ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

DOI: 10.5336/dentalsci.2020-76235

Effects of Bleaching Agents on Surface Roughness and Color Change of Discolored Resin Composites

Beyazlatma Ajanlarının Renklenmiş Rezin Kompozitlerin Yüzey Pürüzlülüğü ve Renk Değişimine Etkileri

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ABSTRACT Objective: The aim of this study was to evaluate the effects of 2 home bleaching agents [16% carbamide peroxide (CP) and 6% hydrogen peroxide (HP)] on the color change and surface roughness of discolored anterior and posterior resin composites. **Material and Methods:** Estelite Sigma Quick (ES) and Estelite Posterior (EP) resin composites were used in the present study. A total of 60 samples were prepared (thirty samples from each resin composite). Samples were immersed into the coffee solution throughout the 12 days. Samples were randomly divided into 3 groups, to applying 2 different bleaching agents and a control group (n=10). Bleaching agents were applied for 14 consecutive days. The color changes of the samples were measured at 3 different times, baseline (T0), after discoloration (T1) and bleaching procedures (T2). Surface roughness changes were measured at T1 and T2. Color differences were calculated using the CIEDE 2000 (ΔE_{00}) formula. Differences were analyzed using one way, two-way analysis of variance and Tukey multiple comparison tests. **Results:** ΔE_{00} values showed significant differences after coffee immersion and bleaching applications in both resin composites ($p<0.05$). Immersion in coffee caused more color change in EP samples (ΔE_{00}=12.46±0.47). Bleaching agent was a significant factor for the color recovery in ES samples ($p<0.05$). CP application in ES groups and HP application in EP groups increased the surface roughness ($p<0.05$). **Conclusion:** Bleaching agents used in the present study showed color recovery effect on discolored resin composites. The potential effect of bleaching agents on surface roughness and the sensitivity of the posterior resin composites to discoloration should be considered in restorative treatment.

Keywords: Bleaching; color stability; resin composite; surface roughness

ÖZET Amaç: Çalışmanın amacı, renklenmiş anterior ve posterior kompozitlerde 2 farklı ev tipi beyazlatma ajanının [%16 karbamid peroksit (KP) ve %6 hidrojen peroksit (HP)] renk değişimine ve yüzey pürüzlülüğüne etkisini değerlendirmektir. **Gereç ve Yöntemler:** Çalışmada, Estelite Sigma Quick (ES) ve Estelite Posterior (EP) kompozitleri kullanıldı. Her kompozit grubundan otuzar örnek olacak şekilde toplamda 60 örnek hazırlandı. Örnekler, 12 gün boyunca kahve solüsyonu içerisinde bekletildi. Ardından 2 farklı beyazlatma ajanı ve bir kontrol grubu olmak üzere örnekler rastgele 3 gruba ayrıldı (n=10). Renklenen örneklere, 14 gün boyunca beyazlatma ajanları uygulandı. Örneklerin renk değerleri, 3 ayrı zamanda başlangıç (T0), renklenme sonrası (T1) ve beyazlatma sonrası (T2) ölçüldü. Pürüzlülük değerleri ise T1 ve T2'de ölçüldü. Renk değişimleri CIEDE 2000 (ΔE_{00}) formülü ile hesaplandı. Elde edilen sonuçlar, tek ve çift yönlü varyans analizi ile çoklu karşılaştırmalı Tukey testleri kullanılarak analiz edildi. **Bulgular:** Her 2 kompozit grubunda da kahvede bekletmeden sonra ve beyazlatma uygulamasından sonra ΔE_{00} değerlerinde anlamlı bir farklılık gözlemlendi ($p<0,05$). Kahvede bekletme EP örneklerinde daha faza renk değişikliğine neden oldu(ΔE_{00}=12,46±0,47). ES grubunda, KP ve HP anlamlı bir farklılık gösterdi ($p<0,05$). ES grubunda, KP uygulaması ve EP grubunda, HP uygulaması yüzey pürüzlülüğünü artırdı ($p<0,05$). **Sonuç:** Çalışmada kullanılan her 2 beyazlatma ajanı, renklendirilmiş kompozitlerin rengi üzerinde beyazlatıcı etki gösterdi. Beyazlatıcı ajanların yüzey pürüzlülüğüne potansiyel etkisi ve posterior kompozitlerin renk değişimine duyarlılığı, restoratif tedavide göz önünde bulundurulmalıdır.

Anahtar Kelimeler: Beyazlatma; renk stabilitesi; rezin kompozit; yüzey pürüzlülüğü

Tooth bleaching which is one of the esthetic approaches, has become popular in the last two decades. Since it is a non-invasive procedure and preferred to remove tooth discoloration.[1] Bleaching systems can generally be classified as office bleaching, home bleaching and over-the-counter products.[2] Home

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Peer review under responsibility of Turkiye Klinikleri Journal of Dental Sciences.

Received: 12 May 2020 ***Received in revised form:*** 23 Jul 2020 ***Accepted:*** 01 Sep 2020 ***Available online***: 02 Feb 2021

bleaching became popular later than office bleaching. Clinicians have different alternatives for home bleaching agent with low concentrations of hydrogen peroxide (HP) or carbamide peroxide (CP).[2] However, high concentrations of HP or CP can be applied by a clinician in clinic.[3] Home bleaching procedures are more popular than office-type ones due to some advantages. These include lower risk and tooth sensitivity, lower costs and fewer visits.[4] Another advantage is that bleaching agents's exposure time on dental hard tissues and restorations is longer during home bleaching applications than office type.[5] Home bleaching agents breakdown large pigmented molecules by decomposition of peroxides into stable free radicals.[6] Because of the longer exposure time, home bleaching agent application may cause an alteration on the color of pre-existing restorative materials.[7,8] Researchers reported that the color of restorative materials may vary due to the oxidation of surface pigments and amine compounds. The degree of conversion and amount of resin matrix have been attributed for color variations of different restorative materials.[9,10]

Since the acidic component in the bleaching agent causes chemical reaction in the organic matrix, resin composite materials especially are more prone to color change compared to other materials.[11,12] Additionally this chemical reaction may accelerate the hydrolytic degradation and induce oxidative cleavage of polymer chains in resin matrix which may change the surface characteristics.[11,13-15]

Color stability of resin composites is influenced by various intrinsic and extrinsic factors.[16] Intrinsic factors leading to discoloration are reported that the variations of filler or matrix contents of resin composites and inadequate polymerization. Extrinsic factors may include adsorption and absorption of stains on exposure to various beverages, tobacco, and other food color additives.[17,18]

Various studies evaluated the color change of the materials after bleaching applications and claimed that concentrations and exposure time of bleaching agents and the composition of experimental material effect the results.[6,16,17,19-26] Therefore; the aim of the present study was to evaluate the color recovery and surface roughness effect of two home bleaching agent which include different active ingredients (16% CP and 6% HP) on discolored anterior and posterior composites. The null hypothesis is that the bleaching agents will not effect color change and surface roughness of the resin composites.

MATERIAL AND METHODS

SAMPLE PREPARATION

Sixty disk-shaped A2 shade resin composite samples were made with the Estelite Sigma Quick (Tokuyama Dental, Tokyo, Japan) (ES) and Estelite Posterior (Tokuyama Dental, Tokyo, Japan) (EP) resin composites (thirty samples from each resin composite). The contents of the materials are shown in Table 1.

The samples were prepared by using a teflon mold (8 mm in diameter and 2 mm in thickness). A transparent polyester strip (Hawe, Kerr Dental, CA, USA) was placed between the mould and a glass slide and then lightly pressed with a glass slide to remove the excess materials. Polymerization was performed with a light-emitting diode curing unit (Elipar S10; 3M ESPE; St. Paul, Minnesota) at a light intensity of 1,200 mW/cm^2 for 40 seconds. The tip of the light

TABLE 1: Details of the investigated materials.

Codes	Materials	Manufacturer	Composition
ES	Estelite Sigma Quick	Tokuyama Dental, Tokyo, Japan	Resin matrix: Bis GMA/TEGDMA Filler: ZrO2-SiO2, wt/vol 82/71
EP	Estelite Posterior	Tokuyama Dental, Tokyo, Japan	Resin matrix: Bis GMA/TEGDMA, Bis MEPP; Filler: ZrO2-SiO2, wt/vol 84/70
CP	Opalescence PF 16%	Ultradent, South Jordan, UT, USA	Home bleaching, carbamide peroxide 16%
HP	Opalescence Go 6%	Ultradent, South Jordan, UT, USA	Home bleaching, hydrogen peroxide 6%

Bis GMA: Bisphenol A-glycidyl methacrylate; TEGDMA: Triethylene glycol dimethacrylate; Bis MEPP: 2,2-bis-[4-(2-methacryloyloxy ethoxy) phenyl] propane.

curing unit was in contact with the glass. The surface of each sample was polished with 800 to 1,200 silicon carbide grit. Then, samples were stored in distilled water for 24 h.

DISCOLORATION PROCEDURE

All the samples were immersed in the coffee during 12 days. The coffee (Nescafe Classic) was renewed every day. In a previous study it was claimed that the coffee cup consumption per day is 3.2 g and the average time consumption is 15 minutes (48 minutes per day). Thus, one month of consumption is equivalent to 1,440 minutes (24 hours). Therefore, samples were immersed in the coffee for 12 days which is equivalent to 1 year of coffee consumption.[27]

BLEACHING PROCEDURE

Groups and treatments were designed as follows (n=10):

Group 1: 16% CP group. Bleaching agent was applied for 6 h per day for 14 consecutive days.

Group 2: 6% HP group. Bleaching agent was applied for 90 min per day for 14 consecutive days according to the manufacturers' instructions.

Group 3: Control-Non-bleaching group. Distilled water was used which renewed for 14 days.

After daily bleaching procedure, samples were cleaned with water for 1 minute, dried and stored in distilled water until the next day. When the bleaching process was completed, samples were washed, dried and ready to color and surface roughness measurements.

COLOR CHANGE MEASUREMENT

A spectrophotometer (VITA Easyshade V, VITA Zahnfabrik) was used to detect the color changes. The device was calibrated using a calibration block according to the manufacturer's instructions before measuring. Color measurements were performed with D65 illumination. The probe tip was placed at the center of each sample. The measurement procedures were repeated three times. The average of the data was recorded. Samples were placed on a white background to eliminate background light. The same operator performed all the procedures. The color measurements were made on three occasions: baseline (T0), after 12 days of staining (T1) and after bleaching for a period of 14 days (T2). Color changes were calculated with the CIEDE 2000 (ΔE_{00}) formula.

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

ΔL', ΔC' and ΔH' define the changes in lightness, chroma and hue differences between the two samples. S_L, S_C and S_H are the weighing functions for the lightness, chroma and hue parameters. K_L, K_C and K_H are the regulated factors with respect to different observed parameters and were accepted 1 according to other studies.[28,29] The clinical acceptability threshold was set at 2.25 ΔE_{00} units as mentioned by Ghinea et al.[30] The color differences were evaluated by comparisons with 50:50% perceptibility and 50:50% acceptability thresholds. The perceptibility (0.81 units) and acceptability (1.77 units) values for CIEDE 2000 (1:1:1) were obtained from a recent study.[31]

SURFACE ROUGHNESS MEASUREMENTS

The mean roughness of the samples was evaluated using a profilometer (Marsurf M 300 C, Mahr, Gottingen, Germany) before and after bleaching, using a standardized tip. The device was calibrated as recommended by the manufacturer. The profilometer tip was (Marsurf PS1) contact with samples surface and three measurements were made from different parts then a mean of the data was calculated for each sample.[18]

STATISTICAL ANALYSIS

SPSS 22.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. After verifying the normality, one-way ANOVA was used for each parameter, the two-way ANOVA and Duncan multiple comparison tests were used for the interaction between the type of bleaching agent and the resin composite. $p<0.05$ is statistically significant.

RESULTS

All of the samples showed clinically unacceptable color changes after immersion in coffee ($\Delta E_{00}>2.25$). Coffee caused more discoloration in EP groups than ES groups ($p<0.05$) (ES: ΔE_{00} 7.93±0.72; EP: ΔE_{00}

TABLE 2: Mean color changes (ΔE_{00}), standard deviations and mean Ra values of resin composites.

	Coffee staining	p value	After bleaching		p value	Ra after bleaching
Estelite Sigma Quick			CP	8.07±1.18^{a}		2.61±0.35^{a}
	7.93±0.72		HP	5.08±0.80^{b}	p=0.03	1.80±0.05^{b}
		p=0.000	CONT	1.43±0.11^{c}		1.81±0.10^{b}
Estelite Posterior						
			CP	10.64±0.56^{a}		2.10±0.06^{b}
	12.46±0.47		HP	10.78±0.56^{a}	p=0.004	2.60±0.04^{a}
			CONT	2.72±0.67^{b}		1.86±0.09^{c}

There is no statistical difference with the same letter.

CP: Carbamide peroxide; HP: Hydrogen peroxide; CONT: Control.

12.46±0.47). Mean ΔE_{00} values and standard deviations after immersion in coffee are presented in Table 2.

The bleaching applications resulted in a significant decrease in the DE_{00} values of EP and ES groups ($p=0.03$; $p<0.05$). The mean DE_{00} values after bleaching with CP (16%) and HP (6%) showed that; bleaching agent was a significant factor for the color recovery in ES groups ($p=0.004$; $p<0.05$). CP showed more color recovery effect than HP (Table 2 and Figure 1). The mean DE_{00} values and standard deviations after bleaching are presented in Table 2.

In the analysis of surface roughness, the bleaching processes with CP in ES groups and HP in EP groups caused statistically significant increase in surface roughness ($p<0.05$) (Figure 2). Mean Ra values and standard deviations are presented in Table 2.

DISCUSSION

The color recovery and the surface roughness effect of two different home bleaching agents (16% CP and 6% HP) were compared in the present study. The null hypothesis is that the bleaching agents will not effect color recovery and surface roughness of the resin composites was rejected.

Researchers reported that bleaching agents have different effects on different restorative materials. Therefore, clinicians should be careful in choosing restorative materials and bleaching agents.[32-34]

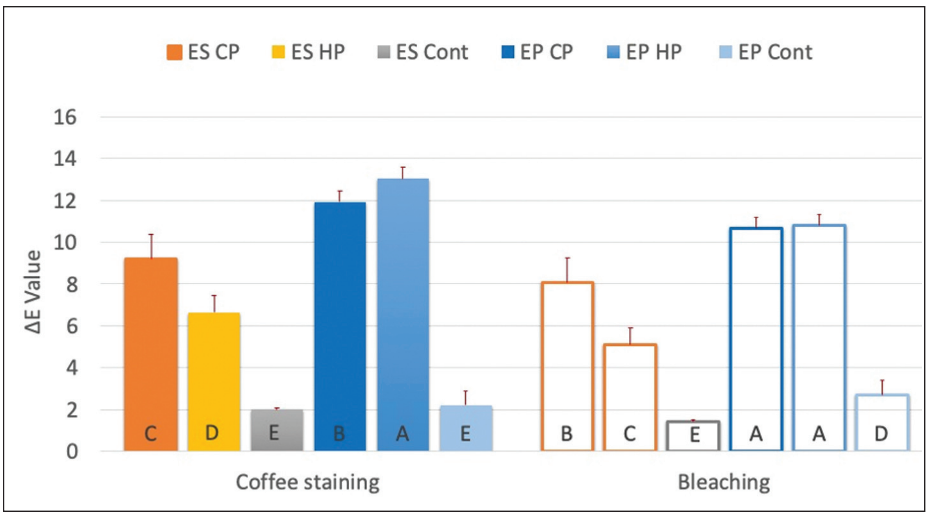

FIGURE 1: ΔE values of ES and EP groups after coffee staining and bleaching. Data are the mean ΔE values of independent experiments. The bars with different letters are significantly different ($p<0.05$).

ES: Estelite Sigma Quick; CP: Carbamide peroxide; HP: Hydrogen peroxide; EP: Estelite Posterior.

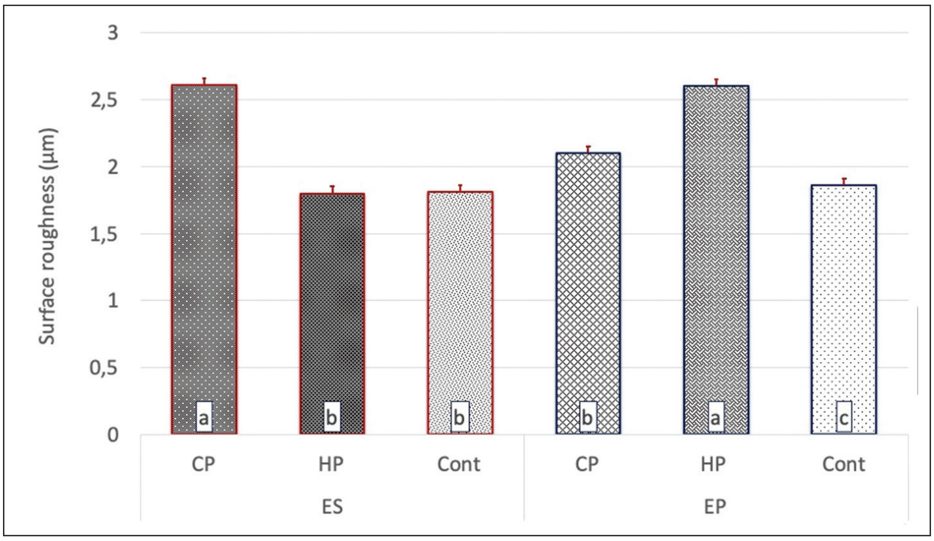

FIGURE 2: Surface roughness values of ES and EP groups after bleaching. Data are the mean roughness values of the independent experiments. The bars with different letters are significantly different ($p<0.05$).
ES: Estelite Sigma Quick; CP: Carbamide peroxide; HP: Hydrogen peroxide; EP: Estelite Posterior.

Replacement of the resin composite restorations because of the discoloration is still a major problem.[33] Color change degree originate from both intrinsic and extrinsic factors and effected the degree of polymerization, water sorption, eating habits, oral hygiene, and the regularity of restoration surfaces.[35] Surface roughness is an important problem for clinicians, because of plaque accumulation and coloration.[36-38]

Color changes were calculated with the CIEDE 2000 formula in the present study. Researchers reported that this formula is actual for assessment of color changes.[39] 2.25 for ΔE_{00} was accepted for color difference threshold using CIEDE 2000 formula.[39] According to a study, these values were annoying by 50% of the observers.[40] As a result of the present study, coffee caused perceptible discoloration of both composite samples ($\Delta E_{00}>2.25$). Tannins, caffeine and caffeic acid in coffee and less polar colorants can go deep into the material and cause discoloration.[18,24,41]

Hydrophilicity of the resin matrix may be interralate to stain susceptibility of composites. Therefore they can absorb water and other colorant solutions resulted color change of resin composites.[34] In the present study, EP groups showed most color change after immersion in coffee. This could be attributed to the structure of this composite, which mainly consists of triethylene glycol dimethacrylate (TEGDMA) and 2,2-bis-[4-(2-methacryloyloxyethoxy) phenyl] propane (Bis-MPEPP). The presence of the hydrophilic ethoxy group in TEGDMA, may lead to increased water sorption and hence increasing the staining susceptibility.[42]

ES has prepared by a sol-gel method which made them uniformly spherical and include supra-nano particles with a particle size of 0.2 µ. Particules distributed evenly in the resin matrix. EP has (mean particle size 2 µm, which equals 2,000 nm) bigger particle size. In nanohybrid composites, smaller voids remain on the surface after polishing procedures. It was reported that when the filler particle size and irregular-shape fillers of the composite increase, the surface roughness values increase proportionally.[41] So, shapes and sizes of the fillers in ES could have attributed with the color stability and surface roughness difference in the present study.

Filler shape and size, chemical integration of the fillers and matrix, staining solution, the occlusal load, and the finishing and polishing applications affect the surface roughness of a resin composite.[27] Many researchers claimed that the surface roughness of composites increased after bleaching applications.[8,32,33] In the present study, the bleaching processes with CP in ES groups and HP in EP groups caused statistically significant increase in surface roughness. Similar to this study, Gurgan and Yalcin reported that both HP and

CP increased the surface roughness of the materials.[43] Different results have been reported in a review involving studies evaluating the effect of bleaching agents on the surface properties of composite resins. It is claimed that the differences in results may be attributed with the bleaching agent and its concentration, resin composites that used and the presence of saliva.[10]

It is not clear how exactly bleaching agents affect the restorative material. CP breakdowns into HP and urea in aqueous solution. It is estimated that the active agent HP penetrates the restoration surface and weakens the bond between the staining agent and the resin composite.[26] Many reseachers reported that staining on composite restoration can be removed by bleaching.[6,9,10] Canay ve Cehreli claimed that 10% HP provided better color changes compared with 10% CP, and there was clinically noticeable color change in HP samples.[6] A study by Fay et al. showed that 10% CP successfully removed stains from resin composite samples.[44] Differences in studies might be attributed to different active ingredient contents, different application times and resin composite materials.

Researchers reported that the pH of the home bleaching agents was in general fairly neutral, ranging from 5.66 to 7.35 with a mean of 6.48.[45] The pH of the bleaching agents used in the study was also between 5.5- 6.5; enabled effective bleaching on discolored composites.

The limitations of this study were the lack of saliva and use of a single shade of composites. The different shades and presence of saliva may affect the discoloration and whitening processes.

CONCLUSION

Within the limitations of this study, it was shown that posterior resin composite (EP) showed more discoloration than anterior resin composite (ES). The color recovery and surface roughness effect of tested home bleaching agents over discolored resin composite samples were significant. The active ingredient of bleaching agent was an effective factor for the color recovery and surface roughness process of resin composite. Different bleaching agents with different ingredient could cause varied color recovery and roughness results on different resin composites.

Acknowledgement

The authors thank to Prof. Zeki Kara, MD for his contribution to the statistical evaluation.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Makbule Tuğba Tunçdemir;* ***Design:*** *Makbule Tuğba Tunçdemir, Tuğba Temizci;* ***Control/Supervision:*** *Makbule Tuğba Tunçdemir, Tuğba Temizci;* ***Data Collection and/or Processing:*** *Makbule Tuğba Tunçdemir, Tuğba Temizci;* ***Analysis and/or Interpretation:*** *Makbule Tuğba Tunçdemir, Tuğba Temizci;* ***Literature Review:*** *Makbule Tuğba Tunçdemir, Tuğba Temizci;* ***Writing the Article:*** *Makbule Tuğba Tunçdemir, Tuğba Temizci;* ***Critical Review:*** *Makbule Tuğba Tunçdemir, Tuğba Temizci;* ***References and Fundings:*** *Makbule Tuğba Tunçdemir, Tuğba Temizci.*

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