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Effect of Denture Cleansers on Color Stability of Different Acrylic Resin Materials

Fouad Salama[1], Safa Al-Rashed[2], Nouf Al-khunaini[2], Ala'a Abou-Obaid[3], Mohamed Elsharawy[4]

[1]*Department of Pediatric Dentistry and Orthodontics, College of Dentistry, King Saud University, Riyadh, Kingdom of Saudi Arabia*
[2]*Dental Interns, College of Dentistry, King Saud University, Riyadh, Kingdom of Saudi Arabia*
[3]*Department of Prosthetic Dental Science, College of Dentistry, King Saud University, Riyadh, Kingdom of Saudi Arabia*
[4]*Bio-Medical Engineer Researcher, Dental Biomaterials Research Chair, College of Applied Medical Sciences, King Saud University, Riyadh, Kingdom Of Saudi Arabia*
Running Title: Denture cleansers and color of denture base
Correspondence address: Professor Fouad Salama

Abstract
Objective: *The objective of this investigation was to assess the effects of different denture cleansers and distilled water on color stability of self-polymerized (SP) and heat-polymerized (HP) acrylic denture base materials.*
Methods: *Specimens were prepared from HP (Lucitone 199) and SP (Rapid Repair) acrylic resin denture base materials and distributed into different groups/15 each. Specimens were immersed in distilled water as control and in three different denture cleansers (Corega, Polident, and StainAway Plus) according to the manufacturer's specifications and immersion was repeated 7 times over 7 days. All specimens in different groups were measured for color stability using a spectrophotometer against a white background under a standard illumination of D65. Statistical analyses were performed using one and two-way analysis of variance and independent t-test.*
Results: *No significant color change in HP acrylic base material immersed in denture cleansers compared to the control group (P=0.531). However, a significant change in the color was found in SP resins (P=0.000). A significant increase in color change for SP resins immersed in Corega (ΔE = 5.300 ± 2.94) and Polident (ΔE = 6.167 ± 2.80) compared with the control group (ΔE = 2.753 ± 1.35) (P<0.05). A statistically significant lower color change was recorded after immersion in StainAway Plus compared to Corega and Polident (P<0.05). There was a significant increase in (ΔE) for SP resins immersed in Corega and Polident compared to HP resins (P<0.05).*
Conclusions: *Short-term immersion of acrylic denture base materials in denture cleansers showed significant color change of self-polymerized compared to heat polymerized acrylic resins. Immersion of self-cure acrylic reins in Polident and Corega denture cleansers produced appreciable color changes compared to a slight change after immersion in StainAway Plus.*
Keywords: *Denture Cleansers, Color, Denture Bases, Acrylic Resins*

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I. Introduction

Complete dentures have been the most common prosthodontic treatment option for the for edentulous patients.[1,2] Most dentures worldwide are fabricated from acrylic resins because of its low cost and ease of manipulation.[2,3] Despite its advantages, acrylic resin is not an ideal material, with discoloration and surface roughness being two weaknesses.[2,3]

Poly-methyl-methacrylate (PMMA) is consider as the conventional denture base material.[4] Denture base material could be fabricated from a heat-cured acrylic resin or self-cured acrylic resin.[5] As a daily use of the denture without appropriate denture hygiene and disinfection, oral microorganism accumulation could aggravated and causing soft tissue diseases.[6] Acrylic resin denture base stains and attracts the organic and inorganic depositions.[7] Denture cleansers are categorized into chemical or mechanical agents according to their mode of action. The mostly used and the highly effective method is mechanical removal of bacterial biofilm. The chemical cleaning method can be achieved when antifungal and antibacterial denture cleansers solution used by immersing the denture in these agents according to the manufacturer specifications. Also, combination

of these methods have been used.[6] Denture cleansers can be categorize according to the active composition such as sodium perborate, sodium hypochlorite and alkaline peroxide.[8,9]

Color stability of acrylic resin is one of the most important feature for denture wearers.[10] Many patients use detergent solutions to remove denture stains.[10,11] Ideally, denture cleansers should not produce any changes in the mechanical and physical properties of the denture base material.[10] In recent times, adult or elderly patients becoming an aesthetic demanding.[11] So, any changes in the denture color lead to patient satisfaction and unacceptable aesthetic outcome.[12] Heat cured acrylic resin had been shown to have different color stability characteristic when immersed in a different denture cleansers solution.[11] One study found a marked discoloration of the heat cured resin after immersed in Fittydent denture cleanser tablets.[12] Another study found that, significant color changes in the polyamide resin after immersed in sodium perborate denture cleanser solution.[8] Hafezeqoran et al. (2016) found that sodium hypochlorite solution induce a significant color changes in the Vertex thermoplastic resin.[13] Furthermore, shah et al. (2015) found that for both PMMA and nylon resins the maximum color changes was noticed with Clinsodent, Valclean and Polident respectively.[14]

The mechanical and physical properties of acrylic dentures including color can be influenced by different methods of hygiene.[15] One of ultimate properties of denture cleanser is not to produce damaging effects to the denture base materials. Therefore, the purpose of this *in vitro* study was to determine the effect of different denture cleansers and distilled water on color stability of the self- and heat-curing acrylic denture base materials. The null hypothesis tested was that there is no effect of the different denture cleansers on the color stability of the self- and heat-curing acrylic denture base materials.

II. Material And Methods

Specimen Fabrication

Sixty specimens with unified shape, diameter and thickness (10 x 10 x 4 mm) of heat polymerized acrylic resin (Lucitone 199, DENTSPLY, Salzburg, Austria) and autopolymerized acrylic resin (Rapid Repair, Dentsply, Salzburg, Austria) were prepared and polymerized in metal molds according to the instructions of the manufacturer. Specimens were stored in distilled water at 25°C for 72 hours and then one surface of each specimen was finished first using metal burs (DFS Daimon, Reidenburg, Germany) mounted on slow speed hand piece followed by a stone wheel finishing burs (Shofu, San Marcos, USA). Later, it was polished using poly buffs brushes and polishing paste (Hatho, Freiburg, Germany) followed by a slurry of pumice then by the use of rouge applied on a dry wheel using metal finishing bur (DFS Daimon, Reidenburg, Germany). The other surface of the specimen was kept unpolished and marked with a symbol to distinguish the experimental surface used for color measurement.

Immersion Procedures

The specimens of each acrylic base were divided into 4 subgroups (n=15) corresponding to the different denture cleansers used. Table 1 shows denture materials, denture cleansers, and immersion procedures. Specimens of each group were immersed in distilled water (200 mL) as control and in three different denture cleansers at 37°C according to the instructions of the manufacturer. Table 2 shows ingredients of denture cleansers used in this study. For all groups, after each immersion, the specimens were rinsed in running water for 10 seconds, dried, immersed in a new solution and the procedure repeated 7 times over 7 days. After 1 week of immersion in the denture cleansers, the specimens were again rinsed with water for 10 seconds, and then air-dried. Color measurement was made at the center of the polished surface of each specimen.

Color Measurements

The color was measured 3 times in each specimen using a spectrophotometer (Color-Eye 7000, NY, USA) against a white background under a standard illumination of D 65. The color change (ΔE) of each specimen was assessed using the standard Commission International de l' Eclairage (CIE L*a*b*) color system through the following equation: $\Delta E = [(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2]1/2$. To correlate the differences in the color of the acrylic resin base materials with the clinical environment, the color change was quantified by the National Bureau of Standards (NBS) units using the following formula NBS units = $\Delta E \times 0.92$ (Table 3).

Statistical Analysis

The statistical tests were completed using the SPSS 16.0 program (SPSS Inc., Chicago, IL, USA). The data distribution was checked using the Shapiro–Wilks test. Although, this test showed that the data in some groups was not normally distributed, statistical analyses was performed using one and two-way analysis of variance (ANOVA) and independent t-test. The Kruskal-Wallis analysis of variance and Mann–Whitney test were performed for comparison and no differences was found in the results between the parametric and non-parametric tests. Therefore, parametric tests were chosen to report the results. All statistical analyses were set at a significance level of $p<0.05$.

III. Results

The null hypothesis tested in the present study was rejected since statistically significant color change was found in self-cure acrylic base material after immersion in different denture cleansers ($p<0.05$). Table 4 showed the mean color change (ΔE) values, standard deviation and National Bureau of Standards (NBS) units for denture base resin materials after immersion in different denture cleansers.

One way ANOVA reveled no significant color change in heat-cure acrylic base material immersed in denture cleansers compared to the control group ($P=0.531$). However, a significant change in the color was found in self-cure resins ($P=0.000$).Games-Howell post hoc test for multiple comparisons showed a significant increase in color change for self-cure resins immersed in Corega ($\Delta E = 5.300 \pm 2.94$) and Polident ($\Delta E = 6.167 \pm 2.80$) compared with the control group ($\Delta E = 2.753 \pm 1.35$) ($P<0.05$). On the other hand, a statistically significant lower color change was recorded after immersion in StainAway Plus compared to Corega and Polident denture cleansers ($P<0.05$) (Figure 1).

Two-way analyses of variance (ANOVA) was performed to determine whether there were statistically significant differences among materials and denture cleansers (Table 5). The results showed that self-cure resins had a significantly greater color change compared to heat-cure resins ($P<0.05$). Independent t-test revealed a significant increase in (ΔE) for self-cure resins immersed in Corega and Polident compared to heat-cure resins ($P<0.05$).

IV. Discussion

Color alteration of acrylic denture base materials could be attributed to different factors such as changes in the matrix of the material, surface roughness, solubility, water sorption and staining or leakage of colorants.[16-18] The present study showed significant difference in the mean color change of self-polymerized acrylic base material after immersion in denture cleansers. This was in agreement with another study who reported greater color stability of heat-polymerized denture base acrylic resin and the visible-light-polymerized hard direct reline acrylic resins compared to the tested auto-polymerized hard direct reline resins.[19] The results showed that the effect of denture cleansers on the color stability of denture base acrylic resins differs according to the kind of denture cleanser used.[19] Previous studies reported more leaching of coloring material from self-cure resins due to the tendency of higher water sorption and solubility than heat-cure acrylic resins.[20] Another possible reason is the plasticizing effect resulted from water immersion which was proved to have an effect on surface texture of resin materials.[21] Moreover, the amount of residual monomer found in resin materials processed by cold-polymerized technique was greater than heat processed materials.[22] According to Kedjarune et al. (1999), the powder liquid (P/L) ratio of the cold-cure resin material and method of polymerization increase the amount of the residual monomer released.[23] This results in greater surface porosity and subsequently more color alterations. Some studies reported larger chromatic instability for self-cure resins due to the presence of a great amount of additional reagents such as benzoyl peroxide.[24,25] This remains after polymerization and may alter the material's color.[24,25] In addition; oxidation of the aromatic dimethyl-p-toluidine in self-cure resins may produce more color degradation.[26]

Greater color change was noticed after immersion in Corega and Polident compared to the control group. This contributed mainly to the mechanism of action of the alkaline peroxide denture cleansers. Alkaline peroxide solution prepared by dissolving sodium perborate in water.[27] Sodium perborate is an oxidizing agent that decomposes to form sodium metaborate, hydrogen peroxide, and nascent oxygen when hydrated, the bubbling created by this release of oxygen is the mechanism behind the mechanical cleansing effect.[28] In addition, the oxidizing agents help to remove stains.[27] Hydrogen peroxide also discharges active oxygen, which begins the bleaching process.[29] Therefore, it is likely that color change reported after chemical disinfection may have been a result of surface alterations caused by the oxygen-liberating solution.. Studies showed that peroxide cleansers might cause bleaching of acrylic resin when used for routine denture cleansing.[25,30,31]

Several studies showed alteration on the acrylic resin properties produced by alkaline peroxide solutions. Factors such as immersion time, water temperature, and following the instructions of the manufacturer are considered critical and could cause some variations between the different cleansers.[32] Recently the markets have been modifying the composition of the different denture cleansers to reach to the most effective solution that has little changes on the properties of the resin materials. In this study, all the denture cleansers are the most commonly used alkaline peroxides. StainAway plus is newly introduced in the markets. To the best of authors' Knowledge, there is no enough information exist in the literature about its influence on the color of acrylic resin base materials. One recent study evaluated the effect of commercially available fast-acting denture cleansers on the color stability of heat-cure denture base resin at different time intervals (90 and 180 days). The color change of denture base resin was greater for the resins immersed in StainAway Plus followed by Polident and Fixodent scope plus, and distilled water respectively after 180 days of immersion. They reported "slight change" or "noticeable change" for an immersion period of 90 days. However, all groups except for the control group exhibited "very much" color change following immersion for 180 days.[33] Another study that simulate the

overnight immersion of acrylic resins for one and a half year period in NaOCl and alkaline peroxide (Corega), produced a "noticeable" color alterations according to NBS, being more intense for the alkaline peroxide.[34] However, comparison between the results is difficult due to different immersion intervals.

All the tested peroxide denture cleansers considered as fast acting cleansers, with short recommended immersion time to overcome the damaging effect caused by prolong soaking of acrylic denture bases in high alkaline solutions. The recommended immersion time by the manufacturer for StainAway plus was ranged between 10-20 minutes, which was different from Corega (3 minutes) and Polident (3-5 minutes). The results in this study showed that 10 minutes of immersion in StainAway plus produced a slight color change compared to appreciable changes with other solutions, which may be mainly attributed to the composition of the each solution and the differences in the percentage of the main ingredients such as sodium carbonate and percarbonate between the solutions. Moreover, immersion of the resin base material in the cleaning solution results in leaching out of colorant from the resins and absorption of colorants from the cleansers which leads to color change of the material.

The manufacturer recommends StainAway Plus for it is bleaching effect. Moreover, it contains less colorants (FD & C Blue) compared to the other tested denture cleansers. These could explain the slight color change of the material compared with other solutions. However, long-term studies are still needed to evaluate its effect. The limitations of this study includes: testing only three commercially available denture cleansers, short period of *in vitro* evaluation, variations produced by the operator, finishing and polishing procedures did not resemble the methods used in other studies and the lack of simulation of oral environment.

V. Conclusions

Within the limitations of this study, the following conclusions can be drown:

1) Short-term immersion of acrylic denture base materials in the tested denture cleansers showed significant color change in self-polymerized compared to heat polymerized acrylic resins.
2) Immersion of self-cure acrylic reins in Polident and Corega denture cleansers produced appreciable color changes compared to a slight change after immersion in StainAway Plus.

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Table 1. Denture materials, denture cleansers, and immersion procedures used in this study

Group Number/n	Denture Material	Denture Cleansers	Immersion Procedures
1/15	Heat-polymerized	Corega	Immersion for 3 minutes then brushed 5 strokes with soft toothbrush (Sensodyne) and then washed with water and kept in container filled with water for 24 hours
2/15	Heat-polymerized	Polident	Immersion for 5 minutes then brushed 5 strokes with soft toothbrush (Sensodyne) and then washed with water and kept in container filled with water for 24 hours
3/15	Heat-polymerized	StainAway Plus	Immersion for 10 minutes then brushed 5 strokes with soft toothbrush (Sensodyne) and then washed with water and kept in container filled with water for 24 hours
4/15	Heat-polymerized	Distilled water	Immersion for 10 minutes then brushed 5 strokes with soft toothbrush (Sensodyne) and then washed with water and kept in container filled with water for 24 hours
5/15	Self-polymerized	Corega	Immersion for 3 minutes then brushed 5 strokes with soft toothbrush (Sensodyne) and then washed with water and kept in container filled with water for 24 hours
6/15	Self-polymerized	Polident	Immersion for 5 minutes then brushed 5 strokes with soft toothbrush (Sensodyne) and then washed with water and kept in container filled with water for 24 hours
7/15	Self-polymerized	StainAway Plus	Immersion for 10 minutes then brushed 5 strokes with soft toothbrush (Sensodyne) and then washed with water and kept in container filled with water for 24 hours
8/15	Self-polymerized	Distilled water	Immersion for 10 minutes then brushed 5 strokes with soft toothbrush (Sensodyne) and then washed with water and kept in container filled with water for 24 hours

Table 2. Ingredients of denture cleansers used in this study

Denture Cleansers	Manufacturer	Ingredients
Corega	Dungarvan, Co. Waterford, Ireland	Sodium Bicarbonate, Citric Acid, Sodium Carbonate, Potassium Monopersulfate, Sodium Carbonate Peroxide, Sodium Lauryl Sulfoacetate, Sodium Benzoate, PVP/VA Copolymer, Aroma
Polident	GlaxoSmithKline KK, Tokyo, Japan	Sodium Bicarbonate, Citric Acid, Sodium Carbonate, Potassium Monopersulfate, Sodium Percarbonate , Sodium Lauryl Sulfoacetate, Sodium Benzoate, PVP/VA Copolymer, Aroma, Blue 1 Aluminum Lake, Blue 2, Yellow 5 Aluminum Lake, Yellow 5
StainAway Plus	Regent Labs Inc., USA	Potassium Monopersulfate, Sodium Carbonate, Sodium Percarbonate, Sodium Bicarbonate, Citric Acid, Sulfamic Acid, Geropon, FD&C Blue

Table 3. The National Bureau of Standards (NBS) units of color difference

Marks of color difference	NBS units
Trace	0.0 - 0.5
Noticeable	0.5 - 1.5
Slight	1.5 - 3.0
Appreciable	3.0 - 6.0
Much	6.0 - 12.0
Very much	>12.0

Table 4. Mean of color change (ΔE), standard deviation and National Bureau of Standards (NBS) units for acrylic resins after immersion

Material	Mean	Std. Deviation	NBS Unit
Distilled water	2.922	1.93	2.75
Corega	2.656	1.90	2.50
StainAway Plus	3.232	1.70	3.04
Polident	2.266	1.67	2.13
Distilled water	2.753	1.35	2.59
Corega	5.300	2.94	4.98
StainAway Plus	3.000	1.45	2.82
Polident	6.167	2.80	5.80

Table 5. Two-way ANOVA results for color change (ΔE) of denture base materials

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	206.914	7	29.559	7.072	0.000
Intercept	1501.223	1	1501.223	359.147	0.000
Material	70.795	1	70.795	16.937	0.000
Solution	39.704	3	13.235	3.166	0.027
Material * Solution	96.415	3	32.138	7.689	0.000
Error	468.157	112	4.180		
Total	2176.294	120			
Corrected Total	675.071	119			

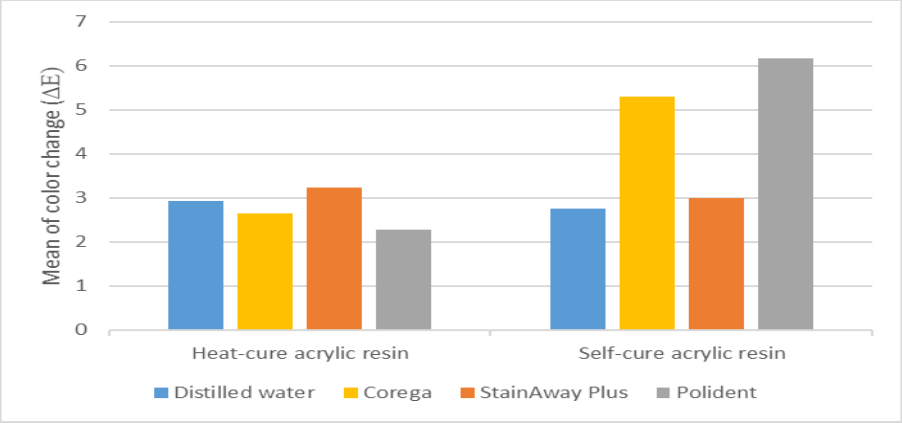

Figure 1. Mean of color change (ΔE) of denture base materials after immersion in different denture cleansers