Staining Susceptibilities of Two Different Shaded Acrylic Denture Teeth and Effectiveness of Brushing Versus Denture Cleansers on the Stain Removal: An in Vitro Study

İki Farklı Renkte Akrilik Dişin Renklenme Dirençleri ve Renklenmenin Uzaklaştırılmasında Protez Temizleyicilerine Karşın Fırçalamanın Etkinliğinin Değerlendirilmesi: in Vitro Bir Çalışma

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Abstract

Objective: The objective of the present study is to evaluate the color stability of two different shaded acrylic denture teeth and the effectiveness of different cleansing methods on stain removal.

Material-Method: Baseline color readings of 50 right maxillary central incisors of both A1 and A2 shaded denture teeth were performed with a spectrophotometer. Specimens were immersed in a staining solution for 72 hours (h), and the second color readings were carried out. Stained A1 and A2 shaded denture teeth were randomly divided into five subgroups according to cleansing methods as Corega 5-min (Groups of 1C5 for A1, 2C5 for A2), Protefix 3-min (Groups of 1P3, 2P3), Corega 3-min (Groups of 1C3, 2C3), brushing (Groups of 1B, 2B), distilled water (Groups of 1control, 2control) (n=10). Third color readings were performed after the related denture cleaning procedures were applied to the stained teeth. First color change (ΔE_1) values were calculated according to baseline and second color readings, while second color change (ΔE_2) values were calculated according to second and third color readings. Differences among ΔE_1 values of the A1 and A2 shaded groups were analyzed with the Independent Samples Test. ΔE_2 values were analyzed with two-way analysis of variance (2-way ANOVA). Multiple comparisons were made using the Tukey HSD test.

Results: ΔE_1 values were higher for A2 shaded teeth, while ΔE_2 values were higher for A1 shaded denture teeth ($p<0.05$) for all groups. The investigated denture cleansing methods caused higher ΔE_2 values than the control groups for both A1 and A2 shaded brands ($p<0.05$). For the A1 shaded brand, the highest ΔE_2 value was observed for Group 1C3 ($p<0.05$). For the A2 shaded brand, ΔE_2 values were similar among the test groups ($p>0.05$).

Conclusions: The shade of denture teeth and denture cleansing method had a significant effect on ΔE values.

Keywords: Acrylic Denture Teeth, Cleaning Ability, Coffee Staining, Denture Cleanser, Stain Removal.

Özet

Amaç: Bu çalışmanın amacı, iki farklı renkte akrilik yapay dişin renk stabilitelerinin ve farklı protez temizleme yöntemlerinin renklenmeyi gidermedeki etkinliklerinin değerlendirilmesidir.

Materyal-Metot: 50 adet A1 ve A2 renkte yapay dişin her biri için ilk renk ölçümleri spektrofotometre kullanılarak yapıldı. Örnekler 72 saat boyunca renklendirici solusyonda bekletildi ve ikinci renk ölçümleri gerçekleştirildi. Renklenen A1 ve A2 yapay dişler, protez temizleme yöntemine göre Corega 5-dak (A1 için 1C5, A2 için 2C5 Grupları), Corega 3-dak (1C3 ve 2C3 Grupları), Protefix 3-dak (1P3 ve 2P3 Grupları), fırçalama (1B, 2B Grupları) ve distile su (1 kontrol, 2 kontrol Grupları) olarak rastgele 5 alt gruba ayrıldı. Renklenmiş dişlere ilgili protez temizleme işlemlerinin uygulanmasının ardından üçüncü renk ölçümleri gerçekleştirildi. İlk renk değişimi (ΔE_1) değerleri ilk ve ikinci renk ölçümlerine göre hesaplanırken, ikinci renkdeğişimi (ΔE_2) değerleri ikinci ve üçüncü renk ölçümlerine göre hesaplandı. A1 ve A2 renk grupların ΔE_1 değerleri arasındaki farklılıklar Independent Samples Test ile analiz edildi. ΔE_2 değerleri çift-yönlü varyans analizi (2-way ANOVA) ile test edildi. Çoklu karşılaştırmalar Tukey HSD testi ile yapıldı.

Bulgular: Tüm gruplarda ΔE_1 değerleri A2 renkli yapay dişler için daha yüksek iken, ΔE_2 değerleri A1 renkli yapay dişler için daha yüksek idi ($p<0,05$). İncelenen protez temizleme yöntemleri hem A1 hem A2 renkli yapay dişler için kontrol grubundan daha yüksek ΔE_2 değerlerine neden oldu ($p<0,05$). A1 renkli yapay dişler için, en yüksek ΔE_2 değerleri Grup 1C3 için elde edildi ($p<0,05$). A2 renkli yapay dişler için, test gruplarının ΔE_2 değerleri benzer idi ($p>0,05$).

Sonuç: Yapay diş rengi ve protez temizleme metodu ΔE değerleri üzerinde etkilidir. .

Anahtar kelimeler: Akrilik Yapay Dişler, Temizleme Etkinliği, Kahve Renklenmesi, Protez Temizleyicileri, Renklenmenin Giderilmesi.

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Introduction

Recently, esthetic expectations increased among removable denture wearers as any other fields of dentistry. Denture teeth have a significant role in the overall esthetics of the denture in terms of color stability and staining susceptibility (1).

Denture teeth could be stained by coffee and other colorants (1, 2). Mechanical or chemical denture cleansing methods are available for the purpose of removing extrinsic staining (3). Enzymes, alkaline peroxides, alkaline hypochlorites, disinfectants, and acids are some of the chemical denture cleansing methods, while mechanical cleaning includes using of microwave ovens, brushes, and ultrasonic cleansers (4).

Different denture cleansers were investigated in a few studies with respect to their effectiveness on stain removal by optical density (5-7). There are differences among the studies about investigated cleansers, immersion time, and duration. Al-Huraishi et al. (6) and Jagger et al. (5) evaluated the effectiveness of denture cleansers with the immersion period of 1 minute (min) while Kurtulmus and Deniz (7) preferred immersion period of 14h for the same purpose. The authors of the present study claimed to examine the effectiveness of denture cleansers with a more realistic immersion procedure. There is also a lack of information about the effectiveness of brushing versus denture cleansers with respect to coffee staining removal from acrylic denture teeth.

The aims of this in vitro study were 1) to investigate the color stability of two different shaded acrylic denture teeth (A1-A2) stained with coffee, 2) to evaluate the effectiveness of denture cleansers and brushing on stain removal from the coffee-stained acrylic denture teeth by evaluating the color difference (ΔE). The null hypotheses of the present research were 1) there would be no difference between the staining susceptibilities of two different shaded acrylic denture teeth after immersion in a coffee solution for 72h; 2) there would be no difference between stain removal efficacies of brushing and the investigated denture cleansers.

Material and Methods

The present study was carried out at the Bolu Abant İzzet Baysal University, Faculty of Dentistry, Department of Prosthodontics. One brand of shade A1 and A2 artificial teeth, three commercially available denture cleansers, an electric toothbrush, and dentifrice were used in the present research (Table 1). Baseline color readings of 50 right maxillary central incisors for both shade A1 and A2 were recorded with an intraoral spectrophotometer (Vita Easyshade, Vita Zahnfabrik, Bad Sackingen, Germany) using Commission Internationale de l'Eclairage (CIE) L*, a*, b* system relative to a standard illuminant against a white background. To be able to perform the readings at the same area for each specimen, a white acrylic jig was prepared in the middle of a custom made Teflon mold for positioning the acrylic teeth (Figure 1) (8). For each specimen, readings were repeated 3 times, then the mean of L0*, a0*, b0* data was calculated.

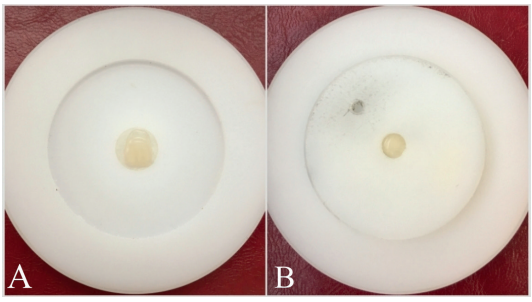

Figure 1. A-White acrylic jig prepared in the middle of the custom made teflon mold. B- Spectrophotometric analysis was performed at the same area for all of the acrylic denture teeth

Table 1. Materials evaluated in the present study

Material	Product	Manufacturer	Active Ingredients
Acrylic denture teeth	NT Optima-A1	Toros Dental, Antalya, Turkey	PMMA
	NT Optima-A2	Toros Dental, Antalya, Turkey	PMMA
Denture Cleanser	Corega-5 min	Stafford Miller Ltd, Waterford, Ireland	Potassium monopersulfate, sodium bicarbonate, sodium carbonate, sodium carbonate peroxide, TAED, sodium benzoate, poly ethylene glycol-180, sodium lauryl sulfoacetate, polyvinylpyrrolidone/vinyl acetate copolymer, sodium, aroma, colorants
	Protefix-3 min	Helago-Pharma GmbH, Erftstadt, Germany	Potassium caroate, sodium bicarbonate, sodium carbonate, citric acid, sorbitol, polyvinylpyrrolidone/vinyl acetate copolymer, sodium lauryl sulfate, sodium lauryl sulfoacetate, aroma, colorant
	Corega-3 min	Stafford Miller Ltd, Waterford, Ireland	Sodium bicarbonate, citric acid, potassium caroate, sodium carbonate, sodium carbonate peroxide, taed, sodium benzoate, poly ethylene glycol-180, sodium lauryl sulfate, Polyvinylpyrrolidone/Vinyl Acetate copolymer, aroma, cellulose gum, colorants
Electronic toothbrush/ soft toothbrushes	Braun Oral-B Advance Power, Oral-B Sensitive Clean	Braun GmbH, Kronberg, Germany/Procter & Gamble, Cincinnati, USA	-
Toothpaste	Ipana 3D Whitening Toothpaste	Procter & Gamble, Cincinnati, USA	Hydrated silica, sodium lauryl sulphate, tetrapotassium pyrophosphate, disodium pyrophosphate, tetrasodium pyrophosphate, carbomer, tri-closan

*Informed by the manufacturers

Staining Procedure in Coffee Solution

After the first color readings, 20 grams (g) of coffee (Nescafe Classic; Nestle Suisse, Vevey, Switzerland) was poured into 1000 milliliters (ml) of boiling water. After the solution was cooled down to 37°C, it was filtered through a filter paper. The coffee staining procedure was performed for 72h at 37°C. The staining solution was renewed within every 12h. After 72h of immersion in coffee solution, the specimens were rinsed with distilled water and air-dried. Second color readings were performed using the intraoral spectrophotometer in the manner described for first color readings, and L1*, a1*, b1* data were calculated. ΔE_1 values were calculated using the following formula:

ΔE_1*=[(L1*-L0*)2+(a1*-a0*)2+(b1*-b0*)2] ½ (1)

Then, each group was divided into five subgroups according to cleaning method as Corega tabs 5-min (Groups of 1C5, 2C5), Protefix tabs 3-min (Groups of 1P3, 2P3), Corega tabs 3-min (Groups of 1C3, 2C3), brushing (Groups of 1B, 2B), distilled water (Groups of 1control, 2 control) (n=10). The groups of the present study are listed in Table 2.

Table 2. Groups of the present study

Shade	Cleansing procedure	Group
A1	Corega tabs 5-min	1C5 (n=10)
	Corega tabs 3-min	1C3 (n=10)
	Protefix tabs 3-min	1P3 (n=10)
	Brushing	1B (n=10)
	Distilled water	1 control (n=10)
A2	Corega tabs 5-min	2C5 (n=10)
	Corega tabs 3-min	2C3 (n=10)
	Protefix tabs 3-min	2P3 (n=10)
	Brushing	2B (n=10)
	Distilled water	2 control (n=10)

Immersion Procedure for Groups of 1C5 and 2C5

The specimens were stored in a 24°C water bath for 20 seconds (s), after 5min of immersion in a 45°C denture cleansing solution (Corega 5-min, Stafford Miller Ltd, Waterford, Ireland). This procedure was repeated for 90 times.

Immersion Procedure for Groups of 1C3 and 2C3

The specimens were stored in a 24°C water bath for 20s, after 3min of immersion in a 45°C denture cleansing solution (Corega 3-min, Stafford Miller Ltd, Waterford, Ireland). This procedure was repeated for 90 times.

Immersion Procedure for Groups of 1P3 and 2P3

The specimens were stored in a 24°C water bath for 20s, after 3min of immersion in a 45°C denture cleansing solution (Protefix 3-min, Helago-Pharma GmbH, Erftstadt, Germany). This procedure was repeated for 90 times.

Brushing Procedure for Groups 1B and 2B

The specimens were placed into the white acrylic jig described above. A small amount of tap water and a rice-grain-size amount of dentifrice (Ipana 3D Whitening Toothpaste, Procter & Gamble, Cincinnati, USA) were placed onto the central portion of the buccal surface, and the specimen was brushed with hand pressure (9).

After the cleansing procedures, the specimens were taken from solutions, rinsed with distilled water, and air-dried. Third color readings were performed as described above for first color readings and L2*, a2*, b2* data were calculated. ΔE_2 values were calculated using the following formula:

ΔE_2*=[(L2*-L1*)2+(a2*-a1*)2(b2*-b1*)2] ½ (2)

Statistical Analysis

The ΔE_1 and ΔE_2 values of the tested groups were normally distributed according to the Kolmogorov Smirnov test. Differences among ΔE_1 values of the A1 and A2 shaded groups were analyzed with the Independent Samples Test. ΔE_2 values were analyzed with 2-way ANOVA. Multiple comparisons were made using the Tukey honestly significant differences (HSD) test. p values less than 0.05 were considered statistically significant.

Results

The means (SDs), and group differences of ΔE1, ΔE2 values for the tested groups are listed in Table 3.

ΔE_1 and ΔE_2 values were different for A1, and A2 shaded brands. ΔE_2 value was higher for A1 shaded denture teeth ($p<0.05$), while ΔE_1 value was higher for A2 shaded denture teeth ($p<0.05$).

According to the results of 2-way ANOVA, the investigated denture cleansing methods caused higher ΔE_2 values than the control groups for both A1 and A2 shaded denture teeth ($p<0.05$).

For the A1 shaded denture teeth, the observed ΔE_2 value was highest for Group 1C3. The difference was significant for Group 1C5 ($p<0.05$). For the A2 shaded denture teeth, ΔE_2 values were similar among the test groups ($p>0.05$).

Results of 2-way ANOVA of all groups for ΔE_2 values are listed in Table 4.

Table 3. The means (SDs) and statistical significance of ΔE_1 and ΔE_2 values

Shade	ΔE_1 (SD)	ΔE_2 (SD)	Groups	ΔE_2 (SD)
A1	1.80 (0.74)^{A}	1.67 (0.92)^{C}	1C5	1.51 (0.6)^{a}
			1C3	2.29 (0.62)^{b}
			1P3	2.13 (0.47)^{a,b}
			1B	2.09 (0.85)^{a,b}
				0.34 (0.16)^{c}
A2	3.80 (1.65)^{B}	1.27 (0.28)^{D}	2C5	1.91 (0.26)^{d}
			2C3	1.43 (0.71)^{d}
			2P3	1.67 (0.43)^{d}
			2B	1.62 (0.86)^{d}
				0.46 (0.16)^{e}

Lover superscript letters (a, b, c, d, e): different letters in the same column indicate a significant intragroup difference in mean ΔE2 scores. Upper superscript letters (A, B, C, D): different letters in the same column indicate intergroup differences in mean ΔE1 and ΔE2 scores

Table 4. Results of 2-way ANOVA of all groups for ΔE_2

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Corrected Model	39.153	9	4.350	13.360	0.001
Intercept	218.431	1	218.431	670.817	0.001
Shade	3.919	1	3.919	12.034	0.001
Cleansing procedure	32.735	4	8.184	25.133	0.001
Shade×Cleansing procedure	2.499	4	0.625	1.919	0.114

Discussion

The first null hypothesis that there would be no difference between the staining susceptibilities of two different shaded acrylic denture teeth after immersion in the coffee solution for 72h was rejected. The second null hypothesis that there would be no difference between stain removal efficacies of brushing and the investigated denture cleansers, was accepted for A2 shaded denture teeth while it was rejected for A1 shaded denture teeth.

Coffee has been used as a staining agent in many studies (1, 7, 10-15), besides some of the studies concluded that coffee was the most chromatic agent (1, 2). In the present study, coffee was preferred as the staining agent as it causes more staining comparing with other staining agents such as tea and cola (1, 2). Similar to the present study, coffee was preferred as the only staining agent in some researches (13-15) for the purpose of evaluating the color stability of restorative materials. Coffee manufacturers claim that 1 cup of coffee takes 15 min to drink, and the average consumption of coffee is 3.2 cups per day (16). 72h of storage in coffee solution simulates the consumption of this beverage for approximately 3 months of usage. Alternative staining solutions and their effectiveness were not evaluated, which could be considered as a limitation for the present research.

Different soaking times are preferred for the purpose of evaluating stain removal efficiency of denture cleansers in the studies (5-7, 10). Zoidis et al. (10) claim that realistic denture cleansing protocols should be used. Denture cleanser manufacturers recommend that dentures should be soaked in denture cleanser solution once a day. In the present research, a realistic immersion period was repeated 90 times for all of the investigated denture cleansers to simulate 3 months of usage.

The Sonicare toothbrush instructions suggest brushing whole dentition for 2min (17, 18). It is assumed that brushing each tooth surface takes 2s. Therefore, brushing the specimens for 10min corresponds to normal brushing for 3 months (9).

Acrylic resin, porcelain, and composite resin artificial teeth are available in the dental market for removable dentures (7). Cross-linked acrylic, microfilled hybrid, and nanocomposite resin teeth were developed physical and mechanical properties of acrylic resin teeth (19). Acrylic teeth were reported to have lower bacterial adhesion and fluorescence values than filler-supplemented and cross-linked resin teeth (20). Acrylic denture teeth are routinely used, especially in public dental hospitals, and prosthodontic departments of dental faculties, besides A1 and A2 are the most preferred shades. A1 and A2 shaded brands of acrylic denture teeth were evaluated in the present study for the purpose of often simulating clinical conditions. In a study (7), conventional PMMA artificial teeth exhibited better color stability in comparison to reinforced acrylic and nanocomposite resin artificial teeth. It can be said that, the compositions of artificial teeth may influence their optical properties after storing in different solutions. Other types of artificial teeth materials such as porcelain, cross-linked acrylic, microfilled hybrid, and nanocomposite resin were not evaluated in this research. Therefore, this is another limitation of the present study.

CIE L*a*b* color system was used for the purpose of measuring color differences (ΔE), in the present study. In the dental literature, there are several studies focused on color perceptibility (21-25) and acceptability (21, 24-28) thresholds for different dental materials. Douglas et al. (21) determined the thresholds using denture teeth and reported that ΔE values lower than 2.6 were perceptible while higher than 5.5 were clinically unacceptable. ΔE values suggested by Douglas at al. (21) were used in the present study.

The calculated ΔE_1 values were 1.80±0.74, and 3.80±1.65 for A1 and A2 shaded denture teeth, respectively. These ΔE_1 values were higher than ΔE values reported by Kurtulmus, and Deniz (7) for different brands of A2 shaded PMMA acrylic denture teeth (Ivostar, SR Vivodent PE, Major Dent). The differences between the reported ΔE values of two studies could be depending on different soaking times and different brands of acrylic denture teeth. Kurtulmus and Deniz (7) calculated ΔE values after 14h of immersion, while 72h of immersion was performed in the present research, thus could explain higher ΔE values. After 72h of coffee staining, A2 shaded denture teeth stained more than A1 shaded denture teeth ($p<0.05$) according to the present results. The discoloration after staining in the coffee solution for 72h was perceptible to the human eye ($\Delta E_1>2.6$) for A2 shaded group, while it was not for A1 shaded group. This finding does not agree with Gregorius et al. (29), who reported that less chromatic shades had larger changes in ΔE values after staining procedures. The difference between the results could be related to different brands of teeth and different immersion procedures.

In the present study, denture cleansers were more effective on bleaching of A1 shaded denture teeth than A2 shaded ones ($p<0.05$). Moon et al. (8) investigated optical properties of A1, B1, and C1 shaded denture teeth after subjected to different denture cleansers. They concluded that, effectiveness of denture cleansers were not affected by tooth shade. Both of the studies evaluated the effect of denture cleansers on different shaded denture teeth. Moon et al. (8) investigated hue and value parameters of the shade, while the chroma and value parameters of the shade were evaluated in the present research. A direct comparison between these studies is not possible. Future researches could be planned about the effectiveness of

denture cleansers on denture teeth by differentiating both hue and chroma values.

The investigated denture cleansing methods caused higher ΔE_2 values than the control groups (distilled water) for both A1 and A2 shaded brands ($p<0.05$) in the present research. Stain removal efficiencies of the investigated denture cleansers and brushing were not different ($p>0.05$) except group 1C5 and 1C3. Corega 5-min caused lower ΔE2 values than Corega 3-min for A1 shaded denture teeth ($p<0.05$). The ingredient of Corega 3-min is slightly different from Corega 5-min, because of citric acid addition. Citric acid may lead to an increase in stain removal efficiency.

Approximately 3 months of clinical usage was simulated in the present study. Further evaluation of these materials for a longer time period would be fruitful due to denture wearers retain their dentures for more than 3 months. Even if the researchers tried their best to simulate realistic staining and cleansing procedures, in vitro experiments could not simulate the exact intraoral environment. Future researches in vivo conditions should be performed.

Conclusion

Following conclusions could be drawn within the limitations of the present research; A1 shaded denture teeth were more resistant to staining than A2 shaded denture teeth ($p<0.05$); the denture cleansers and brushing were found to be more effective on removing staining for A1 shaded denture teeth than A2 shaded denture teeth ($p<0.05$), thus the clinicians can prefer A1 shaded denture teeth instead of A2 shaded ones, for proper cases. All of the investigated denture cleansers and brushing were more efficient than control groups with respect to removing coffee staining for both A1 and A2 shaded denture teeth ($p<0.05$). Corega 3-min was more efficient in removing coffee staining than Corega 5-min for A1 shaded denture teeth ($p<0.05$). All of the denture cleansers and brushing were similarly effective on removing coffee staining for A2 shaded denture teeth ($p>0.05$); thus Corega 3-min seems to be a better choice for both shaded denture teeth.

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