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# Evaluation of staining susceptibility of teeth after office bleaching

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## Abstract

**Aim:** The aim of this study was to evaluate the discoloration effect of different beverages on previously office-bleached teeth.

**Methodology:** Forty upper incisor teeth with indication for extraction due to periodontal reasons were used in this study. Teeth with discoloration, fractures, caries, or restorations on the crown surface were excluded. Before applying the bleaching agent to the enamel surface, the teeth were embedded into acrylic resin. Two office bleaching sessions were applied. Teeth were randomly divided into five experimental groups (n=8): tea, coffee, cola, and milk, with artificial saliva as the control. The teeth were soaked in beverages for 5 minutes a day for 1 month and were kept in artificial saliva for the rest of the time. Color measurements were taken using a spectrophotometer and the L, C, h values were recorded. Initial color measurements were taken after bleaching sessions. Color measurements were repeated for each beverage after soaking for 24 hours, 72 hours, 1 week, and 1 month and color changes ($\Delta E_{00}$) were calculated using the CIEDE2000 formula. Data were analyzed by two-way repeated analysis of variance using the IBM SPSS 25.0 program ($p<0.05$).

**Results:** Teeth kept in coffee and tea revealed significantly different mean $\Delta E_{00}$ values in the comparisons between the 1st month and 24th hour and between the 72nd hour and 1st week ($p<0.001$, $p<0.001$, and $p=0.002$, respectively). During inter- and intragroup comparisons of the milk and cola groups, no significant differences were detected at examination intervals ($p>0.05$). In the 1st month measurements, the mean $\Delta E_{00}$ values obtained from samples soaked in coffee and tea were statistically higher than the artificial saliva group ($p=0.006$ and $p=0.007$). The mean $\Delta E_{00}$ values obtained at the 24th and 72nd hour and at the 1st week did not differ significantly among the tested beverages ($p>0.05$).

**Conclusion:** After bleaching, discoloration increased over time. Tea and coffee caused the most significant discoloration.

**Keywords:** Discoloration, staining, hydrogen peroxide, tooth whitening, office bleaching, CIEDE2000

## Introduction

Nowadays, with the increase in the aesthetic perception of individuals, the demand for aesthetic and cosmetic applications has increased. Since white teeth are considered beautiful and healthy, teeth bleaching systems are of interest to individuals (1).

Many methods for bleaching treatments are available in the literature. There are various bleaching agents, concentrations of agents, application times, application techniques and different techniques in which light activation can be used (2). Home and office bleaching which can be performed under the supervision of a dentist and bleaching with over-the-counter products (3). In at-home bleaching, a low concentration of bleaching gel is applied to the teeth with customized trays for at least 2 weeks (4).

In-office bleaching employs high concentrations of bleaching agents for brief durations, resulting in substantial teeth whitening often achievable in a single session. The bleaching gel is administered onto teeth post-protection of soft tissues, with subsequent potential activation of hydrogen peroxide facilitated by either heat or light (5). However, more than one appointment may be required for optimum bleaching (3, 6). Over-the-counter products usually include low concentrations of bleaching agents and can be self-applied to the teeth using strips or paint-on products. Application time of these products is usually twice a day for up to 2 weeks (7, 8).

Depending on external and/or internal factors, tooth color can change because of chemical and physical interactions between the dental tissues. Extrinsic factors include tea, coffee, red wine, cola and smoking (9, 10). After bleaching, patients are typically advised by dentists to avoid coffee and tea intake and abstain from smoking or other behaviors that may lead to discoloration. Research indicates that bleaching agents have the potential to alter the morphology and texture of the enamel surface (11). The loss of organic components from the surfaces of enamel and dentin can occur in bleached teeth, leading to changes in their microstructure. These alterations may be attributed to protein denaturation or loss (12). These changes can predispose to the formation of extrinsic discoloration (13). Hence, it is crucial to consider the impacts of these agents both during and after bleaching treatments (14).

To assess color differences, the CIEDE2000 color difference formula fits better than the CIELAB color difference formula, which makes it a better measure of human perceptibility and acceptability in dentistry and supports its application in this area (15-17).

Research exploring how ingested colorants influence post-bleaching outcomes is scarce. Thus, our study aimed to examine the impact of beverages such as coffee, tea, cola, and milk on teeth color after office bleaching. Our null hypothesis was that the tested beverages had no effect on the color change of the previously bleached teeth at any testing period.

## Materials and Methods

The study protocol was approved by the Research Ethics Committee of Istanbul Okan University (10.01.2024-2024/172).

Power analysis showed that 40 teeth were adequate for detecting 95% significance. In this study, upper incisors with extraction indications for periodontal reasons were used. Discoloration, fracture, caries, and restoration on the crown surface of the teeth were excluded from the study.

Before applying the bleaching agent to the enamel surface, the teeth were embedded in acrylic resin with the crown exposed. The teeth underwent two sessions of office bleaching (Opalescence 40%, Ultradent Products Inc., South Jordan, Utah, USA). After bleaching, a polishing paste (Diapolisher paste, GC Corporation, Tokyo, Japan) was applied to the teeth surfaces using a felt brush. Following polishing, topical fluoride gel (Sultan Topex neutral pH gel; Sultan Dental Products, York, PA, USA) was applied to the teeth surfaces for 4 minutes. The teeth were randomly assigned to five groups based on the beverage used: artificial saliva (control), coffee (Nescafe 3 in 1, Turkey), cola (Coca-Cola, Turkey), tea (Yellow Tea, Lipton, Turkey), and milk (Tarım Kredi, Ankara, Türkiye). Teeth were soaked in the beverages for 5 min daily for 1 month, depending on the beverages used (18); at other times they were stored in artificial saliva. Color was measured using a spectrophotometer (VITA Easyshade V, Zahnfabrik, Bad Säckingen, Germany), and the L, C, and h values were recorded. The initial color measurement was performed after bleaching. Color measurement was repeated after 24 hours, 72 hours, 1 week and 1 month and the color change ($\Delta E_{00}$) was calculated using the CIEDE2000 formula.

### Statistical analysis

Analyses were performed using the SPSS software (IBM SPSS Statistics version 25.0, IBM Inc., Armonk, NY, USA).

Following the computation of the $\Delta E_{00}$ values, a two-way repeated-measures analysis of variance was conducted to assess variations across four distinct time points. The post hoc Bonferroni test was employed to identify significant differences between the groups, with statistical significance set at $p<0.05$.

## Results

Table 1 displays the mean $\Delta E_{00}$ values and the corresponding standard deviations for each group.

Statistically significant differences were found between the 1st month and other time intervals (24th hour, 72nd hour, 1st week) in the mean $\Delta E_{00}$ values obtained from the samples kept in coffee after bleaching ($p=0.002$). There was no statistically significant

difference in the mean $\Delta E_{00}$ values obtained from the samples kept in tea after bleaching between 24th hour and 72nd hour, whereas there was a difference between the mean $\Delta E_{00}$ values obtained from 1st week and 1st month time intervals ($p$=0.002). No significant differences were obtained in milk and cola groups according to time ($p$>0.05). The mean $\Delta E_{00}$ values obtained at 24 hours, 72 hours, and 1 week did not differ significantly according to the beverages ($p$>0.05).

**Table 1.** Mean $\Delta E_{00}$ values and standard deviations

| | Mean $\Delta E_{00}$ ± SD | | | |
|---|---|---|---|---|
| **Groups** | 24th hour | 72nd hour | 1st week | 1st month |
| **Coffee** | 4.40±1.58 $^{a.A}$ | 5.21±4.10 $^{a.A}$ | 7.07±2.93 $^{a.A}$ | 14.80±6.60 $^{a.B}$ |
| **Milk** | 3.97±3.77 $^{a.A}$ | 4.08±1.61 $^{a.A}$ | 4.59±4.22 $^{a.A}$ | 8.16±4.48 $^{a.b.A}$ |
| **Tea** | 4.07±1.95 $^{a.A}$ | 4.57±2.31 $^{a.A}$ | 8.90±3.77 $^{a.B}$ | 14.69±6.85 $^{a.C}$ |
| **Cola** | 4.56±1.44 $^{a.A}$ | 5.86±2.55 $^{a.A}$ | 5.94±1.97 $^{a.A}$ | 9.04±4.91 $^{a.b.A}$ |
| **Artificial Saliva** | 2.08±0.90 $^{a.A}$ | 2.60±1.41 $^{a.A}$ | 4.69±1.64 $^{a.A}$ | 4.94±1.71 $^{b.A}$ |

*Different superscript capital letters in the same row indicate a statistically significant difference between time intervals within each group ($p$<0.05).
** Different superscript lowercase letters in the same column indicate a statistically significant difference among different beverages within the same time interval ($p$<0.05).

## Discussion

This in vitro study showed that all the tested beverages produced various amounts of discoloration at different periods, thus demonstrating that bleached teeth are susceptible to extrinsic staining. Although the color change observed at 24 and 72 hours among the tested beverages was not significant, the discoloration was evident from the 1st week. Therefore, the null hypothesis was rejected.

Several methods have been proposed for the evaluation of color changes, including subjective (19) and objective methods (13). The objective methods known for their high accuracy include spectrophotometry, colorimetry, and computer digitalization (13). In this study, a spectrophotometer was used to obtain more accurate results.

In order to account for the effects of illumination and vision on color difference evaluations, CIEDE2000 incorporates corrections for the non-uniformity of the CIELAB color space through the weighting function ($S_L$,$S_C$,$S_H$), a rotation term ($R_T$), which primarily affects low chroma colors, and the so-called parametric factors ($k_L$,$k_C$,$k_H$) (16). To better align with visual perception, the ISO and the CIE have together recommended the use of the CIEDE2000 color difference formula, which is also based on CIELAB color space, for total color difference computation (15-17). Hence, we used the CIEDE2000 formula in this study.

Before bleaching, the teeth surfaces were cleaned with a polishing paste and a polishing brush to examine the teeth under natural conditions. Considering the irregularities that may occur on the surface of the teeth after bleaching, polishing, and fluoride application were performed on the buccal surface of all teeth to ensure standardization between teeth in terms of adsorption of beverages and color determination (20). During the experiment, the teeth were immersed in artificial saliva to replicate both the remineralization process (21) and the pivotal role of saliva in tooth discoloration (22, 23).

Numerous studies have investigated the adverse impacts of hydrogen peroxide-based bleaching agents on tooth enamel, yielding inconsistent findings. Some studies have indicated minimal destruction on the microstructure of enamel and dentin after bleaching (24, 25), while some have documented adverse effects on enamel and/or dentin surfaces, including alterations in surface morphology (26, 27). Beyond surface texture, discoloration may be influenced by other factors such as enamel composition, changes in permeability that may alter the water absorption rates, irregularities on bleached enamel surfaces that can enhance dye deposition, and the pH of the beverages (26, 28, 29). In the present study, cola exhibited the lowest pH value (2.88). The highest $\Delta E_{00}$ value was observed in the cola group at 24 and 72 hours. This finding may be attributed to the adverse impact of the acidic pH of cola on the enamel surface.

Liporoni et al. (30) showed that enamel was sensitive to red wine discoloration after bleaching, while coffee did not affect the bleaching process. However, Côrtes et al. (31) reported that the ΔE values of bleached teeth after soaking in coffee and wine showed statistically significant differences compared to the control group. In line with Côrtes et al. (31) in our study, the coffee group showed the highest mean $\Delta E_{00}$ value at the end of one month.

Paravina et al. considered a $\Delta E_{00}$ value greater than 1.8 to be clinically unacceptable at a 50%:50% confidence interval (32, 33). According to the results of our study, the mean $\Delta E_{00}$ values obtained at all times after immersion in tea, coffee, milk, or cola were above the clinically acceptable limit. The artificial saliva group showed the lowest mean $\Delta E_{00}$ value at all times.

Karadaş et al. (34) evaluated the effect of tea, coffee, red wine, and cola drinks on discoloration at different time intervals after home bleaching. According to the results of this study, the ΔE values obtained after keeping in tea, cola, and red wine beverages were statistically different from the control group. In our study, the mean $\Delta E_{00}$ values obtained from the tea and coffee groups in the 1st month were significantly different from those of the control group.

## Limitations

The main limitation of this in vitro study was that the bleached teeth were kept in different beverages throughout the experiments without teeth brushing. In reality, teeth are not soaked in beverages. Besides, the role of masticatory muscles and tongue in cleaning teeth surfaces could not be benefited.

# Conclusion

After bleaching, discoloration increased with time. Tea and coffee drinks caused the most discoloration. Therefore, it is recommended that patients should pay attention to the consumption of these beverages following bleaching.

## Disclosures

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**Ethical Approval:** Ethics committee approval was received for this study from the Okan University Research Ethics Committee, in accordance with the World Medical Association Declaration of Helsinki, with the approval number: 2024-172.

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**Author Contributions:** Conception – M.Ç.; Design – M.Ç.; Supervision – M.K.Ö.; Materials – M.Ç., M.K.Ö.; Data Collection and/or Processing – M.Ç., M.K.Ö.; Analysis and/or Interpretation – M.K.Ö.; Literature Review – M.Ç., M.K.Ö.; Writer – M.Ç.; Critical Review – M.K.Ö.

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