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Effect of Toothpaste with Blue Covarine on Color Stability and Demineralization after Bleaching Treatments

Mavi Kovarin İçeren Diş Macununun Beyazlatma Tedavilerinden Sonra Renk Stabilitesi ve Demineralizasyon Üzerindeki Etkisi

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ABSTRACT

Objective: The aim of this study is to investigate the effect of toothpaste containing blue covarine after in-office and at-home bleaching treatments on color stability and demineralization of enamel.

Methods: Sixty patients aged between 18 and 30, with at least four anterior teeth of color A2 or above, were divided into three groups: light-activated in-office bleaching treatment with 25% HP bleach, in-office chemical bleaching treatment with 40% HP bleach, and home bleaching treatment with 16% CP content. After bleaching, each group was divided into two subgroups, using toothpaste containing blue covarine and conventional toothpaste (n = 10). Color changes were measured using a spectrophotometer initially, immediately after bleaching treatment, and at one-week and one-month follow-up periods. Demineralization levels were measured using a laser fluorescent device. Data were analyzed using repeated measures analysis of variance and multivariate analysis of variance with statistical significance.

Results: In terms of color change, at-home bleaching differed significantly from in-office bleaching treatments (P<.05). Toothpaste containing blue covarine after in-office and at-home whitening treatments exhibited no significant difference from traditional toothpaste in terms of color stabilization and demineralization (P>.05).

Conclusion: The use of blue covarine-containing toothpaste after in-office and at-home bleaching has similar effect on color stabilization and demineralization as only silica-containing toothpaste.

Keywords: Blue covarine, color stability, demineralization, home bleaching, office bleaching, whitening toothpaste

ÖZ

Amaç: Bu çalışmanın amacı, ofiste ve evde uygulanan beyazlatma tedavilerinden sonra mavi kovarin içeren diş macununun minenin renk stabilitesi ve demineralizasyonu üzerindeki etkisini araştırmaktır.

Yöntemler: En az dört ön dişi A2 veya üzeri renkte olan, 18 ila 30 yaşları arasındaki altmış hasta üç gruba ayrıldı: %25 HP ağartıcı ile ışıkla aktive edilen ofis tipi beyazlatma tedavisi, %40 HP ağartıcı ile ofis tipi kimyasal beyazlatma tedavisi ve %16 CP içerikli ev tipi beyazlatma tedavisi. Beyazlatmadan sonra, her grup mavi kovarin içeren diş macunu ve geleneksel diş macunu kullanan iki alt gruba ayrıldı (n = 10). Renk değişiklikleri başlangıçta, beyazlatma tedavisinden hemen sonra ve bir haftalık ve bir aylık takip dönemlerinde bir spektrofotometre kullanılarak ölçüldü. Demineralizasyon seviyeleri lazer floresan cihazı kullanılarak ölçüldü. Veriler, istatistiksel anlamlılık düzeyinde tekrarlayan ölçümler varyans analizi ve çok değişkenli varyans analizi ile değerlendirildi.

Bulgular: Renk değişimi açısından, evde yapılan beyazlatma, ofiste yapılan beyazlatma tedavilerinden önemli ölçüde farklıydı (P<,05). Ofiste ve evde yapılan beyazlatma tedavilerinden sonra mavi kovarin içeren diş macunu, renk stabilitesi ve demineralizasyon açısından geleneksel diş macunundan önemli bir fark göstermedi (P >,05).

Sonuç: Ofiste ve evde yapılan beyazlatmadan sonra mavi kovarin içeren diş macununun kullanılması, renk stabilitesi ve demineralizasyon üzerinde yalnızca silika içeren diş macunuyla benzer etkiye sahiptir.

Anahtar Kelimeler: Mavi kovarin, renk stabilitesi, demineralizasyon, evde beyazlatma, ofiste beyazlatma, beyazlatıcı diş macunu

INTRODUCTION

Tooth bleaching, which occupies an important place in esthetic dentistry, is an effective, conservative and low-cost method applied in the treatment of tooth discoloration. Vital teeth discolored due to various reasons are whitened using peroxide-containing gels.[1] Bleaching treatments performed either at home

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or in the office come with various advantages and disadvantages. Patient-applied whitening may seem to be more advantageous than in-office bleaching applications, since it uses lower-concentration hydrogen peroxide (HP) gels and is less costly. However, this method also presents several disadvantages, such as a lengthy treatment duration, treatment success depending on the motivation and capability of the patient, some patients being unable to tolerate night plaques, the possibility of soft tissue irritations, low-concentration carbamide peroxide (CP) gels proving ineffective on dark gray and-or brown stained teeth, and the potential for over-the-counter (OTC) products to be improperly used by patients.[2] Although office-type applications use high-concentration HP gels and involve greater costs, they also offer a number of advantages, such as being personally applied by the dentist, not requiring plaques, better protection of soft tissues thanks to gingival barriers, and most importantly, the treatment being completed in a shorter timeframe.[3]

In addition to in-office and at-home bleaching procedures, OTC whitening products with low HP levels (3%-6%), including whitening toothpastes and mouthwash solutions, are attracting increasing consumer interest.[2] A new advancement in teeth bleaching is an improvement in the perception of tooth whiteness.[4] This theory states that a change in color from yellow to blue is an important parameter of teeth bleaching, and that a decrease in the value of the b* color parameter is the most important indicator of teeth whitening.[5] Blue covarine particles have been reported to cause an optical change (yellow to blue) when deposited on tooth enamel, causing teeth to appear whiter. Optical pigments such as blue covarine have been added to the content of toothpastes to give the impression of whiter teeth.[6]

Although the effects of HP bleaching treatment on enamel have not been clearly demonstrated, some studies have reported that it causes chemical, structural, and morphological changes, and that the bleaching process causes a decrease in the abrasion resistance and microhardness of the enamel.[7] Mineral loss in this context is due to hydroxyapatite crystal dissolution. Calcium and phosphorus ions are the main components of the hydroxyapatite crystal. This is associated with the release of calcium and phosphorus ions and causes a decrease in enamel properties during the bleaching treatment.[8] Often, saliva increases the microhardness of bleached enamel by supplying phosphate and calcium ions. Also, other active substances added to the structure of whitening agents create an active environment to reduce demineralization or to promote remineralization in enamel.[9]

Bleaching efficiacy and especially color retention is an important issue for treatment. In the literature, different results have been shown. Some studies have reported tooth color remained stable throughout the observation period,[10,11] whereas others have reported regression of color at the end of the observation period.[12] Staining agents might contribute to the color regression of bleached teeth. The whitening effect after dental bleaching can be maintained through the use of whitening mouthrinses and toothpastes.[13] Based on the information provided, this study aimed to analyze both office and home bleaching systems containing different concentrations of HP and CP bleaching agents routinely used in bleaching processes. The objective was to compare their effectiveness, demineralization-remineralization levels, and tooth sensitivity. Additionally, the study sought to evaluate the effectiveness of toothpastes containing blue covarine in maintaining bleaching treatment outcomes.

The null hypotheses of this study were as follows:

1. There is no difference between office bleaching and home bleaching in terms of the effectiveness of whitening, color stabilization, enamel mineralization levels, or tooth sensitivity.

2. The use of toothpaste containing blue covarine after professional bleaching treatments does not affect the color stabilization and mineralization level of the enamel.

METHODS

This study was approved by the Ataturk University Faculty of Medicine Clinical Research Ethics Committee (Date: 30.05.2019, Number. B.30.2.ATA.0.01.00/266) and was supported Ataturk University BAP commission (TDH-2019-7426). The research was performed in the Ataturk University, Faculty of Dentistry, Department of Restorative Dentistry. Informed consent forms were obtained in writing from each participant participating in the study.

Study Design and Sample Size

The patients participating in this study were selected from individuals who presented to the Department of Restorative Dentistry requesting bleaching treatment between December 2019 and June 2020.

Power analysis (G*Power 3.1.9.4 software (Heinrich-Heine Dusseldorf University) showed that a minimum of 60 individuals in six groups should be included in the study with a test power of 0.96, an effect size of 0.20, and a margin of error of 0.05. Sixty volunteers aged 18-30 meeting the patient selection criteria were eventually included (37 female and 23 male). One hundred thirteen individuals underwent bleaching treatment, but only 60 patients completed follow-up. Groups and the toothpaste to be used for maintenance for each group were determined through a draw according to different teeth bleaching treatments. The bleaching treatments and follow-ups for the groups were carried out by the same dentist, and the toothpaste used by the patients was unknown to the dentist.

Individuals with good general health, aged 18-30, with no caries or restoration in the teeth to be whitened, non-smokers, and with at least four anterior teeth A2 or darker in color were enrolled. Individuals who were allergic to teeth bleaching agents, with tetracycline discoloration in their anterior teeth, who were pregnant or breastfeeding, with periodontal disease, or were undergoing orthodontic treatment were excluded from the study.

Color Measurements

In order to ensure standardization of tooth measurements, these were always performed in the same unit, by the same physician, and under D65 lighting conditions.

Tooth color measurements were performed on six maxillary teeth by the same physician using a spectrophotometer (VITA Easy Shade V, Zahnfabrik H.Rauter GmbH&Co. KG, Germany) device under D65 lighting conditions. Color was measured by positioning the tip of the device on the buccal surface of the tooth in such a way as to touch the center of the middle third area, in accordance with the instructions for use. The spectrophotometer was calibrated before each use in accordance with the manufacturer's instructions. Color measurements were taken four times, once before starting the bleaching treatment (T_0), immediately after the bleaching treatment(T_1), and one week (T_2) and one month after the procedure (T_3). The CIEDE2000 formula was used to calculate ΔE_{00} for patients according to the L*, a*, and b* values. $\Delta E_{00}=[(\Delta L'/K_L S_L)^2 +(\Delta C'/KcSc)^2 +(\Delta H'/K_H S_H)^2 +RT(\Delta C'/KcSc)(\Delta H' / K_H S_H)]^{½}$ were determined using the ΔE_{00} value calculated using the formula. The formula contains three weighting functions: chroma, lightness and hue.

ΔE_{001} values indicate the color difference between the T_0 and T_1

ΔE_{002} values indicate the color difference between the T_0 andT_2

ΔE_{003} values indicate the color difference between the T_0 and T_3

ΔE_{004} values indicate the color difference between the T_1 and T_2
ΔE_{005} values indicate the color difference between the T_1 and T_3
ΔE_{006} values indicate the color difference between the T_2 and T_3

Enamel Mineralization Grade Measurement

A DIAGNOdent PEN (KaVo Dental Corporation, Bieberach, Germany) device was used to determine tooth demineralization rates after bleaching. Measurements were taken and recorded with the tip of the device in direct and perpendicular contact with the working area. In order to ensure standardization, the measurements were taken by the same physician after the buccal surface had been divided into three equal parts in the mesiodistal and inciso-gingival directions. Three measurements were taken from the center of the buccal surface, the average of which was used for analysis.

Evaluation of Tooth Sensitivity

Tooth sensitivity during and after the bleaching procedure, and patients' pain and sensitivity levels were determined using a visual analog scale (VAS) ranging between 0 and 10 (Figure 1). Patients were asked to mark the severity of the pain they experienced on the appropriate point on the VAS.

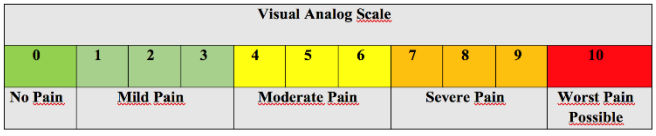

Figure 1. Visual Analog Scale (VAS)

Application of Bleaching Treatment

The flowchart diagram of the study is given in figure 2. Group 1 and Group 2 received an office type teeth bleaching system containing 25% HP (Zoom2 Advanced Power, Discuss Dental, USA). Three periods of 15 minutes were applied to the lower and upper anterior teeth using a Philips Zoom WhiteSpeed UV light device (Zoom Advanced Power, Discuss Dental, USA) in accordance with the manufacturer's instructions. The content of the bleaching agents is given in Table 1.

In Group 3 and Group 4, an office bleaching agent containing 40% HP (Opalacence BOOST, Ultradent Products, Utah, USA) was applied to the anterior teeth of the lower and upper jaws in accordance with the manufacturer's instructions. The bleaching process was applied in two periods of 20 minutes each.

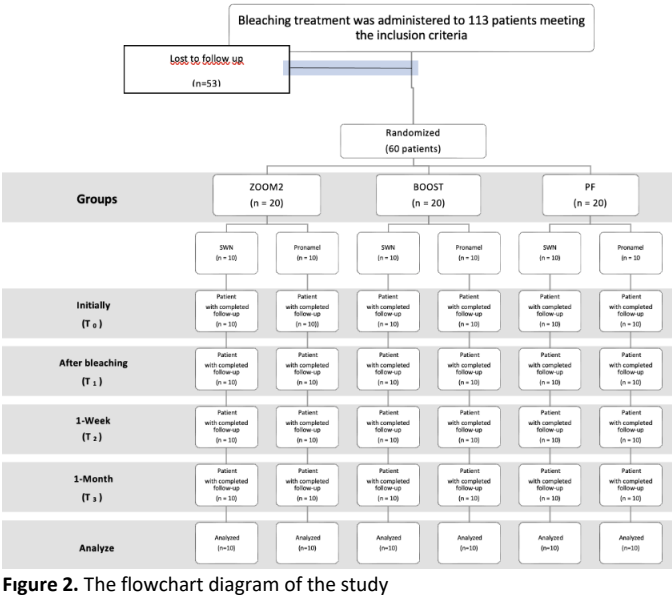

Figure 2. The flowchart diagram of the study

Table 1. Contents of materials used in the study.

	Manufacturer	Composition	pH	Lot Number
Zoom2 Advanced Power	Discus Dental, USA	25% HP , ACP, KNO^3	5.8-6.3	19199004
Opalacence Boost	Ultradent Products, Utah, USA	NaF , 40% HP	1.8-2.8	BHFRM
Opalacence PF %16 Melon	Ultradent Products, Utah, USA	16% CP, NaF	6-7.2	BGGL7
Signal White Now (SWN)	Unilever, France	Blue covarine, sodium fluoride (1450 ppm fluoride), sorbitol, water, hydrated silica, PEG-32, sodium lauryl sulfate, flavor, cellulose, sodium saccharin, PVM/MA copolymer, trisodium phosphate and mica	-	9183FCC
Sensodyne Pronamel	Glaxo Smith Kline, AB	Sodium Fluoride (1450 ppm fluoride), potassium nitrate, water, Sorbitol, hydrated silica, glycerin, PEG-6, cocamidopyyl betaine, flavor, xanthine, sodium saccharin, titanium dioxide, sodium hydroxide, lemon, alcohol	-	8153TKWC

A home bleaching agent containing 16% CP gel (Opalacence PF 16% Melon, Ultradent Products, Utah, USA) was applied in accordance with the manufacturer's instructions in personalized transparent plaques in Group 5 and Group 6. Patients were instructed to apply the bleaching agent for 4-6 hours a day for 14 days.

Recommending Toothpastes for Use in the Groups

All participants were advised to brush their teeth twice a day using the toothpaste recommended for the study groups after bleaching treatments, with the help of a medium-hard toothbrush. Signal White Now (SWN) toothpaste was recommended to participants in groups 1, 3, and 5, and Sensodyne Pronamel toothpaste for those in groups 2, 4 and 6.

Statistical analysis

The study data were analyzed on SPSS 20 software (IBM, SPSS Corp., Armonk, NY, USA). *P* values <.05 were regarded as statistically significant. The Kolmogorov-Smirnov test was applied to determine normality of distribution. The Kruskal Wallis test was applied for non-normally distributed VAS data. The Mann Whitney U test was used to identify groups exhibiting differences.

Parametric tests were used for the statistical evaluation of normally distributed ΔE_{00} and DIAGNOdent data. For intra-group comparisons, Repeated measures ANOVA was used to determine differences related to bleaching systems and toothpaste follow-up periods. For inter-group comparisons, Multivariate analysis of variance (MANOVA) was used to determine differences between the groups in each follow-up period.

RESULTS

ΔE_{00} Value Findings

Tests of within-subjects effects for the ΔE_{00} data revealed significant differences among period and period*bleaching systems (*P* <.05; Table 2), while tests of between-subjects effects did not show significant differences between bleaching systems, toothpastes, and bleaching systems*toothpastes (*P*>.05).

Table 2. Intragroup comparison results at repeated measurements for ΔE_{00} values.

EFFECT	Type III Sum of squares	df	Mean of squares	F	*P*
Period	253.542	5	50.708	27.646	**<.001**
Period * Bleaching System	115.000	10	11.500	6.270	**<.001**
Period * Toothpaste	8.854	5	1.971	1.074	.375
Period * Bleaching System * Toothpaste	18.369	10	1.837	1.001	.442
Error	495.233	270	1834		

p values written in bold indicate a statistically significant difference.

In Figure 3, the comparison of bleaching systems was depicted based on ΔE_{00} values. Across all ΔE_{00} values, a significant difference was observed for ΔE_{001} between the PF, ZOOM2, and BOOST groups (*P* <.05). However, no significant differences were found for ΔE_{002}, ΔE_{003}, and ΔE_{006} among the various bleaching systems (*P* >.05). Notably, significant differences were identified between the PF and BOOST groups for both ΔE_{004} and ΔE_{005} (*P*<.05).

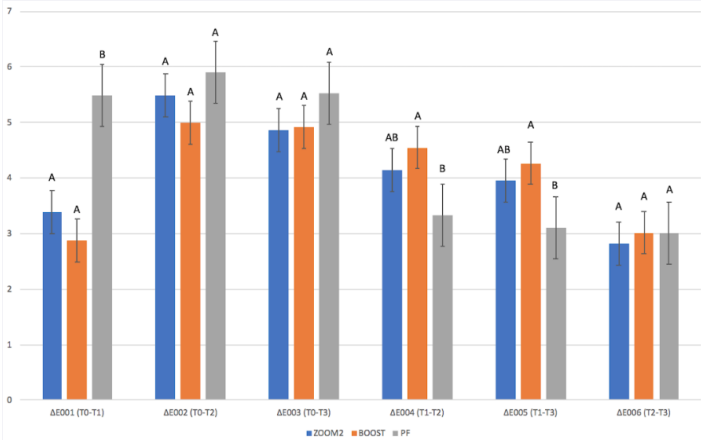

Figure 3. The comparison of bleaching systems is depicted based on ΔE_{00} values. Uppercase letters in the figure indicate a statistically significant difference among the bleaching systems in terms of follow-up periods (*P*<.05).

Table 3 presents the intragroup comparison of ΔE_{00} values. Specifically, within the ZOOM2 group; when examining ΔE_{00} values for SWN toothpaste, a significant difference was observed between ΔE_{002} and ΔE_{003} (*P*<.05) In the comparison of ΔE_{00} values for pronamel toothpaste within the ZOOM2 group, $\Delta E00_1$ exhibited a significant difference with ΔE_{002}, ΔE_{003}, and ΔE_{004} (*P* <.05).In the BOOST group, a noteworthy distinction in ΔE_{00} values for SWN toothpaste was observed, with ΔE_{001} exhibiting a significant difference compared to ΔE_{002}, ΔE_{003}, ΔE_{004}, and ΔE_{005} (*P*<.05). Similarly, in the case of pronamel toothpaste, ΔE_{001} displayed a significant difference when compared to ΔE_{002}, ΔE_{003}, ΔE_{004}, and $\Delta E00_5$ (*P* <.05).

Within the PF group, ΔE_{001}, ΔE_{002}, and ΔE_{003} for SWN toothpaste showed a significant difference with ΔE_{004}, ΔE_{005}, and ΔE_{006} (*P*<.05). Similarly, ΔE_{002} and ΔE_{003} values for pronamel toothpaste exhibited a significant difference with ΔE_{004}, ΔE_{005}, and ΔE_{006} (*P* <.05).

Findings Related to DIAGNOdent Data

Tests of within-subjects effects for the DIAGNOdent data revealed significant differences among period (*P*<.05; Table 4), while tests of between-subjects effects did not showed significant differences between bleaching systems, toothpastes, and bleaching systems* toothpastes (*P*>.05).

When groups were evaluated according to follow-up periods, SWN toothpaste exhibited a significant statistical difference compared to the baseline in all follow-up periods only with the Zoom whitening system, whereas Pronamel toothpaste showed a statistically significant difference compared to the baseline in all follow-up periods for all bleaching systems. (*P* <.05; Table 5).

Intragroup analysis in terms of DIAGNOdent values in the follow-up periods revealed a significant difference between the initial DIAGNOdent values in all groups and the first week and first-month values at the end of treatment (*P*<.05; Figure 4). General similarities were observed between the other periods.

Table 3. Mean and standard deviation values of the ΔE_{00} values in the study groups.

Groups		ΔE_{001} (T_0-T_1)	ΔE_{002} (T_0-T_2)	ΔE_{003} (T_0-T_3)	ΔE_{004} (T1-T_2)	ΔE_{005} (T_1-T_3)	ΔE_{006} (T_2-T_3)
ZOOM2	SWN	3.76 ± 0.55^{ad}	6.19 ± 0.45^{b}	5.16 ± 0.25^{c}	4.08 ± 0.31^{a}	3.72 ± 0.42^{ad}	3.00 ± 0.39^{d}
	Pronamel	3.00 ± 0.37^{a}	4.79 ± 0.40^{b}	4.56 ± 0.49^{bc}	4.21 ± 0.33^{c}	4.19 ± 0.77^{abc}	2.65 ± 0.39^{a}
BOOST	SWN	2.65 ± 0.50^{a}	4.93 ± 0.54^{bc}	5.03 ± 0.28^{b}	4.30 ± 0.26^{c}	4.02 ± 0.27^{c}	3.19 ± 0.19^{a}
	Pronamel	3.10 ± 0.35^{ac}	4.93 ± 0.52^{b}	4.80 ± 0.38^{b}	4.79 ± 0.38^{b}	4.50 ± 0.44^{ab}	2.84 ± 0.40^{c}
PF	SWN	6.02 ± 0.89^{a}	5.83 ± 0.83^{a}	5.59 ± 0.77^{a}	3.13 ± 0.36^{b}	3.20 ± 0.43^{b}	2.42 ± 0.39^{b}
	Pronamel	4.95 ± 0.70^{ab}	5.99 ± 0.67^{a}	5.47 ± 0.60^{a}	3.52 ± 0.42^{b}	3.02 ± 0.39^{b}	3.58 ± 0.62^{b}

The lowercase superscript letters in the table indicate a statistically significant difference in the same row (P<.05) (ANOVA test for repeated measurements)

Table 4. Intragroup comparison results of repeated measures ANOVA for DIAGNOdent values

EFFECT	Sum of squares	sd	Mean of squares	F	*P*
Period	48.195	3	16.065	46.987	**<.001**
Period * Bleaching system	2.047	6	0.341	0.998	.429
Period * Toothpaste	0.747	3	0.249	0.728	.536
Period * Bleaching System * Toothpaste	1.134	6	0.189	0.553	.767
Error	55.389	162	0.342		

P values written in bold indicate a statistically significant difference.

Table 5. Mean and standard deviation values for the groups' DIAGNOdent data.

Groups		Evaluation Time			
		Initially (T_0)	**After bleaching (T_1)**	**1-Week (T_2)**	**1-Month (T_3)**
ZOOM2	SWN	3.93 ± 0.57^{a}	2.95 ± 0.47^{b}	2.51 ± 0.71^{c}	2.58 ± 0.57^{bc}
	Pronamel	4.20 ± 0.71^{a}	3.36 ± 0.60^{b}	2.91 ± 0.59^{b}	3.03 ± 0.64^{b}
BOOST	SWN	3.48 ± 0.75^{a}	3.19 ± 0.25^{a}	2.76 ± 0.62^{b}	3.05 ± 0.53^{ab}
	Pronamel	3.93 ± 0.49^{a}	3.31 ± 0.39^{b}	2.68 ± 0.52^{c}	2.76 ± 0.48^{c}
PF	SWN	3.85 ± 0.97^{a}	2.98 ± 1.22^{ab}	2.86 ± 0.90^{b}	2.95 ± 1.33^{ab}
	Pronamel	3.99 ± 0.72^{a}	3.05 ± 0.93^{b}	2.76 ± 0.70^{b}	2.78 ± 0.54^{b}

The lowercase superscript letters in the table indicate a statistically significant difference in the same row. (P<.05) (repeated measures ANOVA test)

VAS Analysis

Statistical results for intergroup comparison of tooth sensitivity VAS values after bleaching are given in Table 6. Tooth and gingival sensitivity in the PF groups was significantly lower than in the ZOOM and BOOST groups (*P*<.05). No significant difference was observed between the other two groups (*P*>.05).

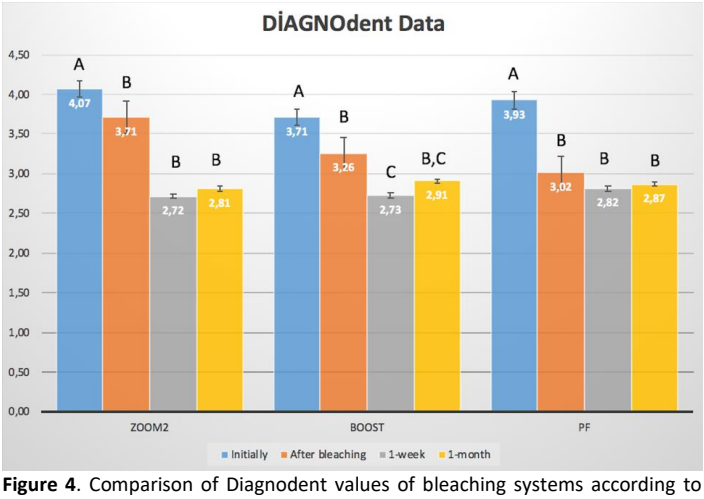

Figure 4. Comparison of Diagnodent values of bleaching systems according to follow-up periods. Uppercase letters in the figure indicate a statistically significant difference among the follow-up periods in terms of bleaching systems (*P*<.05).

Table 6. p values for VAS scores between the groups after bleaching.

	ZOOM2	BOOST
BOOST	0.795	
PF	**0.000**	**0.002**

P values in bold indicate a statistically significant difference for two overlapping groups in row and column. (Kruskal Wallis test)

DISCUSSION

The clinical findings of this study revealed a significant difference between the bleaching systems in terms of color stability and sensitivity. However, no difference was determined in terms of enamel mineralization levels. In addition, the use of toothpaste containing blue covarine after bleaching treatment had no significant effect on color stability and mineralization level. The first null hypothesis was rejected, while the second null hypothesis was confirmed.

Color differences in patients' L*a*b* values in the CIEDE2000 color system, $\Delta E_{00}=[(\Delta L'/K_L S_L)^2+(\Delta C'/KcSc)^2+(\Delta H'/K_H S_H)^2+RT(\Delta C'/KcSc)(\Delta H'/K_H S_H)]^{1/2}$

were determined using the ΔE_{00} value calculated using the formula. The formula contains three weighting functions: chroma, lightness and hue. The CIEDE2000 system is a better indicator of human perceptibility and acceptability of colour changes. A ΔE_{00} value of ≥1.8 has been adopted as the threshold value for detecting clinical color change in previous studies.[14,15] All ΔE_{00} values determined in this study were higher than 1.8.

When the bleaching systems were compared in terms of ΔE_{00} values obtained during the follow-up periods, home bleaching treatment exhibited higher success for ΔE_{001} values than the ZOOM2 and BOOST systems. Analysis of the ΔE_{002} and ΔE_{003} values revealed no difference between the groups in terms of whitening. Moghadam et al.[16] reported found that home and office bleaching treatments exhibited similar effectiveness. Mondelli et al.[17] compared home, office, and LED/laser-assisted bleaching and reported that home bleaching was more successful. In agreement with that study, home bleaching treatment was also more successful than office bleaching in the present study. We attribute this to the bleaching agent used in home bleaching treatment being applied at a lower concentration for an extended period.

Ontiveros and Paravina,[18] investigated the effectiveness of the use of light on bleaching and reported more effective whitening results in the light-activated group. However, there are also studies reporting that two in-office bleaching systems, one with and one without light activation, exhibited similar results.[17,19] Consistent with these results, no significant difference was found between the light-activated and non-light-activated office bleaching systems in the present study in terms of the effectiveness of bleaching.

In-office bleaching is performed with relatively high-concentration bleaching agents and is generally more effective than at-home bleaching.[20] However, some studies have reported that in-office bleaching exhibits relatively lower color stabilization after the procedure than at-home bleaching.[21] Similarly in the present study, home bleaching was more successful in terms of color stabilization than office bleaching.

Jiang et al.[5] reported that toothpaste containing blue covarine was more successful in terms of color stabilization than conventional toothpaste in their in vivo study involving the use of a whitening toothpaste containing blue covarine for three weeks after office bleaching. Bortolatto et al.[22] compared the effectiveness of whitening toothpastes containing blue covarine and placebo toothpastes after professional teeth bleaching treatments. Those authors reported that whitening toothpastes failed to provide beneficial effects when used after professional whitening treatments. No difference was found in the present study between blue covarine and conventional toothpaste in terms of ΔE_{00} values.

Rotstein et al.[23] reported that 10% CP and 30% HP caused a significant decrease in the calcium-phosphorus ratio in the enamel and that mineral loss occurred after bleaching. Potocnik et al.[24] reported that bleaching agents can cause microstructural damage on the enamel surface, as in initial cavity lesions. From that perspective, it is important to examine the effect of bleaching agents on dental hard tissues.

Comparison of the DIAGNOdent data obtained in the evaluation of mineralization levels between the groups revealed no significant difference in terms of bleaching systems. Light-activated ZOOM2 with 25% HP, Opalescence BOOST with 40% HP, and Opalescence PF with 16% CP exhibited similar effects in terms of demineralization / remineralization. No significant difference was also determined when the DIAGNOdent data were compared between the toothpaste containing blue covarine and the conventional toothpaste used as the control group. Some studies have shown that exposure to HP-based gels results in mineral loss, which may be associated with changes in enamel surface microhardness, roughness, and mineral content.[8] Giannini et al.[25] examined the effect of fluoride- or calcium-containing CP-based bleaching agents on human tooth enamel and concluded that the presence of fluoride impaired mineral loss promoted by bleaching. Borges et al.[26] reported that applying a CPP-ACP (casein phosphopeptide-amorphous calcium phosphate) mixture with a bleaching agent containing HP can reduce tooth sensitivity and protect the enamel from morphological changes during bleaching treatment, without reducing the effectiveness of whitening. The DIAGNOdent data obtained in the evaluation of mineralization levels and the bleaching systems were evaluated in terms of the follow-up periods in the present study. In accordance with those previous results, baseline DIAGNOdent values differed significantly from the values obtained at the end of treatment. Baseline DIAGNOdent values were greater than those at the end of the treatment in these groups. We attribute this result to the effect of fluoride, amorphous calcium phosphate (ACP), nano-hydroxyapatite (n-HAP), and potassium nitrate added to the bleaching agents, thus reducing demineralization and promoting remineralization. Of the three bleaching agents used in this study, Opalascence BOOST and PF bleaching agents both contain fluoride, while ZOOM2 whitening agent contains potassium nitrate and ACP.[27] This may have contributed to slowing the demineralization process and enhancing enamel remineralization.

In a study, in-office bleaching treatment using 35% HP caused a reduction in enamel microhardness. However, later it was seen that the enamel was remineralized.[28] Saliva and other active substances play an important role in creating and maintaining an appropriate environment to reduce demineralization and ensure remineralization on tooth surfaces exposed to bleaching treatment.[29] Consistent with this information, the DIAGNOdent values obtained after bleaching in the present study were generally preserved in the follow-up periods. We attribute that this is due to the remineralizing effect of saliva and fluoride in the toothpastes used.

Tooth sensitivity is the most frequently reported side-effect during and after vital bleaching treatments.[30] Various clinical studies have reported that 15-65% of patients experience tooth sensitivity during bleaching treatment.[30,31] In the present study, the detection of tooth sensitivity during and after the bleaching procedure, and the degree of pain and sensitivity experienced by the patients were determined using a VAS with values between 0 and 10.

A number of studies have compared the effect of home and office bleaching treatments on tooth sensitivity and have determined that office bleaching causes greater sensitivity.[16,32,33] In the present research, less tooth sensitivity was observed with Opalescence PF compared to the groups in which office bleaching was performed. We attribute this finding to the lower HP concentration in Opalescence PF gel.

The limitations of this study include the short follow-up period, and that the participants consisted of young individuals, which prevented the results from being generalized to older individuals.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1. All three bleaching systems evaluated in this study produced noticeable whitening when measured using spectrophotometry. Home bleaching was more successful in terms of both the effectiveness of bleaching and color stabilization compared to office bleaching.

2. The findings of this study show that the use of toothpaste containing blue covarine after in-office and at-home bleaching has similar effect on color stabilization and demineralization as only silica-containing toothpaste. Although further studies with longer follow-up periods are now needed.

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