



Comparative Evaluation of Color Change Induced by Over-the-Counter Whitening Pens

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Research Article

History

Received: 24/09/2025

Accepted: 12/11/2025

ABSTRACT

Objectives: To evaluate and compare the short-term whitening efficacy of three over-the-counter (OTC) whitening pens and one at-home bleaching product using spectrophotometric color analysis on extracted human teeth.

Materials and Methods: Sixty maxillary central incisors were randomly assigned to five groups (n = 12): three OTC whitening pens (iSmile, SDI Pola Luminare, CleverCool), one home bleaching gel (SDI Polanight), and a control group. Whitening agents were applied for 7 days following manufacturer instructions. Color measurements were performed at baseline (T0), after 7 days (T7), and at day 14 (T14) using a spectrophotometer. Color change (ΔE) was calculated using the CIE Lab formula. Data were analyzed using one-way ANOVA and Tukey HSD tests ($p < 0.05$).

Results: All whitening groups showed significantly greater ΔE values compared to the control ($p < 0.001$). The iSmile pen produced the highest color change at both T7 and T14. SDI Polanight showed comparable but slightly lower efficacy. Pola Luminare and CleverCool achieved moderate whitening effects without significant difference between them.

Conclusions: OTC whitening pens can produce visible color improvement in the short term. However, their efficacy varies by product formulation. Higher peroxide concentration was associated with greater whitening effect.

Keywords: Carbamide peroxide, color change, over-the-counter whitening, spectrophotometer, tooth bleaching

Reçetesiz Beyazlatma Kalemlerinin Neden Olduğu Renk Değişiminin Karşılaştırılması Olarak Değerlendirilmesi

Araştırma Makalesi

Geçmiş

Geliş: 24/09/2025

Kabul: 12/11/2025

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Öz

Amaç: Üç farklı reçetesiz (OTC) beyazlatma kalemi ile bir ev tipi beyazlatma ürününün kısa dönem beyazlatma etkinliğini, çekilmiş insan dişlerinde spektrofotometrik renk analizi ile değerlendirmek ve karşılaştırmaktır.

Gereç ve Yöntemler: Altmış maksiller kesici diş rastgele beş gruba ayrıldı (n = 12): üç OTC beyazlatma kalemi (iSmile, SDI Pola Luminare, CleverCool), bir ev tipi beyazlatma jeli (SDI Polanight) ve bir kontrol grubu. Beyazlatıcı ajanlar üretici talimatlarına göre 7 gün boyunca uygulandı. Renk ölçümleri başlangıçta (T0), 7. gün sonunda (T7) ve 14. günde (T14) spektrofotometre kullanılarak yapıldı. Renk değişimi (ΔE), CIE Lab formülü kullanılarak hesaplandı. Veriler tek yönlü ANOVA ve Tukey HSD testleri ile analiz edildi ($p < 0,05$).

Bulgular: Tüm beyazlatma grupları, kontrol grubuna kıyasla anlamlı derecede daha yüksek ΔE değerleri gösterdi ($p < 0,001$). iSmile kalemi hem T7'de hem de T14'te en yüksek renk değişimini sağladı. SDI Polanight benzer ancak biraz daha düşük etkinlik gösterdi. Pola Luminare ve CleverCool orta düzeyde beyazlatma etkisi sağladı ve aralarında anlamlı bir fark bulunmadı.

Sonuçlar: OTC beyazlatma kalemleri kısa dönemde gözle görülür renk iyileşmesi sağlayabilir. Ancak etkinlikleri ürün formülasyonuna göre değişmektedir. Daha yüksek peroksit konsantrasyonu daha güçlü beyazlatma etkisi ile ilişkilidir.

Anahtar Kelimeler: Diş beyazlatma, karbamid peroksit, reçetesiz beyazlatma, renk değişimi, spektrofotometre

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How to Cite: Yıldırım Manav E, Yılmaz Çakıroğlu AE. (2026) Comparative Evaluation of Color Change Induced by Over-the-Counter Whitening Pens. Cumhuriyet Dental Journal, 29(1): 99-103.

Introduction

Tooth color plays a crucial role in the perception of facial esthetics and overall oral health. In response to increasing patient demand for whiter teeth, a wide range of whitening products—ranging from in-office bleaching treatments to over-the-counter (OTC) solutions—have been developed. Among these, whitening pens have

gained popularity due to their convenience, affordability, and ease of use without requiring professional supervision.^{1,2}

Whitening pens are typically applied directly to the tooth surface using a brush or pen-like applicator and contain low to moderate concentrations of hydrogen

peroxide or carbamide peroxide as active ingredients.³ Unlike professionally applied bleaching systems, these products are not customized to individual patients and may vary significantly in their efficacy depending on the formulation, mode of application, and frequency of use.⁴

Although manufacturers claim visible whitening effects within days, there is limited independent scientific evidence comparing the efficacy of various OTC whitening pens. Moreover, the whitening effectiveness of these products over short-term periods—such as one or two weeks—remains under-investigated. In contrast, home-use bleaching systems with custom trays and higher peroxide concentrations are well-documented and serve as a benchmark in non-professional whitening protocols.^{5,6}

ΔE values derived from spectrophotometric measurements in the CIE Lab* color space provide an objective and reproducible method for assessing tooth color changes over time.⁷ In vitro models offer a controlled environment for comparing the whitening performance of different products while eliminating intraoral variables.

The aim of this study was to evaluate and compare the whitening efficacy of three commercially available OTC whitening pens and one home bleaching agent in terms of color change. A negative control group was included to assess spontaneous discoloration or dehydration effects. The null hypothesis was that there would be no significant

differences in tooth color change (ΔE) among the experimental groups.

Materials and Methods

Ethical Approval and Tooth Selection

This *in vitro* research was approved by the Research Ethics Committee of the Lokman Hekim University (2025201). Prior to inclusion, all teeth were examined under 10× magnification using a stereomicroscope (Olympus, SZ-61, Japan) to screen for morphological defects or enamel fractures, which led to exclusion if detected. Only sound, freshly extracted human maxillary central incisors were included in the study.

Sample Size Calculation

The primary outcome of this study was to evaluate bleaching efficacy using ΔE_{ab} values as an objective colorimetric measure. Based on the study by Barbosa *et al.*, which reported a mean ΔE_{ab} value of 2.9 ± 1.6 for over-the-counter whitening systems, an equivalence limit of $\Delta E_{ab} = 2.7$ was adopted to represent clinically acceptable whitening.^{8,9} Using a significance level of $\alpha = 0.05$ and a statistical power of 90%, a minimum of 8 specimens was required per group. To account for potential specimen loss, four additional samples were included per group, resulting in 12 specimens allocated to each group ($n = 12$), for a total of 60 teeth across the five treatment groups.

Table 1. Composition and application characteristics of whitening products used in the study

Product name	Type	Active ingredient	Concentration	Daily application time	Manufacturer	LOT
SDI Polanight	Home bleaching gel	Carbamide Peroxide	22%	45 minutes/once daily	SDI Limited (Australia)	1190180
iSmile Whitening Pen	OTC whitening pen	Carbamide Peroxide	35%	30 minutes/twice daily	iSmile (USA)	186930
SDI Pola Luminat Whitening Pen	OTC whitening pen	Hydrogen Peroxide	6%	30 minutes/twice daily	SDI Limited (Australia)	P170502
CleverCool Whitening Pen	OTC whitening pen	Carbamide Peroxide	18%	30 minutes/twice daily	CleverCool (China)	161021

Experimental Design

The present study aimed to evaluate two main factors: (1) Whitening products, divided into four groups: SDI Polanight (SDI Limited, Australia), iSmile Whitening Pen (iSmile, USA), SDI Pola Luminat Whitening Pen (SDI Limited, Australia), and CleverCool Whitening Pen (CleverCool, China) (Table 1). An additional group, serving as the negative control, was not exposed to any bleaching agents. (2) Time points were evaluated at three stages: before treatment (T0), on day 7 of treatment (T7), and 7 days after the end of treatment (T14).

Sample Preparation and Randomization

The roots of maxillary first incisor teeth were sectioned approximately 3 mm apical to the cemento-enamel junction using a low-speed diamond disc (Isomet 1000, Buehler Ltd., Lake Bluff, USA). Each tooth was assigned a unique identifier, and random allocation

into experimental groups was performed using a simple randomization method via an Excel spreadsheet.

Initial Color Evaluation

To ensure consistent positioning of the spectrophotometer (VITA Easyshade Advance 4.0, VITA Zahnfabrik, Bad Säckingen, Germany), customized guides were fabricated for each group using dense condensation silicone (Coltoflax and Perfil Cub Kit, green, Vigodent, Rio de Janeiro, RJ, Brazil). A circular window measuring 6 mm in diameter was created in the middle third of the buccal surface of each specimen using a metal template, enabling accurate alignment of the spectrophotometer tip.^{10,11} The tip was then placed into the silicone guide to obtain color measurements, including L^* , a^* , and b^* values. The L^* coordinate indicates lightness, with a scale from 0 (black) to 100 (white), a^* reflects the red–green chromatic axis, and b^* represents the yellow–blue chromatic axis.¹²

Group Allocation

A total of 60 maxillary first incisor teeth were randomly allocated to five groups (n = 12) based on the whitening product used:

- Group 1: Control (no whitening)
- Group 2: SDI Polanight (22% carbamide peroxide)
- Group 3: iSmile Whitening Pen
- Group 4: SDI Pola Luminare Whitening Pen
- Group 5: CleverCool Whitening Pen

Whitening Protocols

A single calibrated and experienced operator performed all treatment protocols, including application of the whitening pens and the at-home bleaching agent. In the whitening pen groups, the products were applied to the facial enamel surface according to the manufacturers' instructions using a standardized protocol across all groups; each application was performed twice daily for 30 minutes over 7 consecutive days. In the at-home bleaching group (SDI Polanight), the bleaching gel was applied directly to the tooth surface and left in place for 45 minutes per day over 7 consecutive days, following the manufacturer's instructions. After each bleaching session, residual gel was removed with gauze, and only the buccal surface was gently rinsed with deionized water. Specimens in the control group received no bleaching treatment.

Throughout the experimental period, all specimens were stored in artificial saliva at 37 °C (composition: 0.4 g NaCl, 0.4 g KCl, 0.795 g CaCl₂·2H₂O, 0.78 g NaH₂PO₄·2H₂O, 0.005 g Na₂S·9H₂O, and 1 g urea per liter of distilled water; pH = 7.0). The solution was refreshed daily.

Final Color Evaluation

The bleaching efficacy was measured at baseline (T0) and at 7 days (T7) and 14 days (T14) after the end of the treatment protocol for each group, using a digital

spectrophotometer (VITA Easyshade Advance 4.0, VITA Zahnfabrik, Bad Säckingen, Germany). The same color parameters (L*, a* and b*) previously described were measured. The difference in color (T0 vs. T7 and T0 vs. T14) was calculated using the formulas: CIE Lab formula, $\Delta E_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.¹²

Statistical Analysis

The data obtained from this study were analyzed using SPSS (Statistical Package for the Social Sciences), version 23. The normality of the data was assessed with the Shapiro–Wilk test, and the homogeneity of variances was examined with Levene's test. A one-way ANOVA was conducted to compare the five groups, followed by Tukey's HSD test for pairwise comparisons. Statistical significance was set at $\alpha = 0.05$ for all analyses.

Results

The comparison results of the color change between baseline and day 7 (T0 vs T7) and between baseline and day 14 (T0 vs T14) for the five groups are presented in Table 2. Significant differences were found among the five groups for both the color change between baseline and day 7 and between baseline and day 14 ($p < 0.001$; $p < 0.001$; Table 2).

Regarding the color change between baseline and day 7, the lowest change was observed in the control group. The SDI Polanight and iSmile groups exhibited similar changes, which were higher than those in the other groups ($p = 0.102$). The color changes in the SDI Pola Luminare and CleverCool groups were comparable ($p = 0.999$).

Regarding the color change between baseline and day 14, the lowest change was again observed in the control group. The highest change was observed in iSmile and SDI Polanight, respectively. The color changes in the SDI Pola Luminare and CleverCool groups were comparable ($p = 0.997$).

Table 2. Mean color change values ($\Delta E \pm SD$) from baseline to day 7 (T0–T7) and day 14 (T0–T14) for each experimental group

Material	ΔE (T0–T7)	ΔE (T0–T14)
Control	0.89 ± 0.43 ^a	0.77 ± 0.52 ^a
SDI Polanight	12.22 ± 1.35 ^b	13.18 ± 1.35 ^b
iSmile	13.3 ± 1.44 ^b	14.86 ± 1.53 ^c
SDI Pola Luminare	3.23 ± 0.95 ^c	4.47 ± 1.22 ^d
CleverCool	3.14 ± 0.7 ^c	4.64 ± 1.23 ^d
p*	<0.01	<0.01

*One-way ANOVA test results. SD: Standard deviation. Different lowercase letters (a, b, c, d) within each column indicate statistically significant differences among groups ($p < 0.05$).

Discussion

This study compared the short-term whitening efficacy of three commercially available over-the-counter (OTC) whitening pens and one at-home bleaching product using spectrophotometric analysis of color change (ΔE) on extracted human incisors. The results demonstrated that all tested whitening products induced significantly greater color changes compared to the untreated control group, confirming their effectiveness in improving dental esthetics over a 7-day application period. Among them, the iSmile Whitening Pen exhibited the highest ΔE values

at both T7 and T14, followed closely by the SDI Polanight group, while CleverCool and SDI Pola Luminare pens showed moderate whitening effects.

These findings align with previous reports indicating that the whitening efficacy of OTC products varies significantly depending on the formulation and concentration of the active ingredients.^{13,14} The iSmile pen, with a higher concentration of carbamide peroxide (35%), showed the most pronounced whitening effect, surpassing that of the 22% carbamide peroxide at-home gel (SDI Polanight). This suggests that both peroxide

concentration and application frequency may contribute to bleaching outcomes, in line with the dose–response behavior described in earlier bleaching literature.¹⁵

The ΔE values observed for iSmile and SDI Polanight ($\Delta E > 12$) significantly exceeded the perceptibility ($\Delta E \approx 1.2$) and acceptability ($\Delta E \approx 2.7$) thresholds for dental color changes, indicating clinically visible and acceptable whitening results.^{16,17} On the other hand, the SDI Pola Luminare and CleverCool pens produced moderate color changes ($\Delta E \approx 4\text{--}4.6$), which may be sufficient for patients seeking mild esthetic improvements but are unlikely to match the effects of higher-peroxide or professional-grade treatments.

Interestingly, color measurements at T14 indicated a slight enhancement or maintenance of the whitening effect compared to T7, suggesting potential delayed action or continued rehydration effects following cessation of treatment. Similar post-treatment color stability has been observed in previous studies, particularly in products with higher peroxide levels and controlled application times.^{18,19}

It is noteworthy that despite their wide availability, OTC whitening pens often lack clinical performance data. A recent systematic review emphasized the need for more controlled studies to verify manufacturers' claims and to establish realistic expectations for patients using OTC products.²⁰ Our study contributes to this body of evidence by providing a controlled *in vitro* comparison of different OTC formulations, highlighting considerable variability in their performance.

The use of a spectrophotometer and CIE Lab* color space provided objective and reproducible measurements of tooth color, minimizing observer bias and facilitating direct product comparisons. However, certain limitations of the present study should be acknowledged. First, *in vitro* models do not fully replicate the complex intraoral environment, such as saliva composition, pH fluctuations, and patient compliance. Second, the duration of the study was limited to 14 days; long-term effects on color relapse or enamel integrity were not evaluated. Additionally, the abrasive potential and peroxide penetration of each product were not assessed and should be explored in future research.²¹⁻²³

Despite these limitations, the findings suggest that select OTC whitening pens—particularly those with higher peroxide concentrations—can achieve noticeable whitening effects within a short period. Nonetheless, clinicians should guide patients in selecting products based on realistic expectations, and caution should be exercised with unsupervised frequent use, as prolonged exposure to peroxide may lead to enamel and pulpal sensitivity.^{24,25}

The findings suggest that OTC whitening pens—particularly those with higher peroxide concentrations—may offer a convenient and effective short-term solution for individuals seeking cosmetic improvement without professional intervention. However, given the variability in efficacy among different products, users should be informed about expected outcomes and potential

limitations. Further clinical studies are needed to evaluate the long-term stability, safety, and biological effects of these products under intraoral conditions.

The null hypothesis of this study assumed that there would be no significant differences in tooth color change (ΔE) among the experimental groups. However, the results demonstrated statistically significant differences between the whitening agents and the control group at both T7 and T14, indicating that the null hypothesis was rejected. All whitening products produced measurable color improvements, with the iSmile whitening pen and SDI Polanight showing the highest efficacy, while SDI Pola Luminare and CleverCool achieved moderate but clinically perceptible effects.

Conclusions

Within the limitations of this *in vitro* study, it can be concluded that all tested over-the-counter (OTC) whitening pens and the at-home bleaching gel demonstrated measurable whitening effects after 7 days of application. Among them, the iSmile Whitening Pen, containing 35% carbamide peroxide, showed the greatest color change, followed by the SDI Polanight home bleaching agent. In contrast, SDI Pola Luminare and CleverCool pens resulted in moderate but still perceptible whitening effects.

Acknowledgements

None.

Conflicts of Interest Statement

The authors declare no competing interests.

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