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Effect of Denture Cleansers on Color Stability of Acrylic and Composite Artificial Teeth

Protez Temizleme Solüsyonlarının Akrilik ve Kompozit Yapay Dişlerin Renk Kararlılığına Etkisi

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ABSTRACT

Objective: The aim of this study was to evaluate the effects of different immersion solutions and denture cleansers on the color stability of acrylic and composite artificial teeth.

Methods: Maxillary anterior and premolar teeth in A2 color were used from 2 different types of artificial tooth materials (n = 8) in the study. After artificial teeth were kept in distilled water, coffee, and tea solutions at 37°C for 7 days, test specimens were immersed in distilled water, alkaline peroxide, and sodium hypochlorite denture cleansers. Color changes were measured by spectrophotometer using the CIE L*a*b* system when specimens were obtained, after exposure to immersion solutions, and after washing with denture cleaners, then color differences (ΔE) were calculated. The obtained data were analyzed with the Student's *t*-test, 2-way analysis of variance (ANOVA), 3-way ANOVA, and Bonferroni multiple comparison tests ($P = .05$).

Results: After being kept in immersion solutions, the highest ΔE values were observed in the composite artificial tooth specimens, and the highest color difference value was observed in the coffee solution group. There was no statistically significant difference between the denture cleansers in terms of the effect of the materials on the color change ($P > .05$).

Conclusion: While the most color difference was observed in the composite material among the artificial denture materials applied with cleaning solutions, there was no difference between the denture cleansers in terms of cleaning efficiency.

Keywords: Acrylic, artificial teeth, coloring, composite, denture cleansers

ÖZ

Amaç: Bu çalışmanın amacı; farklı daldırma ve protez temizleme solüsyonlarının akrilik ve kompozit yapay dişlerin renk kararlılığı üzerindeki etkilerini değerlendirmektir.

Yöntemler: Çalışmada iki farklı yapay diş materyaline ait A2 renginde maksiller anterior ve premolar dişler kullanıldı (n=8). Yapay dişler; distile su, kahve ve çay solüsyonlarında 37°C'de 7 gün süre ile bekletildikten sonra, distile su, alkalen peroksit ve sodyum hipoklorit protez temizleme solüsyonlarına daldırıldı. Renk değişimleri, örnekler elde edildiğinde, daldırma solüsyonlarına maruz bırakıldıktan sonra ve protez temizleyicileri ile yıkandıktan sonra CIE L*a*b* sistemi kullanılarak spektrofotometre aracılığıyla ölçüldü ve renk farklılıkları (ΔE) hesaplandı. Elde edilen veriler student t-testi, iki yönlü ANOVA, üç yönlü ANOVA ve Bonferroni çoklu karşılaştırma testleri ile analiz edildi (P =0,05).

Bulgular: Daldırma solüsyonlarında bekletildiken sonra en yüksek ΔE değerleri kompozit yapay diş örneklerinde, en yüksek renk farkı değeri ise kahve solüsyonu grubunda gözlendi. Protez temizleme solüsyonları arasında, materyallerin renk değişimine etkisi açısından istatistiksel olarak anlamlı bir fark bulunmadı (P >0,05).

Sonuç: Temizleme solüsyonları uygulanan yapay diş materyalleri arasında en fazla renk değişimi kompozit materyalinde görülürken, temizleme solüsyonları arasında, temizleme etkinliği açısından bir fark bulunmamıştır.

Anahtar Kelimeler: Akrilik, kompozit, renklendirme, protez temizleyicileri, yapay diş

INTRODUCTION

Artificial teeth are prone to discoloration. Color changes, caused by the frequent exposure to coloring liquids in the oral environment, can impact the overall aesthetics and long-term quality of these prostheses as well as patient satisfaction.[1,2] For this reason, artificial teeth must have high color stability to maintain their aesthetic appearance.[1] The color stability of prosthesis has been extensively investigated after immersion in different beverages and solutions,[3-5] such as coffee, red wine, tea, and disinfectant solutions.[6-8]

Porcelain, acrylic resin, reinforced acrylic resin, and composite resin are some of the materials used in the production of artificial teeth.[9] Among these, reinforced acrylic and composite resin teeth are used in place of acrylic resin teeth, which have low wear resistance; however, there are some concerns regarding their color stability when exposed to coloring solutions.[5,9] To the authors' knowledge, there is only 1 published study[10] on the color stability of composite artificial dental material.

The hypotheses of this study are:

1. There is no difference between acrylic and composite artificial dental materials in terms of color change after dipping solutions, holding and cleaning solutions, and cleaning processes.
2. There is no difference between the immersion solutions in terms of the color changes they cause in acrylic and composite artificial tooth materials.
3. There is no difference between the cleaning solutions in terms of the color changes they create in acrylic and composite artificial tooth materials.

MATERIAL AND METHODS

According to a study by Mutlu-Sagasen,[11] power analysis was performed to determine the minimum number of samples required for this study; 8 samples were used for each subgroup. In this study, maxillary right and left, central, lateral, canine, and premolar teeth were used.

Preparation of Samples

Three-layered acrylic (Eray, Eraylar, Ankara, Turkey) and composite (Eray Plus, Eraylar, Ankara, Turkey) artificial teeth of the same brand, color (A2), shape, and size (G2-M2; U2-P2) were used. Each tooth of the same material was embedded in autopolymerizing polymethylmethacrylate resin (PMMA; Meliodent, Kulzer GmbH) paste prepared according to the manufacturer's instructions, with the buccal surface parallel to the ground and the corresponding tooth to the midline. The samples were kept in distilled water at 37 ± 2°C for 24 hours in a dark environment. At the end of this period, the samples were dried on blotting paper (Kimwipes Lite 200, Kimberly Clark Corp., Roswell, Ga, USA) for the first color measurements of the samples. Acrylic and composite dental materials were divided into 9 subgroups, with 1 pair of maxillary central, lateral, canine, and premolar teeth in each subgroup (n = 8). The experimental groups in the study are given in Table 1.

Preparation of the Immersion Solutions

In each group, 300 mL of distilled water was used in the control group. Tea (bag tea, Lipton Yellow Label Tea, Unilever Turkey, Istanbul, Turkey) and coffee (Nescafe Classic, Nestle, Bursa, Turkey) solutions were prepared according to the manufacturer's instructions. For the tea solution, 2 × 2 grams of prefabricated tea bag were added to 300 mL of boiling water and allowed to steep for 10 minutes; the coffee solution was prepared by mixing 3.6 g of coffee powder with 300 mL of boiling water and infusing for 10 minutes. Both solutions were filtered using filter paper. All samples were immersed in the solutions and kept in the incubator at 37 ± 2°C in a dark environment for 7 days. The solutions were mixed every 24 hours to avoid any precipitation in the tea and coffee solutions.

Table 1. Experimental Groups

Immersion Solutions	Cleaning Solutions	Acrylic Tooth	Composite Tooth
Distilled water	Distilled water	ADD	CDD
	Sodium hypochlorite	ADS	CDS
	Alkaline peroxide	ADA	CDA
Tea	Distilled water	ATD	CTD
	Sodium hypochlorite	ATS	CTS
	Alkaline peroxide	ATA	CTA
Coffee	Distilled water	ACD	CCD
	Sodium hypochlorite	ACS	CCS
	Alkaline peroxide	ACA	CCA

Application of Cleaning Solutions

After 7 days, the samples were removed from the immersion solutions, washed under running water, and air-dried with water spray. Second, color measurements of the samples were made from the buccal midpoints of the teeth using the first mode in the spectrophotometer (VITA Easyshade® V; VITA Zahnfabrik, Bad Säckingen, Germany), which is recommended in "determination of basic color in the selection of prosthetic teeth." Cleaning solutions were prepared such that there was an equal amount of liquid in all groups. Samples in the control group were washed with distilled water; those in the sodium hypochlorite group were washed with 0.5% sodium hypochlorite (NaOCl, Lider Chemical Industry, İstanbul, Turkey) solution; whereas samples in the alkaline peroxide group were washed in a cleaning solution prepared by dissolving 1 denture cleaner tablet (Corega Tabs, Block Drug Company, Inc., NJ, USA) in 200 mL of warm distilled water as per the manufacturer's instructions. According to the instructions, these samples were to remain in the alkaline peroxide group for 5 minutes. For this reason, all samples in the other groups were kept in the cleaning solution for 5 minutes to ensure standardization among the cleaning solutions. The samples were washed under running water and dried with blotting paper. The third color measurements of these samples were made. Data were analyzed statistically.

Identifying Color Differences

Spectrophotometers can reliably measure the color of artificial teeth and express the measured tooth color based on 3 coordinate values (L*, a*, and b*) that locate the measured tooth color in the CIELAB color space. L* coordinate represents tooth brightness, the a* value represents red or green color, and the b* value represents yellow or blue color. The color difference (ΔE) of the 2 teeth is then determined by comparing the differences between the respective coordinate values for each tooth using the formula: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. The numerical description of the color allows for precise identification of the magnitude of the color difference between measurements. In this study, the ΔE formulation was used to compare the L*, a*, and b* differences between the first, second, and third color measurements of the same tooth in color parameters. Three repetitive measurements were made from the labial midpoints of the teeth with a spectrophotometer, and the average of the L*, a*, and b* measurements was taken.

Statistical Analysis

Data analysis was performed using the Statistical Package for Social Science Statistics software, version 24.0 software (IBM Corp.; Armonk, NY, USA). Results were presented as mean difference values. The Student's *t*-test was used to compare differences between acrylic and composite artificial dental materials, and 2-way analysis of variance (ANOVA) and 3-way ANOVA tests were used to determine color differences after immersion and cleaning procedures. The Bonferroni test was used for post hoc analysis. The level of significance for all statistical analyses applied was $P = .05$.

RESULTS

The color differences in acrylic and composite artificial tooth materials after dipping and cleaning solutions are shown in Figure 1. While there was no statistically significant difference between the first and second measurements of acrylic and composite materials ($P > .05$). The color changes in acrylic and composite materials after soaking in dipping solutions were similar. There was a statistically significant difference between the second and third measurements in acrylic and composite materials ($P < .05$). The color change measured in the composite material was greater than the color change measured in the acrylic material. Also, a statistically significant difference occurred between the first and third measurements of acrylic and composite materials ($P < .05$). The color change measured in the composite material was greater than the color change measured in the acrylic material (Table 2).

According to a 2-way ANOVA, there was no statistically significant difference in the effect of staining solutions on the color change of acrylic and composite materials ($P > .05$).

The effect of cleaning solutions on the color change of the materials was evaluated with a 2-way ANOVA test and no statistical difference was found between the cleaning solutions for both acrylic and composite material at the end of the cleaning process ($P > .05$). While the color change in acrylic material as a result of washing with cleaning solutions was not statistically significant ($P > .05$), results were statistically significant in the composite material ($P < .05$) (Table 3).

Post hoc tests were carried out to determine the cause of the difference in the composite material with the coloring solutions. According to the results, the coffee solution group had the most effect on color change, but the least color change was observed in this group after the cleaning process (Table 4).

Color differences in acrylic and composite artificial tooth materials after dipping and cleaning solutions are presented in Figure 1.

DISCUSSION

In this study, 2 different artificial tooth materials were cleaned with different cleaning solutions after being kept in dipping solutions. Color changes were measured by means of a spectrophotometer after 7 days in immersion solutions and after cleaning with cleaning solution. Our results showed that the color change seen in the composite material was higher than that in the acrylic material. Therefore, the first hypothesis of the study was rejected. The coffee solution was significantly more effective in terms of the color changes caused by artificial dental materials. Based on this observation, the second hypothesis of the study was rejected. In the case of the cleaning solutions, there was no significant difference between cleaning solutions, and the third hypothesis of the study was accepted.

Tieh et al[12] conducted a systematic review of studies that investigated the optical properties and color stability of various artificial teeth: polymethylmethacrylate (PMMA), double cross-linked PMMA, nanocomposite, composite, porcelain, computer-aided design/computer-aided manufacturing (CAD/CAM), and 3-dimensional (3D) produced artificial dental materials. In these studies[3,4,6,13,14] the most assessed artificial tooth material was PMMA; only 1 study[10] researched composite tooth material. In most studies, maxillary anterior teeth, which provide a large

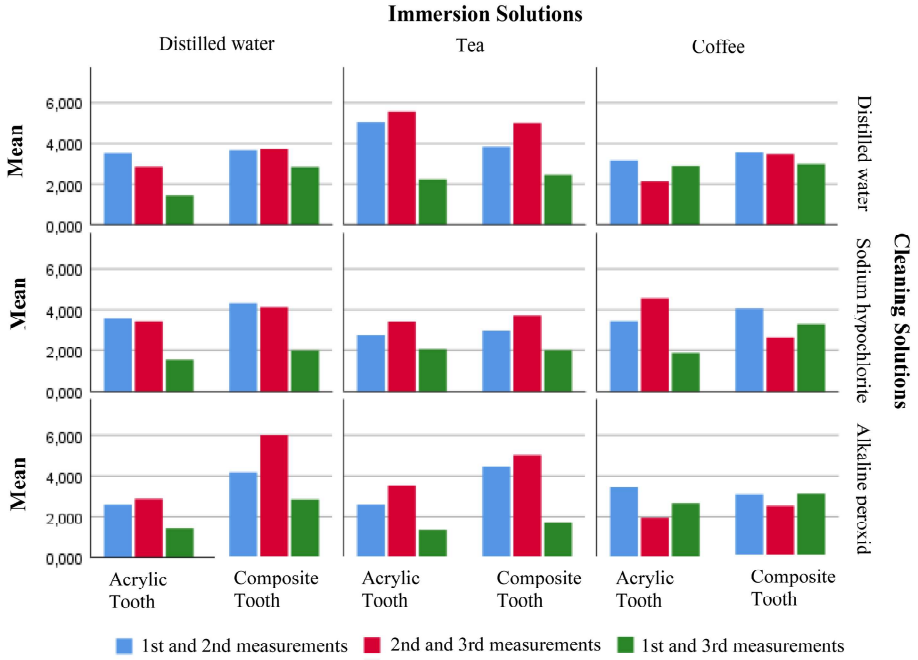

Figure 1. Color differences in acrylic and composite artificial tooth materials after dipping and cleaning solutions.

Table 2. Student *t*-test results

	t	*df*	*P*	Mean Difference
First and second measurements	−1.546	142	.124	−0.445
Second and third measurements	−1.997	142	.048*	−0.669
First and third measurements	−2.897	142	.004*	−0.641

*$P < .05$.

Table 3. Two-way Analysis of Variance Results

Material	Solution	*P*
Acrylic	Immersion solutions	.056
	Cleaning solutions	.185
Composite	Immersion solutions	.001*
	Cleaning solutions	.146

*$P < .05$.

Table 4. Post hoc test results of composite material

Immersion Solution	Cleaning Solutions	*P*
Tea	Coffee	.005*
	Distilled water	1
Coffee	Tea	.005*
	Distilled water	.004*
Distilled water	Tea	1
	Coffee	.004*

*$P < .05$.

and flat surface area, are preferred,[14-16] especially maxillary central incisors.[12] Also, a standard shade of color was determined for comparison of color change, with Vita A2 tooth color being the most commonly preferred in studies.[14-16] In vitro studies generally utilize different immersion solutions, immersion times, and aging protocols.[3,4,6,7,10,13,14] Distilled water is mostly used as the control group,[3,13] and commonly used dipping solutions based on their coloring effect are coffee, Coca-Cola, red wine, and tea.[12] Immersion times vary between studies,[4,6,7,13,14] but the most commonly used time periods are 7, 14, and 15 days.[12] Also, studies evaluating the optical properties and color stability of artificial teeth investigate denture cleaners containing alkaline peroxide[8,15] or sodium bicarbonate, solutions of sodium hypochlorite at different concentrations (0.5%, 1%, 2%, 5.25%)[8,15,17,18] and disinfectant solutions[19] such as povidone-iodine, chlorhexidine gluconate, and glutaraldehyde.[18]

Different methods can be used to determine tooth color, such as color scales that enable visual but subjective comparisons, and spectrophotometers that enable instrumental and objective measurements.[20] Tieh et al[12] stated that the use of spectrophotometers is the most common method for color measurement in studies on the optical properties and color stability of artificial teeth, and the most commonly used spectrophotometer device was Vita Easy Shade. For all these reasons, in this study, maxillary anterior and premolar acrylic and composite artificial teeth in A2 color were kept in distilled water and in coffee and tea solution for 7 days, and afterward they were cleaned with distilled water, sodium hypochlorite, and alkaline peroxide solution before color measurements were made with the Vita Easy Shade device.

Pişkin et al[18] evaluated the effects of different chemical disinfectants, i.e., neutral soap, 2% sodium hypochlorite, 5.25% sodium hypochlorite, sodium perborate, povidone-iodine, chlorhexidine gluconate, and glutaraldehyde, on the color stability of acrylic maxillary central teeth and reported that these disinfectants affect the color values of acrylic teeth. Freire et al[8] evaluated the effects of different cleaning protocols and accelerated artificial aging on the color stability of PMMA maxillary central teeth. They treated these teeth with alkaline peroxide for 5 minutes and 0.5% sodium hypochlorite solution for 20 minutes and reported that the color stability of acrylic artificial teeth was affected by cleaning solutions and artificial aging at the end of the experiment. Our results differ from the results of Pişkin et al[18] and Freire et al[8]'s studies; the reason is that different artificial dental materials, retention times, and different disinfectant solutions were used in these studies, as was the application of different concentrations of sodium hypochlorite solution for a longer time.

Kurtulmuş-Yılmaz and Deniz[15] evaluated the staining susceptibility of 3 different artificial teeth (acrylic, 1 cross-linked acrylic, and 1 nanocomposite maxillary central teeth) and the stain removal efficiency of denture cleaners containing potassium monopersulfate, sodium perborate, and 0.5% sodium hypochlorite. They reported that cross-linked acrylic and nanocomposite artificial teeth were more prone to discoloration and that all these denture cleaners were equally effective in cleaning artificial teeth. The results are similar to the results of this study. In the case of in vivo studies, Rosentritt et al[21] observed no significant relationship between consumption patterns and cleaning methods, while Barão et al[22] reported a significant relationship between the color change values of artificial teeth and coloring solutions.

This in vitro study evaluated the effects of dipping solutions and cleaning solutions on the color change of acrylic and composite artificial teeth. There was no statistically significant difference between dipping solutions and cleaning solutions. The color change was only observed in the composite material, and this was caused by coffee. Coffee solution is one of the most frequently used solutions in studies,[12] and the solution that produces the most color difference is the coffee solution,[23,24] while the tea solution creates the least color change.[15,25]
Within the limitations of this study,

- The color change in composite artificial tooth material was greater than in acrylic artificial tooth.
- Coffee solution has a coloring effect.
- There is no difference between the cleaning solutions applied in accordance with the manufacturer's instructions in terms of the color change caused by the cleaning solutions.

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