies, the perception of the human eye was determined as a reference for the color change to be clinically

acceptable. It has been reported that the critical threshold values for visual perception should be above ΔE ≥3.3.[38,39] As a result of this study, all color-adjustment resin-based composites had an effective whitening efficacy above clinically acceptable threshold value (ΔE ≥3.3) after brushing with whitening toothpaste and home bleaching procedures. The highest whitening effect was observed in Charisma (ΔE=5.95) and Vittra APS (ΔE=5.94), and the least color change was observed in Omnichroma composite (ΔE=4.30). The reason for this may the micro pits formed as a result of the very intense separation of relatively large spherical fillers (260nm) from the surface during brushing when the Sem images of Omnichroma were examined in our study (Figure 3-B).

Villata *et al.*[39] investigated the effects of 2 staining solutions (coffee and red wine) and 3 bleaching systems on the color stability of two dental composites. They reported that agents containing carbamide peroxide with different concentrations were effective in removing coloration regardless of concentration ratios. Asdagh *et al.*[40] applied composite restorations (Gradia Direct, GC/Japan) to Class V cavities prepared on extracted central teeth, followed by 14 days of tea staining. They reported that the application of a whitening agent containing 10% carbamide peroxide for 14 days (8 hours a day) after staining was effective on both teeth and composite resins. Similarly, in this study, the highest color change was observed in the Asteria composite (ΔE=6,79), while the least color change was observed in the Zenchroma composite (ΔE=5,31) after home bleaching agent applying. These differences between all composites were not statistically significant (p>0.05).

Amaral *et al.* [42] compared the effects of brushing with 5 different toothpastes using a simulator on the surface roughness of the resin materials. They stated that the experimental paste containing 1.5% hydrogen peroxide and Rembrant Plus Whitening containing 3.6% hydrogen peroxide had the lowest roughness values and also reported that low concentrations of hydrogen peroxide in the toothpastes did not increase surface roughness.

Demir et al[43.] investigated the effect of manuel brushing (electric toothbrush) using different toothpastes on the color stability and surface roughness of colored composite disc samples (6 x 2 mm). As a result of the study, they stated that while the color change was observed the most in the colgate optic white, the surface roughness of the samples in this group were increased.

Yüzügüllü *et al.*[44] examined the effect of home bleaching agent containing %20 carbamide peroxide on the surface roughness of composite resins for 8 days (6 hours per day). They reported that there was no significant difference between samples applied bleaching agent and stored in distilled water in terms of surface roughness.

In another study, Sharafeddin *et al.*[45], investigating the effect of high concentration bleaching agent (35% carbamide peroxide) application on the surface hardness and roughness of composite resins, and they reported that carbamide peroxide application did not have a significant effect on the surface roughness of composites.

Similarly in this study, although a slight increase in surface roughness values were observed in all composite groups after bleaching procedures, these differences were found to be statistically insignificant (p>0.05) (Table 4). Our study results are parallel with the findings of Amaral *et al.*[42], Yüzügüllü *et al.*[44] and Sharafeddin *et al.*[45] in terms of not observing a significant change in surface roughness. On the other hand, results of this study are in conflict with Demir *et al's* [43] study results. The reason of difference may be related that the composition of composites with different contents, variations in brushing time and polishing systems. In addition, the use of a brushing simulator in this study may have contributed to achieving more realistic results by minimizing the variables depending on the practitioner.

Conclusions

All color- adjustment resin based composites showed coloration above the clinically acceptable threshold in this study. The least color change was observed in Vittra Unique composite while the highest color change was observed in Omnichroma composite, Home bleaching agent application provided greater whitening effects in short-term follow-ups compared to brushing with a whitening toothpaste, but similar whitening effects were observed as the duration extended (except for Omnichroma). Further, whitening procedures did not negatively affect the surface roughness of all color-adjustment resin-based composite resins.

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Conflicts of Interest Statement

None.

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