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Effect of Whitening Mouthwashes on Color Change of Colored One Shade Composite Resins

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ABSTRACT

Aim: The aim of this study was to evaluate the effects of different whitening mouthwashes on the color change of stained four different one-shade composite resins and to compare them with a multi-shade composite.
Materials and Methods: A multi-shade (Filtek Ultimate) and four one-shade (Omnichroma, Charisma Diamond One, Essentia Universal, Vittra Unique) composite resins were used. A total of 160 samples, 32 of each composite were prepared and the initial color parameters of the composite samples were measured with a spectrophotometer and the composite samples in each group were divided into four groups (n=8). Then, the samples were kept in coffee and second color measurements were made. After the samples were kept in four whitening mouthwashes (Colgate Optic White, Listerin Advanced White, Pasta del Capitano Whitening, SPLAT® Professional Bio-Active), third color measurements were made and color changes were calculated with the CIEDE2000 formula. Statistical analyzes were performed using one-way ANOVA and post-hoc Tukey's test.
Results: The color changes observed in the stained composite resins after immersion in mouthwash were statistically significant, varying by mouthwashes and composites ($p \leq 0.05$). Average color change values ($\Delta E00$) were between 0.85 and 4.87. While the highest color change was observed in the Charisma Diamond One group using Pasta del Capitano Whitening ($\Delta E00=4.87$), the lowest color change in all groups was observed in the use of SPLAT® Professional Bio-Active.
Conclusion: One-shade composites showed more color change than the multi-shade composite, with variations depending on the mouthwash used. Almost all groups, whitening mouthwashes caused a color change above the perceptibility threshold level.

Beyazlatıcı Etkili Gargaraların Renklendirilmiş Tek Renk Kompozit Rezinlerin Renk Değişimi Üzerine Etkisi

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ÖZET

Amaç: Bu çalışmanın amacı farklı beyazlatıcı ağız gargaralarının renklendirilmiş dört farklı tek renk kompozit rezinin renk değişimi üzerine olan etkilerini değerlendirmek ve çoklu renk sistemine sahip bir kompozitle karşılaştırmaktır.
Gereç ve Yöntemler: Çalışmada bir çoklu renk sistemine sahip estetik kompozit (Filtek Ultimate) ile dört tek renk kompozit (Omnichroma, Charisma Diamond One, Essentia Universal, Vittra Unique) olmak üzere beş farklı kompozit rezin kullanıldı. Her kompozitten 32 toplamda 160 örnek hazırlandı. Kompozit örneklerin ilk renk parametreleri bir spektrofotometre ile ölçüldü ve her gruptaki kompozit örnekler rastgele dört gruba ayrıldı ve örnekler numaralandırıldı (n=8). Daha sonra kahvede bekletilen örnekler yıkandıktan sonra ikinci renk ölçümleri yapıldı. Örnekler dört beyazlatıcı etkili ağız gargarasında (Colgate Optic White, Listerin Advanced White, Pasta del Capitano Whitening, SPLAT® Professional Bıo-Active) bekletildikten sonra üçüncü renk ölçümleri yapıldı ve renk değişimleri CIEDE2000 formülüyle hesaplandı. İstatistiksel analizler one way ANOVA ve post-hoc Tukey's testi kullanılarak yapıldı.
Bulgular: Renklendirilen kompozit rezinlerin gargarada bekletilme sonunda görülen renk değişimleri kullanılan gargaraya ve kompozitlere göre istatistiksel olarak farklı bulundu ($p \leq 0,05$). Ortalama renk değişim değerlerinin ($\Delta E00$) 0,85 ile 4,87 aralığında olduğu tespit edildi. Kompozitler içinde en çok renk değişimi Charisma Diamond One grubunda Pasta del Capitano Whitening gargara kullanımında gözlemlenirken ($\Delta E00=4,87$), grupların tamamında en düşük renk değişimi SPLAT® Professional Bio-Active kullanımında gözlendi.
Sonuç: Tek renk kompozitler çoklu renk sistemine sahip kompozitten daha fazla renk değişimi göstermiştir ve kullanılan gargaralara göre değişim miktarı farklılık göstermiştir. Grupların genelinde beyazlatıcı ağız gargaraları algılanabilirlik eşik düzeyinin üzerinde bir renk değişimine neden olmuştur.

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INTRODUCTION

Since whiter teeth are considered more aesthetically acceptable by individuals, whitening discolored teeth is one of the most commonly performed procedures in clinical practice.[1, 2] The natural color of the crown part of a human tooth is predominantly white, with slight yellow tones that reflect the color of the dentin beneath the translucent enamel, along with minimal amounts of red tones.[3] Tooth discolorations are classified into two main groups: intrinsic and extrinsic discolorations. Whitening procedures are typically used for external discolorations. In external discoloration, changes in tooth color typically result from pigments that come into significant contact with teeth, such as cigarettes, beverages, and foods, as well as antibiotics, and metals like iron or copper and environmental factors and these colored compounds obtained from these sources can be absorbed into the tooth surface, causing staining to occur.[4, 5]

Teeth whitening is a process performed to lighten and whiten the teeth. Whitening can be achieved through physically removing discoloration or staining, or by chemically whitening or lightening the tooth color through a chemical reaction. The active ingredient in most whitening products is hydrogen peroxide or carbamide peroxide, which breaks down to release hydrogen peroxide. Additionally, various chemicals and natural agents are often added to whitening agents for their whitening purposes. There are various types of products used for teeth whitening purposes. There are many products marketed for teeth whitening purposes, including toothpastes and mouthwashes with higher amounts of detergents and abrasive substances to help remove chromogens from tooth surfaces; whitening agents that react with chromogens to lighten color; products that enhance both cleaning and whitening effects; and whitening strips designed to whiten teeth gradually.[5] More severe or complex discolorations are best treated with professional whitening, whereas for milder cases and daily use, over-the-counter products that are more easily accessible may be preferred. One of the most commonly used materials among these are mouthwashes (mouthrinses). Some of these moutwashes are combined with whitening agents to create whitening mouthwashes, which are marketed for their whitening effects.

Today, with the rapid developments in aesthetic composite resins, one shade composite resins have been introduced to the market, which are color compatible with all 16 colors in the VITA scale and providing comprehensive color matching capabilities thanks to the advanced chameleon and blending effect, and to eliminate the treatment complexity arising from the layering technique.[6, 7] Most studies on tooth color change focus on dental enamel, highlighting the importance of color stability in the success of aesthetic dental restorations. As a result, there is increasing interest in the ability of restorative materials to resist color changes over time. Many studies have shown that factors influencing tooth color can similarly affect aesthetic restorative materials, especially composite resins.[8, 9] Composite resins differ significantly from dental enamel in terms of composition and chemical as well as physical properties. Therefore, when exposed to the same color change factors, they are likely to be affected to varying degrees. This variability can lead to color mismatch, treatment failures, and patient dissatisfaction.[10]

The clinical success of composite resin restorations depends on achieving perfect color matching with natural teeth. Therefore, it is crucial to fully understand the effects of whitening agents on resin composites as well. The literature currently has limited studies on the color change (or color recovery) of one shade composite resins, a popular product today, especially after staining and the use of

whitening products. The aim of this study was to evaluate the effects of different whitening mouthwashes on the color change (color recovery) of stained four different one-shade composite resins and to compare them with a multi-shade composite resin. The null hypothesis of the study was that whitening mouthwashes applied to composites colored with coffee would not significantly change the color of the composites and that the color changes would not be affected by the type of mouthwash and composite.

MATERIALS AND METHODS

In the present study, five different composite resins were used, including one aesthetic composite resin with a multi-shade color system (Filtek Ultimate, A2 Body, 3M ESPE, USA) as a control group and four one shade composite resins [(Omnichroma, Tokuyama, Japan), (Charisma Diamond One, Kulzer, Germany), (Essentia Universal, GC Corp., Japan), (Vittra Unique, FGM Dental, Brazil)]. Detailed information about the composite resins used is presented in Table 1.

Table1: The composite resins used in the study

Composite Resins	Filler Type	Composition	Manufacturer
Filtek Ultimate, A2 Body (control) (multi-shade)	Nanofilled	Bis-GMA, UDMA, Bis-EMA, PEGDMA, TEGDMA, Zirconia, Silica	3M ESPE, St. Paul, MN, ABD
Omnichroma (one-shade)	Spherical Nanofilled	UDMA, TEGDMA, uniform sized supra-nano spherical filler (260 nm spherical SiO_2-ZrO_2) and composite fillers	Tokuyama Dental, Tokyo, Japan
Charisma Diamond One (one-shade)	Nanohybrid	advanced TCD matrix, BPA-free, and BrF B_2O_3-F-Al_2O_3-SiO_2, silica, TiO_2, fluorescent pigments, metallic oxide pigments, organic pigments,	Kulzer, Hanau, Germany
Essentia Universal (one-shade)	Microhybrid	UDMA, Bis-MEPP, Bis-EMA, Bis-GMA, TEGDMA, Prepolymerized fillers, Barium glass, Silica	GC Corp., Tokyo, Japan
Vittra APS UNIQUE (one-shade)	Nanohybrid	UDMA, TEGDMA, advanced polymerization system(APS) composition, co-initiators, silane, boron-aluminum-silicate glass	FGM Dental, Joinville, Brazil

Abbreviations: Bis-GMA: Bisphenol A-diglycidyl methacrylate; UDMA: Urethane dimethacrylate; Bis-EMA: Ethoxylated bisphenol A glycol dimethacrylate; PEGDMA: Polyethylene glycol dimethacrylate; TEGDMA: Triethylene glycol dimethacrylate; TCD: Tricyclodecane; BPA: Bisphenol A; Bis-MEPP: bisphenol-A ethoxylate dimethacrylate.

In this study, each group being divided into four subgroups based on the moutwashes used with α set at 0.05, β set at 0.10, (1-β) set at 0.80 and effect size set at 0.278; it was determined that n=8 samples would be taken from each subgroup, yielding a total sample size of N = 160. The power of the test p=0.80424 was found. Samples were prepared by using plastic molds measuring 8 mm in width and 2 mm in depth, resulting in a total of 160 samples with 32 samples from each composite resin. After placing the composite resins into the plastic molds, polyester strips were placed over them. Subsequently, the samples were positioned between two microscope slides and a slight pressure was applied to create a flat surface. Following this, the samples were light-cured using an LED light device (Valo Cordless, Ultradent Products Inc., South Jordan, UT, USA) with a light intensity of 1000 mw/cm² for 20 seconds on their upper surfaces. After the polymerization process, the samples were removed from the molds and subjected to surface treatments using a disc polishing system (Sof-Lex, 3M ESPE, USA).

Afterward, the samples were immersed in

distilled water at 37°C for 24 hours. The initial color parameters of the composite samples were measured using a clinical type spectrophotometer (Vita Easyshade Compact, Vita Zahnfabrik, Germany) based on the CIE L*a*b* color scale. Following color measurement, the L_1, C_1, H_1, a_1 and b_1 values were recorded, and the composite samples in each group were randomly divided into four groups and numbered (n=8).

Then, the samples were immersed in filter coffee prepared with 4g coffee / 200 ml boiling water (Tchibo Gold Selection, Tchibo GmbH, Hamburg, Germany) at 37°C for 24 hours (equivalent to 1 month of use).[11] After washing and drying the samples using absorbent paper, second color measurements were taken, and L_2, C_2, H_2, a_2 and b_2 values were recorded. The color change ($\Delta E_{00\ 2\text{-}1}$) that occurred after waiting in the coffee was analyzed with the CIEDE2000 formula shown in Figure 1. The analysis was performed using the Excel spreadsheet application of the CIEDE2000 color difference formula.[12]

Figure 1: CIEDE2000 color difference formula

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

Afterwards, the samples were immersed in four different whitening mouthwashes at 37°C for 24 hours (equivalent to daily use of 2 minutes for 2 years).[13, 14] In the study, the following 4 mouthwashes were used: Colgate Optic White (GABA International AG, Therwil, Switzerland), Listerine Advanced White (Johnson & Johnson, Skillman, NJ, USA), Pasta del Capitano Whitening (Farmaceutici Dott. Ciccarelli S.P.A., Milano, Italy), and Splat Professional Bio-Active (Splat-Global, Novgorod, Russia). Detailed information about these mouthwashes is presented in Table 2. After immersing the samples in the four whitening mouthwashes for 24 hours, third color measurements were taken. L_3, C_3, H_3, a_3 and b_3 values were obtained, and the color changes ($\Delta E_{00\ 3\text{-}2}$) induced by immersion in the mouthwashes after staining were analyzed using the CIEDE2000 formula.

Table 2: The moutwashes used in the study

Mouthwash	Composition	Manufacturer
Colgate Optic White (COW)	Aqua, Glycerin, Sorbitol, Propylene Glycol, PVM/MA Copolymer, Tetrapotassium Pyrophosphate, Polysorbate 20, Sodium Fluoride, Sodium Saccharine, CI 42051	GABA International AG, Therwil, Switzerland
Listerine Advanced White (LAW)	Water, Alcohol, Sorbitol, Tetra Potassium Pyrophosphate, Penta Sodium Triphosphate, Citric Acid, Poloxamer 407, Flavors, Sodium Saccharin, Sucralose, Sodium Fluoride, SodiumBenzoate, Tetra SodiumPyrophosphate, Menthol, Eucalyptol, Thymol, Aroma, Propylene Glycol, Disodium Phosphate.	Johnson & Johnson, Skillman, NJ, USA
Pasta del Capitano Whitening (PDC)	Aqua, Glycerin, Alcohol, Potassium Citrate, Polisorbate 20, PVP, PEG-40, Sodium Benzoate, Aroma, Betaine, Lactic Acid, Sodium Lactate, Sodium Bicarbonate, Sodium Fluorit, Sodium Monoflorophasphate, SodiumSaccarin, Eugenol, Limonen, CI47005, CI 42051.	Farmaceutici Dott. Ciccarelli S.P.A., Milano, Italy
Splat Professional Bio-Active (SPL)	Water, Hydrogenated Starch Hydrolysine, PVP, Polyglyceryl-4 Lourate/Sebacate, Polyglyceryl-6 Caprylate/Caprate, Sodium Coco-Sulphate, Aroma, Cyclodextrin, Zinc Gluconate, Citrus Lemon Peel Oil, Pineapple Fruit Extract, Maltodextrin, Thyme Oil, Licorice Root Extract , Stevia Leaf Extract, Glycerin, Pentylene Glycol, ida Ferment Lysate, Phthalimido-peroxy-caproic acid, Potassium Thiocyanate, Lacoein, Lactoperoxidase, Glucose Ondase, Glucose Pentaacetate, Sodium Benzodl, Potassium Sorbate, Benzyl Alcohol, Limonene, Citral, Linalool	Splat-Global, Novgorod, Russia

Abbreviations: PVM/MA: Polyvinyl methyl ether/Maleic anhydride; PVP. Poly- Vinyl Pyrrolidone; PEG: Polyethylene glycol.

Statistical Analysis

Based on the data obtained in the study, statistical evaluations were performed using IBM SPSS version 22.0 for Windows (SPSS, Chicago, IL, USA). Firstly, the normality and homogeneity of the data were assessed using the Kolmogorov-Smirnov and Levene tests, respectively. Subsequently, the data were analyzed using one-way ANOVA (analysis of variance). Post hoc pairwise comparisons were conducted using the Tukey test with a significance level (α) set at 0.05.

RESULTS

As a result of statistical evaluation of color change values, the color change ($\Delta E_{00\ 2\text{-}1}$) seen in composite resins colored with coffee were found to be statistically different compared to the composites used ($p \leq 0.05$). The average $\Delta E_{00\ 2\text{-}1}$ values observed after immersion in coffee are presented in Table 3. After immersion in coffee, the greatest color change was observed in the Charisma Diamond Diamond One group, while the least color change was observed in the Essentia Universal group. Essentia Universal showed color change similar to the multi-shade composite resin Filtek Ultimate as control group.

The color changes (color recovery) ($\Delta E_{00\ 3\text{-}2}$) observed in composite resins stained with coffee after immersion in mouthwashes were found to be statistically different based on the mouthwash used and the composites ($p \leq 0.05$). It was determined that the average color change values ($\Delta E_{00\ 3\text{-}2}$) of composite resins stained with coffee and subsequently immersed in mouthwashes ranged from 0.85 to 4.87 (Table 4). After immersion in mouthwashes, the highest color change was observed in the Charisma Diamond One group when using PDC mouthwash (ΔE_{00}=4.87), while the lowest color change was observed in the Filtek Ultimate group when using SPL (ΔE_{00}=0.85).

Table 3: Average color change ($\Delta E_{00\ 2\text{-}1}$) and standard deviation values of composites after immersion in coffee

	$\Delta E_{2\text{-}1}$
Filtek Ultimate (control)	3.49* (0.39)
Omnichroma	3.89 (0.43)
Charisma Diamond One	5.46 (0.64)
Vittra APS Unique	4.72 (0.54)
Essentia Universal	3.24* (0.33)
p value	<0.01

* indicates statistically similar groups. $p<0.05$ indicates statistical differences between groups.

Table 4: Average color change ($\Delta E_{00\ 3\text{-}2}$) and standard deviation values of stained composite resins after immersion in mouthwashes

	COW	LAW	PDC	SPL	p values
Filtek Ultimate (control)	1.74 (0.18) ^{A}	1.91 (0.22) ^{A}	1.87 (0.23)^{A}	0.85 (0.13) ^{B}	0.03
Omnichroma	2.62 (0.32) ^{CK}	2.44 (0.30) ^{CJ}	3.08 (0.29) ^{D}	1.91 (0.20) ^{A}	<0.001
Charisma Diamond One	4.04 (0.53) ^{E}	4.41 (0.49) ^{F}	4.87 (0.54) ^{G}	3.43 (0.36) ^{H}	<0.001
Vittra APS Unique	3.23 (0.29) ^{DH}	3.41 (0.31) ^{H}	4.00 (0.47) ^{E}	2.40 (0.28) ^{CJ}	<0.001
Essentia Universal	2.35 (0.29) ^{J}	2.80 (0.34) ^{K}	3.34 (0.33) ^{H}	1.71 (0.15) ^{A}	<0.001

* Same uppercase superscripts indicate groups showing statistically similar color change

The least color change was observed in all composite resins when using SPL. The highest color change values were observed when using PDC, excluding the Filtek Ultimate group. After immersion in mouthwashes, the least color change was observed in the Filtek Ultimate group as control group across all mouthwash groups, while the highest color change was observed in the Charisma Diamond One group across all mouthwash groups.

When examining color parameters separately, after immersion in coffee, a decrease in L* values was observed (Table 5), whereas an increase was observed after immersion in mouthwashes. For a*, and b* values, an increase was observed after immersion in coffee, while a decrease was observed after immersion in mouthwashes (Table 5).

Table 5: Average L* (Lightness), a* and b* values of samples before coloring with coffee (L_1, a_1, b_1); after coloring (L_2, a_2, b_2) and after waiting in mouthwash (L_3, a_3, b_3).

	L_1	L_2	L_3		a_1 / b_1	a_2 / b_2	a_3 / b_3	
Filtek Ultimate (control)	83.9	78.8	***COW***	81.2	1.1 / 28.0	1.5 / 28.8	***COW***	1 / 28.0
			LAW	80.9			***LAW***	0.5 / 26.7
			PDC	81.0			***PDC***	0.6 / 27.0
			SPL	80.0			***SPL***	1.3 / 28.7
Omnichroma	82.0	78.9	***COW***	80.9	-3.7 / 9.8	-2.9 / 14.0	***COW***	-3.5 / 11.0
			LAW	81.5			***LAW***	-3.4 / 11.8
			PDC	81.9			***PDC***	-3.6 / 11.0
			SPL	79.1			***SPL***	-3.4 / 11.4
Charisma Diamond One	79.4	74.9	***COW***	78.4	-1.7 / 9.0	-0.7 / 15.3	***COW***	-1.8 / 11.0
			LAW	79.0			***LAW***	-1.8 / 10.8
			PDC	79.3			***PDC***	-1.8 /10.1
			SPL	77			***SPL***	-1.2 / 10.6
Vittra APS Unique	82.8	79.8	***COW***	81.6	-2.3 / 6.0	-2.1 / 11.8	***COW***	-2.2 / 7.6
			LAW	82			***LAW***	-2.6 / 7.7
			PDC	82.7			***PDC***	-2.3 / 7.0
			SPL	80.4			***SPL***	-2.5 / 8.6
Essentia Universal	80.2	76.2	***COW***	78.3	1.5 / 21.7	2.0 / 24.9	***COW***	1.1 / 21.5
			LAW	79			***LAW***	1.2 / 21.1
			PDC	79.6			***PDC***	1.0 / 20.5
			SPL	77.3			***SPL***	1.4 / 22

DISCUSSION

There are numerous studies focusing on the changes that mouthwashes cause in the color parameters of composite resins; however, studies specifically related to color change of stained composite resins (especially one-shade composites) are limited.[13, 15-19] In the present study evaluating the color change (color recovery) of one-shade composites stained with coffee using whitening mouthwashes, significant color changes were observed in all groups. It was observed that this change varied statistically depending on the type of composite and mouthwash used. Therefore, the null hypothesis was rejected.

Due to dissatisfaction with tooth color among patients and their desire for whitening, the use of over-the-counter whitening products has increased in recent years. Products claiming to provide whitening effects have also gained popularity. Among these products, mouthwashes are prominent due to their ease of use, low cost, and ready availability. In recent years, mouthwashes containing whitening agents have become popular due to their perceived whitening effects. Therefore, our

study evaluated the impact of these whitening mouthwashes on the color change (whitening effect) of stained composites.

In dentistry, color selection or determination of restoration color compatibility can be achieved through visual inspection or with the assistance of various devices. In the study, to obtain objective results and eliminate human errors, [4] a clinical type of spectrophotometer was used. Although different color systems such as CIELAB (ΔE_{ab}) and CIEDE2000 (ΔE_{00}) are used in the analysis of color changes, it has been stated in studies that the CIEDE2000 color system is superior to the CIELAB color system in determining perceptibility and acceptability.[20, 21] Therefore, in our study, we used the CIEDE2000 (ΔE_{00}) color system and formula for analyzing color changes.

When reviewing the literature, there are various opinions regarding the perceptibility and acceptability of color changes in restorations[22]. Recently, Paravina et al.[21] indicated threshold values where they defined the perceptibility threshold as ΔE_{00}=0.8 and the acceptability threshold as ΔE_{00}=1.8. They also reported in their study that the ΔE_{00} value should be greater than 1.8 in order for whitening to be interpreted as effective.[21] When the ΔE_{00} values obtained as a result of the present study were examined, it was found that all of the obtained values were higher than the perceptibility threshold value (ΔE_{00}>0.8) and effective whitening was achieved in almost all of the groups (ΔE_{00}>1.8), except for a few groups.

Whitening agent application can cause changes in the color of existing restorative materials due to the breakdown of large pigment molecules.[23] Changes in the color of restorative materials are attributed to the oxidation of surface pigments and amine compounds.[15, 24] The amount of resin matrix and the degree of polymerization of the resin matrix can lead to differences in color changes among different restorative materials.[25, 26] The chemical agents used during whitening not only affect teeth but can also impact existing restorations due to their organic matrix content, potentially causing color changes. Variations in the composition of composites used in this study, including differences in resin matrix formulations, may have led to varying degrees of color change in composite resins.[27] One shade composite resins are composites that do not contain color pigments and have color matching ability. Changes made to the composition of one shade composites [28] and color matching abilities of them may explain more color variation compared to multi-shade composite. In this study, similar to the study of Fidan and Yağcı [29], the most coloration and the most color change after waiting in mouthwash were found in the Charisma Diamond One group. The significant color variation observed in Charisma Diamond One compared to the other materials may be due to the presence of filler particles, which can result in inadequate cross-linking between the polymer matrix and the fillers.[30] The tricyclododecane monomer found in Charisma Diamond One exhibits a considerable affinity for coffee, a low-polarity beverage. This characteristic may explain the monomer's contribution to the material's decreased color stability.[29,31] The high color change observed in Charisma Diamond One after soaking in mouthwash can also be attributed to its higher translucency.[32] However, studies on the color change of this material as a result of the application of whitening agents are limited.[29]

Studies investigating color changes after whitening procedures have reported that the results are influenced by the concentrations of whitening agents, exposure durations, and particularly the composition of the test materials.[24, 33] Whitening effective mouthwashes contain various ingredients aimed at whitening and preventing discoloration, such as peroxide derivatives, sodium hexametaphosphate, pyrophosphate, sodium citrate, plasdone (polyvinylpyrrolidone or PVP), phthalimido-peroxy-caproic acid, detergent derivatives, and some enzymes.[34-37] Hydrogen peroxide (HP) is a common bleaching agent used both in professional clinical settings and in products for at-home use.[38, 39] HP is a potent oxidizing agent that breaks down long-chain organic pigment

molecules into shorter-chain compounds, thereby facilitating bleaching.[40] However, due to its short shelf life and safety restrictions, its use in mouthwashes is problematic, and typically, mouthwashes contain low concentrations of HP, around 1%-2%.[35, 41] The mouthwashes used in this study do not contain HP.

Various phosphate derivatives such as pyrophosphates and hexametaphosphates have strong binding affinities and can desorb stain components from the tooth surface.[35] The presence of sodium hexametaphosphate and pyrophosphate in whitening agents prevents to being adsorbed onto the tooth surface.[35, 36] Plasdone (PVP), is a water-soluble polymer with high solubility and can form complexes with catechins and other coloring agents, that removes them from the surface of teeth and reduces discoloration.[42] Phthalimido-peroxy-caproic acid is a synthetic organic peroxy acid derived from caproic acid and phthalimide and has high oxidation potential with active oxygen release.[37] In this study, when reviewing the whitening materials in mouthwashes, COW and LAW contain pyrophosphate derivatives, PDC contains Plasdone (PVP), and SPL contains both PVP and phthalimido-peroxy-caproic acid. Among these mouthwashes, excluding the Filtek Ultimate group, PDC was found to be the most effective mouthwash for color recovery of composite resins. Interestingly, SPL, despite containing PVP like PDC, resulted in the lowest color recovery. This could be due to SPL's composition using organic components instead of chemical ones found in other mouthwashes, and its lack of alcohol content, which may not effectively interact with the resin matrix. When examining the color change (recovery) values among groups, although statistically different, some groups showed similar values between LAW and COW.

In the study, when examining the L* values obtained and showed Table 5, after immersion in coffee, the L_2 values showed a decrease compared to the initial values L_1. However, after immersion in mouthwash, the L_3 values showed an increase. This indicates that the mouthwashes shifted the lightness values of the composites from darker to lighter shades, demonstrating a whitening effect. Looking at the a* and b* values obtained, after immersion in coffee, the a_2 and b_2 values showed an increase compared to the initial values a_1 and b_1. On the other hand, after immersion in mouthwash, the a_3 and b_3 values showed a decrease. This situation indicates that after immersion in coffee, the color of composite resins shifts towards the yellowness and redness axes (increased a* and b* values), whereas after using mouthwash, it shifts back towards the blueness and greenness axes (decreased a* and b* values). Additionally, Patent Blue V (Color Index 420151), found in COW and PDC, may contribute to the increased a* value.[35] Similar to this study, Harorli and Barutcugil[35], Bilgili Can and Özarslan[40] have reported that samples immersed in mouthwash after staining recovered their color in their respective studies.

As every in vitro study, this study has some limitations. The present study has limitations such as not being able to imitate the real oral environment exactly, not having a cleaning effect of saliva, not forming a pellicle structure, and the absence of brushing. Furthermore, in vivo studies are needed to better analyze the effects of whitening mouthwashes.

CONCLUSION

Within the limitations of the study; stained one-shade composite resins showed more color change (color recovery) than the multi shade composite, and the amount of change varied depending on the mouthwash used. Almost all groups, whitening mouthwashes caused a color change above the perceptibility threshold level.

Ethical Approval

Since this study did not involve any human or animal subjects, ethical committee approval was not required.

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Conflict of Interest

The authors deny any conflicts of interest related to this study.

Author Contributions

Design: NŞ, EB, Data collection and processing: NŞ, EBG, VK, Analysis and interpretation: VK, Literature review: VK, NŞ, Writing: NŞ, EBG, VK.

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