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Effects of popular Saudi Arabian beverages on tooth shade after home bleaching: an in vitro analysis

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Abstract

This in vitro study aimed to examine the effects of popular Saudi Arabian beverages on tooth shade after home bleaching. A total of 60 extracted single-rooted teeth were used, of which 45 teeth were bleached using a 35% carbamide peroxide gel and an LED light. After bleaching, the teeth were immersed in three different beverages—Cola, Arabic Qahwa, and Black Coffee—for 14 days, while a control group of unbleached teeth ($n=15$) was also exposed to the same beverages (5 teeth/ beverage). Tooth color changes were assessed using a spectrophotometer before and after immersion. Statistical analysis was conducted using Mann-Whitney and t-tests, with significance set at $p<0.05$. Results showed that after bleaching, the Cola group had a slightly higher mean E1 value compared to the control, but the difference was not statistically significant ($p=0.087$). After 14 days of immersion, both the Cola and control groups exhibited increased changes in tooth shade, with no significant difference in ΔE values. In contrast, the Arabian Qahwa group showed significantly ($p=0.001$) greater discoloration than the control group, indicating a stronger staining effect. For the Black Coffee group, the mean E2 value was 16.04 ± 2.97, while the control group had a higher mean of 19.2 ± 2.09, with a statistically significant difference ($p=0.044$). The study concluded that beverages such as Cola, Arabic Qahwa, and Black Coffee can influence tooth shade over time. Black Coffee caused significant discoloration, whereas Cola showed statistically insignificant changes. However, Arabic Qahwa led to significant differences in ΔE values compared to the controls, indicating a notable effect on tooth shade.

Keywords Tooth shade, Aesthetics, Home bleaching, Beverages, Discoloration

Introduction

Tooth whitening, also known as bleaching, is a widely used procedure by both dental professionals and patients. It is considered the least invasive cosmetic treatment for improving the appearance of stained or discolored teeth [1]. Whitening can be achieved either by physically removing surface stains or through a chemical process that lightens the tooth color. Most chemical in bleaching products contain hydrogen peroxide (H_2O_2) as the active ingredient, available in the form of hydrogen peroxide (HP) or carbamide peroxide (CP). CP is a stable compound that decomposes into HP and urea upon contact with water [2].

Dental bleaching for vital teeth can be performed using various approaches, including in-office treatments by professionals, at-home treatments (self-application of the lower concentration of bleaching agent by the patient, as instructed by the professionals), or a combination of

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both, known as the combined or jump-start technique [3]. While these techniques are effective, laboratory studies indicate that they may cause alterations in the enamel surface, including increased roughness, greater susceptibility to demineralization [4], and higher permeability [5]. These changes can influence the overall success of bleaching treatments. Additionally, exposure to staining agents with acidic pH, such as cola-based drinks, coffee, and wine, has been shown to discolor dental structures and negatively affect both the final outcome and long-term durability of bleaching procedures [6–8].

Dentists often advise patients to reduce coffee and tea consumption and avoid smoking or other habits that could lead to tooth staining, particularly after bleaching treatments. This recommendation is based on studies indicating that bleaching agents modify the texture and morphology of the enamel surface [9]. The bleaching process may result in the loss of organic components from enamel and dentin, with changes in tooth microstructure potentially linked to protein degradation or removal [10]. These alterations may increase susceptibility to extrinsic staining [11], highlighting the importance of evaluating the impact of staining substances both during and after bleaching.

Saudi Arabia has a rich tradition of consuming a variety of beverages, many of which play a significant role in social and cultural practices [12]. Among the most popular drinks is Arabian Qahwa, a traditional coffee made from lightly roasted Arabica beans and flavored with cardamom, often served during gatherings and ceremonies [12]. Black coffee is also widely consumed, with an increasing number of specialty coffee shops catering to the growing demand for espresso-based drinks [13]. Additionally, soft drinks, particularly cola-based beverages, have seen a rise in consumption, especially among younger populations, contributing to concerns about their health effects, including dental erosion and staining [14–17].

Coffee is one of the most widely consumed beverages globally, with the increasing availability of coffee capsules and automated machines making a diverse range of coffee types more accessible [18]. However, coffee and other pigmented beverages are associated with discoloration of dental hard tissues, resin-infiltrated white spot lesions (WSLs), and restorative dental materials [19]. Despite this, studies have presented conflicting findings regarding the extent of discoloration in restored dental structures and resin-infiltrated white spot lesions [20, 21]. At-home bleaching treatments using peroxide compounds have demonstrated potential in improving the color of stained enamel and resin-infiltrated teeth [20, 22].

Tooth bleaching, particularly through home bleaching techniques, has become increasingly popular among individuals seeking to improve dental aesthetics [23]. However, maintaining the longevity of these bleaching results remains a significant concern. Dark-colored and acidic beverages such as coffee, tea, and soft drinks, are not only commonly consumed worldwide but are also known to contribute to extrinsic tooth discoloration due to their chromogenic properties and acidic pH. In regions such as Saudi Arabia, beverages like Arabic Qahwa, Cola, and Black Coffee are deeply embedded in daily culture and social practices, making them frequent dietary components. Despite their popularity, limited research exists on their specific impact on post-bleaching tooth shade stability. Understanding the role these beverages play in post-bleaching discoloration is essential for both dental professionals and patients to develop effective dietary and oral hygiene recommendations. Therefore, this study aims to evaluate the discoloration potential of commonly consumed Saudi beverages on bleached teeth, providing evidence-based insights into maintaining the efficacy of at-home bleaching treatments.

Materials and methods

This in vitro study was conducted at the College of Dentistry, King Faisal University, Al-Ahsa, over a period of one month. The sample size was determined using the online tool OpenEpi (www.OpenEpi.com), based on a 95% confidence interval, 80% test power, and means of 3.41 ± 0.37 for Group 1 and 4.09 ± 0.77 for Group 2 at 14 days [24]. This calculation yielded a required sample size of 13 per group. However, to facilitate even grouping and subgrouping, a total of sixty extracted single-rooted teeth (15 per group) were used. For the experiment group, 45 teeth stabilized in a U-shaped seven-arch form using rubber base impression material. A thermoplastic mouth tray was softened in water at 70–80 °C for 10 s, then seated onto the teeth set in the rubber base and pressed to adapt to the arch shape. Subsequently, a 35% carbamide peroxide gel (Advanced Teeth Whitening System, Smile Kit, China) was applied to the labial surface of the thermoplastic tray, which was then positioned onto the arch form, and an LED light was applied close to the teeth for 30 min (Fig. 1). After the treatment period, the gel was removed, and the teeth were stored in artificial saliva. The bleaching gel was re-applied after one week. Upon completion of the bleaching process, baseline tooth shade and ΔE values were measured for both the 45 bleached (experimental) and 15 unbleached teeth (control) using a spectrophotometer (Fig. 2).

The 45 bleached teeth were then randomly assigned to three-experimental groups, each consisting of 15 teeth. The unbleached 15 teeth were assigned to control group by lottery method;

- **Cola Group ($n = 15$)**: Teeth in this group were immersed in 10 ml of a low-pH soft drink (Cola,

Fig. 1 Figure showing an LED light being applied to teeth stabilized in a U-shaped arch made from rubber base impression material

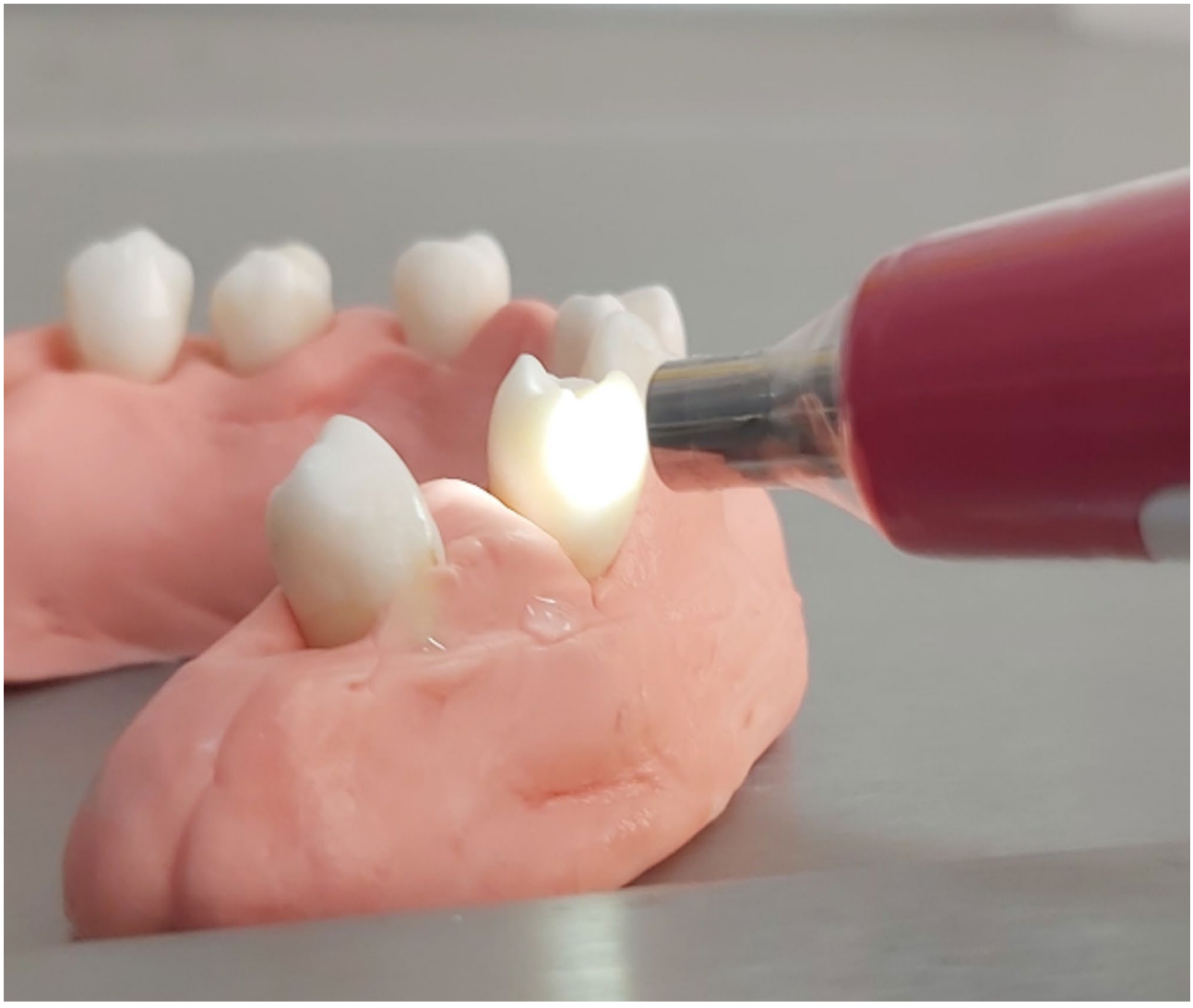

Fig. 2 ΔE value was measured using spectrophotometer

Jeddah, Saudi Arabia), with the solution being replaced every 24 h for a period of 14 days.

- **Arabic Qahwa Group (*n* = 15)**: Teeth in this group were immersed in Arabic Qahwa for 14 days, with the solution replaced every 24 h.
- **Black Coffee Group (*n* = 15)**: Teeth in this group were immersed in 10 ml of black coffee (Nescafé Classic, Nestlé Suisse, Vevey, Switzerland) for 14 days, with the solution replaced every 24 h.

- **Control Group (*n* = 15)**: The 15 unbleached teeth were further subdivided into three sets of five teeth each, and placed in Cola, Arabic Qahwa, and black coffee, respectively (Fig. 3).

At the end of the 14-day period, all teeth were rinsed and stored in distilled water for 24 h. Color change measurements were conducted using a calibrated Vita Easyshade V Compact spectrophotometer (Vita Zahnfabrik, Bad Sackingen, Germany), following the manufacturer's instructions. Before measurement, the teeth

Fig. 3 Teeth were immersed in different beverages

Table 1 Comparison of tooth shade changes for the Cola experimental and control groups

Variables	Effects of Cola on tooth shade ($n=20$)		
	Experimental group ($n=15$) Mean ± SD	Control group ($n=5$) Mean ± SD	*p*-value
After bleaching and before immersion in Cola (E1). No bleaching in control group (E1)	12.0 ± 5.04	11.26 ± 2.00	0.087
After 14 days immersion in drink (E2)	16.2 ± 4.04	15.04 ± 1.09	0.106
Color change (E2- E1: ΔE values)	4.18 ± 1.32	3.78 ± 2.15	0.512

Mann Whitney test

Table 2 Comparison of tooth shade changes for the Arabic Qahwa experimental and control groups

Variables	Effects of Arabic Qahwa on tooth shade ($n=20$)		
	Experimental group ($n=15$) Mean ± SD	Control group ($n=5$) Mean ± SD	*p*-value
After bleaching and before immersion in Arabic Qahwa (E1). No bleaching in control group (E1).	12.9 ± 3.87	13.58 ± 2.29	0.736
After 14 days immersion in drink (E2)	17.1 ± 4.27	14.4 ± 2.22	0.187
Color change (E2- E1: ΔE values)	4.22 ± 1.82	0.82 ± 0.35	0.001

Independent Sample T test

were removed from distilled water, dried with absorbent points, and secured in custom-made boxes. Three readings were taken at the center of each sample using the spectrophotometer's tip. All procedures were performed by the principal investigator.

Statistical analysis

The color difference (ΔE) values before and after immersion in various beverages were calculated and analyzed using SPSS software (Version 25.0, Armonk, NY, USA). The ΔE values before and after immersion were presented as means and standard deviations. A Shapiro–Wilk test of normality for all the variables showed an abnormal and normal distribution of the measured results, and therefore, the Mann-Whitney test and an independent sample t-test respectively, were used to compare every two groups. A p-value of <0.05 was considered statistically significant.

Results

The effects of each beverage on tooth shade were evaluated in two groups (experimental and control). For the Cola group, after bleaching (E1), the mean E1 value was slightly higher in the experimental group (12.0 ± 5.04) compared to the Control (11.26 ± 2.00), but the difference was statistically insignificant ($p=0.087$). Following 14 days of immersion in the respective beverage (E2), the mean E2 value increased in both groups, with the Cola group recording 16.2 ± 4.04 and the Control group recording 15.04 ± 1.09, though this difference was also statistically insignificant ($p=0.106$). The noticeable difference in tooth shade before and after immersion in different beverages was calculated using ΔE values. The calculated ΔE difference between E2 and E1 (ΔE values) showed a mean of 4.18 ± 1.32 in the Cola group and 3.78 ± 2.15 in the control group, with no significant difference between the groups ($p=0.512$), as presented in Table 1.

The effects of Arabian Qahwa on tooth shade were assessed by comparing an Arabic Qahwa group and a Control group. After bleaching (E1), the mean E1 value in the Arabic Qahwa group was 12.9 ± 3.87, while the control group showed a slightly higher value of 13.58 ± 2.29, with no statistically significant difference ($p=0.736$). Following 14 days of immersion in drink (E2), the Arabic Qahwa group recorded a mean E2 value of 17.1 ± 4.27 compared to 14.4 ± 2.22 in the control group; however, this difference was not statistically significant ($p=0.187$). The calculated change in tooth shade (ΔE values) was significantly higher in the Arabic Qahwa group (4.22 ± 1.82) compared to the control group (0.82 ± 0.35), with a significant difference between them ($p=0.001$), as presented in Table 2.

The effects of Black coffee on tooth shade revealed that after bleaching (E1), the mean E1 value was slightly lower in the Black Coffee group (10.08 ± 1.82) compared to the control group (11.68 ± 2.16), but this difference was statistically insignificant ($p=0.380$). After 14 days of immersion in drink (E2), the Black Coffee group exhibited a mean E2 value of 16.04 ± 2.97, while the control group had a higher mean value of 19.2 ± 2.09, with a statistically significant difference ($p=0.044$). Moreover, the Black Coffee group showing a mean ΔE of 7.76 ± 1.42 and the control group recording 7.70 ± 0.99, indicating no significant difference ($p=0.895$), as presented in Table 3.

Table 3 Comparison of tooth shade changes for the Black Coffee experimental and control groups

Variables	Effects of Black Coffee on tooth shade ($n=20$)		
	Experimental group ($n=15$) Mean ± SD	Control group ($n=5$) Mean ± SD	*p*-value
After bleaching and before immersion in Black Coffee (E1). No bleaching in control group (E1).	10.08 ± 1.82	11.68 ± 2.16	0.380
After 14 days immersion in drink (E2)	16.04 ± 2.97	19.2 ± 2.09	0.044 *
Color change (E2- E1: ΔE values)	7.76 ± 1.42	7.70 ± 0.99	0.895

* Independent Sample T test, Mann Whitney test

The comparison of ΔE values between the experimental and control groups revealed varying degrees of discoloration across different staining solutions. For the Cola group, the mean ΔE value was 4.18 ± 1.32, while the control group exhibited a slightly lower mean ΔE value of 3.78 ± 2.15, indicating minimal difference in discoloration between the two groups. In contrast, the Arabian Qahwa group showed a significantly higher mean ΔE value of 4.22 ± 1.82, compared to the control group, which had a mean ΔE value of 0.82 ± 0.35, suggesting that Arabian Qahwa caused a more pronounced discoloration effect. Similarly, the Black coffee group demonstrated the highest level of discoloration among all groups, with a mean ΔE value of 7.76 ± 1.42, which was nearly identical to the control group immersed in Black coffee, showing a mean ΔE value of 7.70 ± 0.99.

Discussion

The staining and color changes of teeth and resin-based restorative materials, especially due to habitual consumption of certain beverages, negatively affect esthetics and impact the clinical longevity of esthetic restorative treatments [20, 24]. The present study examined the effects of different beverages on tooth shade changes following home bleaching, specifically focusing on Black Coffee, Arabic Qahwa, and Cola.

The findings of this study highlight black coffee and arabic qahwa as a strong staining agent, causing significant discoloration over the 14-day immersion period after bleaching. These results are consistent with recent studies that have identified coffee as one of the most chromogenic dietary agents due to its high content of tannins and polyphenols. For instance, Rohym et al. [25] investigated the effect of coffee on the color stability and surface roughness of newly introduced single-shade resin composite materials. Their study concluded that coffee immersion led to significant color changes and increased surface roughness over time, emphasizing coffee's strong staining potential. Similarly, Shiozawa et al. [26] also examined the discoloration of fiber-reinforced composite resin discs after immersion in coffee and curry solutions. They found that coffee immersion significantly increased the color difference (ΔE) values, indicating substantial discoloration. In contrast, a prior investigation on staining effects of red wine, tea, coffee, and cola following bleaching treatment by Karadas and Seven [27] found that red wine and tea caused the most significant discoloration, while coffee exhibited a lesser effect with no statistically significant difference from the control group.

Our study showed that the Cola group exhibited minimal discoloration, with no statistically significant differences compared to the control group. This observation is consistent with a previous study on artificial denture teeth, which found that coffee caused the most staining over 30 days, whereas cola had the least impact [28]. Similarly, cola immersion in the present study resulted in only slight discoloration, reinforcing the concept that cola has a lower staining potential than coffee or tea.

The long-term color stability achieved through dental bleaching depends significantly on post-treatment dietary habits. One study found no significant difference in photoreflectance analysis between specimens exposed to coffee and those that were not after 28 days of bleaching. However, teeth exposed to coffee during at-home bleaching exhibited less stable whitening effects [29]. The impact of peroxide-based bleaching products on enamel remains inconclusive, with some studies reporting no significant harm to enamel microstructure [11, 30], while others suggest morphological alterations [31]. Certain foods and beverages contribute to tooth staining due to their acidity, pigment content, or ethanol composition [12, 32]. The present study confirmed that Arabic Qahwa and black coffee substantially contributed to discoloration, with black coffee being the most impactful, whereas cola had a relatively minor effect.

The effectiveness of at-home bleaching was supported by a randomized controlled clinical trial, which demonstrated that both 10% carbamide peroxide (CP/PF) and 6% hydrogen peroxide (HP/Go) significantly improved tooth shade [33]. The 10% CP/PF system produced greater whitening effects, though its efficacy slightly declined over six months. Furthermore, darker teeth responded better to bleaching than lighter ones. The present study, however, indicated that post-bleaching exposure to Arabian Qahwa and black coffee led to significant discoloration, with black coffee having the most pronounced staining effect. This suggests that patients undergoing bleaching treatments should limit their

consumption of such beverages to maintain esthetic results.

This study had several limitations, including a small sample size, a short observation period, and an in-vitro design, which may not accurately reflect real-life conditions. Additionally, using a single immersion protocol does not account for variations in individual oral hygiene practices and dietary habits. Future research should explore larger sample sizes, extended observation periods, and in vivo studies to gain more comprehensive insights into beverage-induced tooth discoloration. Investigating the effects of different oral hygiene interventions and varying beverage compositions could further enhance the understanding of tooth staining mechanisms and post-bleaching maintenance strategies.

Conclusions

This study found that Black coffee significantly altered tooth shade, highlighting its strong staining potential. Cola caused statistically insignificant changes while Arabic Qahwa showed significant changes in ΔE values compared to controls suggesting a notable effect on tooth shade. Overall, prolonged exposure to these beverages can contribute to tooth discoloration, with varying effects depending on the beverage.

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Author contributions
M.A.A. contributed to conceptualization, formal analysis, investigation of the study, and writing of the manuscript (review and editing).

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of King Faisal University, Saudi Arabia (KFU-REC-2024-SEP- ETHICS2462). All experiments were performed following relevant guidelines and regulations regarding the experiments on the use of human tissue samples. Informed consent to participate was obtained from all of the participants (owners of the extracted teeth) in the study.

Consent for publication
"Not applicable".

Competing interests
The authors declare no competing interests.

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