

# The Efficacy of Denture Cleansing Solutions in Stain Removal of Artificial Teeth

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## Abstract

**Introduction:** Denture cleansers effectively reduce plaque formation; nonetheless, there is a dearth of studies on their efficiency in stain removal and the reduction of multispecies biofilms. The present study aimed to determine the ability of different denture cleansers to remove different stains. **Methods:** A total of 90 central incisors with A1 color were randomly assigned to three groups. Specimens were immersed into three staining solutions (black tea, coffee, and wine). After staining, colorimetry measurements were made, and specimens were immersed in denture cleansers (Protefix Active Cleanser and Aktident Cleansing Tablet) or tap water (control). Color difference ( $\Delta E^*ab$ ) was determined after two, four, and six months ( $n=10$ ). Data were statistically analyzed using the Kruskal-Wallis analysis and Dunn's multiple comparison test at the %95 confidence level. **Results:** There was no significant difference between the stain removal efficacy of denture cleansers and the control group for all staining solutions. When the  $\Delta E^*ab$  values were compared according to different time periods, specimens exposed to three different staining solutions and cleaned by denture cleaners and tap water showed no significant difference ( $P>0.05$ ). In all time periods, teeth exposed to tea and immersed in the Protefix demonstrated higher color difference values ( $\Delta E^*ab>5.5$ ). Color differences of all groups were perceptible to the eye ( $\Delta E^*ab>1.8$ ). There were no significant differences among denture cleansers in different time periods ( $P>0.05$ ). **Conclusion:** There was no significant difference among the denture cleansers regarding stain removal capacity. The soaking time of stained artificial teeth in denture cleansers did not change their color.

**Keywords:** Coloring Agents, Color, Dentures, Denture cleansers

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## Introduction

Despite increased access to dental care and alternative treatment options, such as dental implants, dentures still persist as a common treatment plan for the complete or partially edentulous patient (1). Partial or complete dentures are the conventional treatment option to restore the function and aesthetics of the patients, yielding acceptable or satisfactory results. Artificial teeth are one of the major factors in achieving successful outcomes for both function and aesthetics. Moreover, color stability plays a major role in denture aesthetics (2,3). Discoloration is a sign of damage or the aging of the material (4,5).

Resin artificial teeth are widely used, providing considerable advantages over ceramic teeth, such as chemical bonding to the denture base, lower fracture rates, and light weight. Nevertheless, resin teeth are less wear-resistant and more prone to discoloration (6). Discoloration depends on many factors, such as maintenance, exposure to stains, water sorption, time, and material properties (1,2,7). Discoloration of dentures and artificial teeth due to extrinsic factors can be removed or cleaned by mechanical or chemical methods (2,3).

Denture wearers mainly prefer to clean their dentures using mechanical denture hygiene interventions, i.e., brushing with dentifrices. However, this method can potentially cause abrasive damage to the denture base and artificial teeth, while it may still be inadequate for optimal cleaning (8,9). Chemical denture hygiene interventions are also used for cleaning removable dental prostheses. Different household substances, such as sodium hypochlorite, vinegar, hand washing liquid, or commercially available products, such as denture cleansers, are commonly used for chemical cleaning of removable dentures (7-9,10,11). Denture cleansers are capable of reducing plaque accumulation, extrinsic discoloration, and removing the deposits from the denture surface. They also have antibacterial and antifungal properties (12,13).

Furthermore, it is recommended to simultaneously use both brushing and denture cleansing solutions in order to achieve better denture hygiene (7,8,10). Nonetheless, many researchers are doubtful about the effects of these cleaners on the physical properties of denture resins, such as hardness, surface roughness, and color. The majority of studies failed to prove clinically significant adverse effects in simulated studies (4,9,10). While earlier denture cleansers required overnight immersion to achieve effective plaque control, recently introduced cleansers require a much shorter period of time, such as 10-15 minutes of immersion, to achieve the same effectiveness, and the shortened period of contact with cleansers may attenuate the adverse effects, if any (3,11).

Discoloration can be observed visually and measured by instrumental techniques (14,15). Measurement of color differences is characterized using the Commission Internationale d'Eclairage L\*a\*b\* color space (CIE L\*a\*b\*). The null hypothesis of this study was that cleansing solutions would not affect the stain removal efficiency of stained artificialteeth.

## Materials and Methods

A total of 90 central incisors with A1 color according to the Vita shade scale (Vita Zahnfabrik, Bad Säckingen, Germany) were randomly assigned to three groups (n=30) and were embedded into acrylic resin (Meliodent RR, Heraeus Kulzer, Germany) in order to simulate a denture tooth and secure the specimens during color measurements. Thereafter, specimens were immersed into three staining solutions (black tea, coffee, and wine).

The tea solution was prepared by immersing five black teabags (6 g) (Lipton Yellow Label Tea, Unilever, Istanbul, Türkiye) into 1000 ml boiling water and waiting for 15 min for the tea to brew. Moreover, 10 g coffee (Nescafe Classic, Nestle, Istanbul, Türkiye) was poured into 1000 ml of hot water (85°C). The prepared solutions were then left to cool down to 37°C. Wine (Kavaklıdere, Ankara, Türkiye) was left at room temperature. The solutions were kept in an incubator (Nüve, Türkiye) at 37°C for 30 days and were changed on a daily basis.

After the completion of the staining process, the color of the specimens was assessed by a colorimeter (Vita Easyshade Compact, Bad Säckingen, Germany). The same investigator recorded the data in order to minimize the inconstancy of the technique. Following the measurement of the color of the specimens, they were immersed in beakers containing 1000 mL cleansing solution that was prepared according to the manufacturer's instructions. The denture cleansing solutions were sodium bicarbonate-sodium perborate (Protefix Active Cleanser, Queisser Pharma, Flensburg, Germany) and sodium bicarbonate solution (Aktident Cleansing Tablet, Helago Pharma GmbH, Erfstadt, Germany) (Table I). Tap water was used as the control. The solutions were changed on a simulated daily basis according to manufacturers' instructions. The total simulated cleansing period was six months. The specimens were rinsed under running tap water for 15 sec between solution changes.

**Table I.** Denture cleansers tested in the study

Denture cleanser	Manufacturer	Main ingredients
Protefix	Queisser Pharma, Flensburg, Germany	Sodium bicarbonate, Sodium perborate, Potassium caroate, Citric acid, Sodium laurly sulphate, Aroma
Aktident	Helago Pharma GmbH, Erfstadt, Germany	Sodium Bicarbonate, Potassium Caroate, Citric Acid, Sodium Carbonate, Sorbitol, VP / VA Copolymer, Sodium Lauryl Sulphate, Sodium Lauryl Sulphoacetate, Aroma

The color of the specimens was measured at two, four, and six months of simulated time. Before each measurement, the colorimeter was calibrated using white

and black ceramic tiles, per the manufacturer's instructions. The CIE L\*a\*b\* color system was used. Color measurements were taken from the labial surface of the tooth and repeated for three times: in the center and on each side. Color differences ( $\Delta E^*$ ) and color variables (L\*, a\*, b\*) were calculated to evaluate color stability using the following formula (15):

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

$$\Delta L^* = L^*_o - L^*_t$$

$$\Delta a^* = a^*_o - a^*_t$$

$$\Delta b^* = b^*_o - b^*_t$$

L\*t, a\*t, b\*t: before cleansing

L\*o, a\*o, b\*o: after cleansing

Previous visual judgment thresholds were used in the interpretation of results. Color difference values that  $\Delta E^*_{ab} < 1.8$  was evaluated as perceivable to the eye,  $\Delta E^*_{ab} < 2.6$  was considered as perceptible, and  $\Delta E^*_{ab} > 5.5$  was clinically unacceptable.

The statistical analyses were performed in SPSS software (version 21). The results included the arithmetic mean and the standard deviation, as well as the median and interquartile range (IQR). The Shapiro-Wilk test was applied to analyze the normality of the continuous variables. Since the data were not distributed normally, the color difference after the six months of simulated soaking in denture cleansers was analyzed using Kruskal-Wallis and Dunn's multiple comparisons test. A p-value  $\leq 0.05$  was considered statistically significant.

## Results

When the  $\Delta E^*_{ab}$  values were compared according to different time periods, specimens immersed in coffee, tea, and red wine and cleaned by denture cleaners and tap water showed no significant difference ( $P > 0.05$ ) (Table II). In all time periods, teeth exposed to tea and then immersed in the Protefix exhibited greater color difference values ( $\Delta E^*_{ab} > 5.5$ ). Other groups, except for those exposed to red wine for four months and immersed in tap water ( $2.43 \pm 1.36$ ), were above the perceptibility threshold ( $\Delta E^*_{ab} > 2.6$ ) (Table II). Color differences of all groups were perceivable to the eye ( $\Delta E^*_{ab} > 1.8$ ).

**Table II.** Mean  $\pm$ SD and Median (IQR) of  $\Delta E^*ab$  values of artificial teeth after staining and immersion into denture cleanser at different time periods

Staining solutions	Denture cleansers	Staining-2 months	Staining-4 months	Staining-6 months	P values
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	
		Median (IQR)	Median (IQR)	Median (IQR)	
Coffee	Protefix	3.66 $\pm$ 1.29	4.35 $\pm$ 2.60	3.97 $\pm$ 1.09	>0.99
		3.35 (1.56)	3.54 (1.60)	3.71 (1.11)	
	Aktident	3.93 $\pm$ 2.16	4.71 $\pm$ 1.98	4.03 $\pm$ 2.36	0.529
		3.79 (2.95)	5.24 (2.96)	2.93 (2.63)	
	Tap water	4.51 $\pm$ 1.79	5.34 $\pm$ 2.82	4.30 $\pm$ 1.34	0.905
		3.66 (2.91)	5.33 (2.21)	3.97 (2.48)	
	P-value	0.631	0.538	0.510	
Tea	Protefix	5.52 $\pm$ 2.18	5.74 $\pm$ 1.97	5.53 $\pm$ 2.52	0.741
		4.85 (3.10)	5.40 (2.66)	4.71 (1.87)	
	Aktident	4.08 $\pm$ 1.32	4.66 $\pm$ 2.30	4.52 $\pm$ 2.52	0.497
		3.81 (2.26)	4.05 (1.60)	4.25 (2.56)	
	Tap water	4.17 $\pm$ 1.37	5.46 $\pm$ 2.49	5.02 $\pm$ 2.64	0.905
		3.90 (1.82)	4.54 (2.01)	4.14 (1.80)	
	P-value	0.229	0.312	0.600	
Wine	Protefix	3.12 $\pm$ 1.06	3.48 $\pm$ 1.18	3.15 $\pm$ 1.38	0.368
		3.07 (0.76)	4.06 (0.91)	3.45 (1.26)	
	Aktident	2.83 $\pm$ 2.17	3.42 $\pm$ 1.69	3.59 $\pm$ 1.98	0.368
		1.91 (1.33)	3.09 (1.52)	2.84 (1.14)	
	Tap water	3.65 $\pm$ 2.22	2.43 $\pm$ 1.36	2.65 $\pm$ 1.57	0.717
		3.31 (2.09)	2.08 (1.80)	2.43 (1.34)	
	P-value	0.352	0.143	0.380	

For tea stains, at the end of 4th month, Protefix denture cleaner displayed higher color difference values (5.74 $\pm$ 1.97). However, for wine stains, at the end of 4th month, the control group demonstrated lower color

difference values (2.43 $\pm$ 1.35). According to pairwise comparisons, a significant color difference was observed between wine and tea at the end of the 2nd, 4th, and 6th months (P=0.009, P=0.044, and P=0.028, respectively)

for Protefix denture cleanser. For tap water, a significant color difference was observed between wine and tea and wine and coffee at the end of 4th month ( $P=0.015$  and  $P=0.015$ ), as well as wine and tea at the end of 6th month ( $P=0.036$ ). Pairwise comparisons did not indicate any statistically significant color differences for Aktident denture cleanser ( $P>0.05$  for all).

## Discussion

The null hypothesis of this study was rejected since cleansing solutions were found to be effective in stain removal, regardless of the solution or source of the stain. Due to a marked increase in aesthetic demand, visually detectable color differences or color differences between teeth and artificial teeth are no longer acceptable (2,16). Staining occurs over time following the consumption of various dyestuffs and beverages, along with the aging of materials. The acidity of the drinks or food can also roughen the surface, resulting in color differences. Previously conducted studies reported that acidic drinks caused more color differences compared to other staining solutions (1,4,12,17).

In line with other studies, in the current research, coffee, tea, and red wine were used as staining materials. Although the previous studies reported different results regarding more colorant solutions, researchers all accepted that these solutions were highly staining and discoloration was time-dependent (1,4,12,17). The staining period may vary depending on patients' habits or cultural differences; however, it will eventually occur. Since it is not possible to prohibit patients from consuming staining or coloring food or beverages, the management of these discolorations or staining assumes critical importance. While brushing is the main cleansing method, cleansing solutions are also a major and complementary cleansing procedure for both total and partial removable dentures (8).

Denture cleansers, which are commercially available in effervescent tablet and gel forms, generally include sodium bicarbonate and/or sodium perborate (6,18). These effervescent tablets dissolve in water, forming alkaline peroxide solutions that release oxygen and provide mechanical removal of debris (3,19). Cleansers are effective not only in cleaning the debris but also in reducing biofilms, as well as bacterial and fungal activities on the denture (7,19).

Nevertheless, despite the contradictory reports, prolonged contact with denture cleansers may damage the denture base and cause whitening of the acrylic resin (7,9,19,20). Polychronakis et al. (9) reported that polyamide denture bases displayed color differences after 30 days of cleansing, and in case of solution change or

prolonged contact, the time required for obtaining this color difference was shortened. To overcome this problem, manufacturers introduced fast-acting cleansers in an attempt to reduce contact time (2,3,7,19,20). While contact time was indicated as an important factor affecting color differences, formulation of the cleansing agents was reported to be a major factor as well (17). In the current study, two different formulations were used, and both were found to be effective in stain removal. However, the concentration of peroxide might change the results; therefore, further studies should investigate the effects of different concentrations of peroxide.

In previous studies, it was reported that cleansers were effective in stain removal when compared to water-only cleaning (2,19). However, it is also essential to identify how much stain was removed with the cleansing agents and if it could be detected with the naked eye. In the present study, color differences after staining were perceptible to the eye ( $\Delta E^*_{ab} > 1.8$ ). In the literature, the acceptability threshold (the magnitude that constitutes an unacceptable alteration) value ranged between  $\Delta E^*_{ab}=2.0$  and 4.0. At the same time,  $\Delta E^*_{ab}=5.5$  was reported as acceptable for denture teeth, where a value of 3.7 was given substantially (3,7,15,16). Nonetheless, the perceptibility threshold (magnitude of color difference that is visually detectable) ( $\Delta E^*_{ab}=1.8$ ) was reported to be statistically different from the acceptability threshold (1,15). Moreover, Lohitha et al. (3) reported that color differences of denture base materials, corresponding to  $\Delta E^*_{ab}=6.5$ , would not be detected by patients.

Koksal and Dikbas (6) reported acceptable color differences in denture teeth after various immersions into various solutions ( $\Delta E^*_{ab}<3.3$ ). Gregorius et al. (1) also noticed a similar outcome in their study in which color differences after staining was below the acceptability threshold. On the other hand, they also reported that color differences after immersion were above the perceptibility threshold. Therefore, in this study, the thresholds suggested by Douglas et al. (21) were used,  $\Delta E^*_{ab}< 2.6$  was evaluated as perceptible, and  $\Delta E^*_{ab}>5.5$  was considered clinically unacceptable. Inconsistent with previous studies on color stability, in the current research, color differences over the perceptibility threshold were desired and expected. The results obtained at the end of the current study were above the perceptibility threshold, confirming the ability of denture cleansers to remove stains from the denture teeth.

The color difference of the dental materials is also dependent on the contact period with staining agents. Poly-methyl methacrylates have a tendency to absorb water, thereby displaying color differences even when they are immersed in distilled water (3). In the literature,

immersion time for staining the specimens varied from 7-90 days (1,3). In the present study, the immersion period for staining the specimens was 30 days, simulating a period of 4 years of usage. It was aimed to stain the denture teeth as much as possible and then observe the effects of the cleansers. However, specimens were immersed in cleansing solutions for 60 days, a simulated time of six months.

It was observed that both cleansing solutions were effective in stain removal, and significant removal was achieved after two months of immersion. In agreement with the results of the present research, some studies reported that denture cleansers were effective in stain removal (4,17). On the other hand, other investigations pointed out that commercial denture cleansers had no effect on stain removal (12,22). This discrepancy in the reported results can be ascribed to different staining and cleansing protocols. Increasing the time period of immersion in cleansing agents resulted in an increase in stain removal efficiency (17). Lighter materials were reported to show greater discoloration in previous studies (6). Taking this statement into consideration, it was decided to use artificial teeth with A1 color in the present study.

Among the notable limitations of this study, we can refer to the fact that no mechanical cleaning was performed during the procedure. However, mechanical and chemical cleansing are suggested to be performed together. The cleansing solutions were prepared according to the instructions; nonetheless, different concentrations might have different effects on stain removal. Furthermore, only two types of cleansing agents were used; however, there are many other cleansers available commercially. NaOCl was not used in order to avoid its detrimental effects.

## Conclusion

As evidenced by the results of this study, all denture cleansers were found to be efficient in removing coffee, tea, and red wine stains. Tap water also effectively removed the staining agents used. There was no statistically significant difference among the denture cleansers regarding stain removal capacity. The soaking time of artificial teeth colored with different staining solutions in denture cleansers did not significantly change the color difference.

## Conflicts of Interest

The authors declare no conflict of interest related to this study.

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