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Effect of Staining Solutions on the Colour Stability and Surface Properties of Denture Base Material

SUMMARY

Objectives: *The aim of the study was to examine the effects of staining solutions on the colour stability of heat-cured denture base acrylic resins and cold-curing hard denture liner after 1 month of immersion.*

Methods: *Meliodent, SR Ivocap, Lucitone 199 and Ufi Gel Hard, as well as coffee, tea, orange juice and red wine, were used. 40 disc-shaped specimens from each material were prepared, divided into 4 groups and immersed in solutions everyday. Surface roughness and colour measurements were made before and after immersion. Colour values of the specimens were measured with colorimeter. Surface roughness measurements were made by using profilometer. Statistical analysis was performed with 1 way ANOVA and the Tukey multiple comparison test (α = .05).*

Results: *Ufi Gel Hard showed clinically unacceptable ΔE values in all the solutions except coffee. In coffee, no significant difference was determined between the Δ values of the materials. In tea and red wine the greatest mean colour change was determined in Ufi Gel Hard. In orange juice, SR Ivocap and Ufi Gel Hard showed significantly higher ΔE values than Meliodent and Lucitone 199 ($p < .01$, $p < .05$). The initial and last surface roughness values of Ufi Gel Hard and Ivocap 199 were highest and lowest respectively ($p < .05$).*

Conclusions: *Δ of all 3 heat-cured denture base acrylic resins and cold-curing hard denture liner was changed after the immersion in all of the staining solutions during the experimental process. The combination of acrylic resins, staining solutions and surface properties are significant factors affecting the colour stability.*

Keywords: Colour Stability; Surface; Staining Solutions; Denture Base Materials

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Introduction

It is often difficult to restore a satisfactory smile to patients with removable dentures. Acrylic resin, a denture base material, that is used commonly in dental practice, has disadvantages of being hard, easy to fracture and staining[1,2]. The most popular denture base material for more than 50 years has been heat-cured poly (methyl-methacrylate) (PMMA); however, impact resistant resins have been developed[3,4]. One of the properties of acrylates is water sorption and release[4]. Water absorbed into the acrylic resin acts as a plasticizer and decreases the mechanical properties, such as hardness, transverse strength and fatigue limit[5]. Water sorption can also influence dimensional stability that may result in crack formation and fracture of the denture[4,6,7].

Most resin based materials used for prosthetic treatment are prone to absorption and adsorption of liquids[6,8,9]; thus staining may produce colour changes during service in the oral environment.[1] Scotti et al[2] and Um and Ruyter[5] determined that discoloration of denture base resin is related not only to the chemical-physical properties of the resin, but also to patients' dietary habit. The staining of resin based materials by coloured solutions, such as coffee, tea and other beverages, and colour stability after aging in different solutions, have been reported[10]. There is evidence that beverages, such as tea, coffee and wine, significantly increase the development of stain on acrylic resin. Researchers have studied the effect of denture cleaners, fluids and foods. They have been reported that the staining and physical properties of denture base polymers, both hard acrylics and soft lining materials, have had effect[11]. Discoloration of the denture base polymers may be caused by oxidation of the amine accelerator or by penetration of coloured solutions[12]. Purnaveja et al[13] showed that cold-cured resins have colour stability inferior to that of heat-cured materials. Autopolymerizing denture base resin materials have been found to be less stable than conventional acrylic resins. The colour stability of autopolymerizing denture base acrylic resin varied with chemical composition of the monomer. The quantitative evaluation of colour difference (ΔE) with a colorimeter confers advantages, such as repeatability, sensitivity and objectivity. In general, if a material is completely colour stable, no colour difference will be detected after its exposure to the testing environment ($\Delta E=0$)[14,15].

Bacterial adhesion on hard dental surfaces is followed by accumulation of dental plaque. Surface roughness and the surface free energy play a key role during this process[16]. Several studies have demonstrated that rough acrylic resin surfaces are significantly more prone to bacterial accumulation and plaque formation than smooth surfaces[16-19]. Radford et al[20] maintained that acrylic resin has been less frequently investigated for its surface roughness, effects of polishing, bacterial adhesion, and plaque formation than other dental materials.

The purpose of this *in vitro* study was to investigate the effect of staining solutions on the colour stability and surface properties of 3 different denture base materials and hard relining material. The null hypothesis for this study was that the different denture base and hard relining materials have different colour stability and surface properties after exposure to coffee, tea, orange juice and red wine.

Materials and Methods

The 3 base poly (methyl-methacrylate) heat-cured denture base acrylic resins (Meliodent, SR Ivocap, Lucitone 199) and a PMA-based, cold-curing, permanently hard denture liner material (Ufi Gel Hard) and 4 staining solutions (coffee, tea, orange juice and red wine) and as a control group distilled water, were used in this study (Tab. 1). 40 disc-shaped specimens from each material (160 specimens in total), 12 mm in diameter and 3 mm in depth, were prepared in customized stainless steel moulds. Acrylic resins and hard denture liner were mixed and manipulated according to the manufacturers' instructions.

Table 1. The tested materials

Material	Product name	Manufacturer
Heat-cured denture base acrylic resin	Meliodent	Bayer Dental, Newburg, Germany
Heat-cured denture base acrylic resin	SR Ivocap	Ivoclar AG, Schaan, Liechtenstein
Heat-cured denture base acrylic resin	Lucitone 199	Dentsply Trubyte, York, Pa
PMA-based, cold-curing permanently hard denture liner	Ufi Gel Hard	VOCO GmbH, Cuxhaven, Germany
Tea	Lipton	Gayrettepe, Istanbul, Turkey
Coffee	Nescafe-Classic	Karacabey, Bursa, Turkey
Orange juice	Cappy	Yenibosna, Istanbul, Turkey
Red wine	Yakut red wine	Kavaklıdere,Ankara, Turkey

For the heat-cured denture base acrylic resin specimens - Meliodent (Bayer Dental, Newburg, Germany), SR Ivocap (Ivoclar AG, Schaan, Liechtenstein) and Lucitone 199 (Dentsply Trubyte, York, Pa) - the waxes (Cavex set up modelling wax, Haarlem, Holland) were prepared in 12 x 3 mm (in diameter and depth) dimensions. They were then moulded. The flask was used with dental stone to permit processing of multiple samples[11].

For the compression-moulded method, Meliodent and Lucitone 199 (Dentsply Trubyte, York, Pa) specimens were mixed in a mixing cup for 40s with a glass spatula to a homogenous mix according to the manufacturer's directions - liquid:powder ratio (3:1)[21], and while the resin was in dough stage, it was packed into the stainless steel mould. The halves of the flask were pressed together in a pneumatic press (Kavo EWL, Germany). The pressure was increased up to 40.000 N in several steps in order to remove excess resin[3]. They were prepared in conventional metal denture flasks and polymerized in a water bath for 9 hours at 74°C[21,22]. For the injection-moulded method, SR-Ivocap (Ivoclar AG, Schaan, Liechtenstein) specimens were prepared in special flasks with the injection unit (Dentsply/De Trey). Injection of encapsulated heat-polymerizing resin was done under a pressure of 6×10^5 N/m^2. The pressure was maintained during a 45-minute polymerization in hot water (100°C) and 20-minute cooling off period in cold water[16].

For Ufi Gel hard, PMA-based, cold-curing permanently hard denture liner material, specimens were mixed in a mixing cup for 40s with a glass spatula to a homogenous mix according to the manufacturer's directions, and while the resin was in dough stage, it was packed into the stainless steel mould. The specimens were removed from the mould after they completely polymerized. After the preparation of the specimens, all the specimens were polished on both sides with 300, 400 and 600 grit silicone carbide paper (Fuji Star water paper 933.1200; Chiao-Cen Trading Co, Taiwan), respectively, under water flow, and placed into desiccator (Normax, Fabrica de Vidros Cientificos, Portugal) containing silica gel at 37°C ± 1°C until a constant weight was attained. Specimens were then stored in distilled water at 37°C ±1°C for 24h.

To prepare a standard solution of coffee, 15g of coffee (Nescafe Classic; Karacabey, Turkey) was poured into 500ml of boiling distilled water. After 10 minutes of stirring, the solution was passed through filter paper. The tea solution was prepared by immersing 5 tea bags (Lipton, Gayrettepe, Turkey), into 500ml of boiling distilled water and used after 10 minutes of waiting period. 40 specimens of each material were divided into 4 groups for each test solution and 2 of all 10 specimens stored in distilled water as control groups. Base-line surface roughness and colour measurements were made before immersion in 4 different staining solutions (coffee, tea, orange juice and red wine), and as a control in distilled water, and repeated at the end of the first month. 8 specimens from each material were immersed in each of the 5 solutions for an average of 8 hours per day. Fresh solutions were made each day[11]. The control specimens were kept in distilled water that was changed daily. At the end of the staining procedures, all of the specimens were rinsed with water and kept in fresh distilled water until the next daily application.

To evaluate colour differences, the CIELAB calorimetric system was used. Before colorimetric measurement, the colorimeter was calibrated according to the manufacturer's recommendation by using the supplied white calibration standard[14]. Colour values (L*, a*, b*) of the specimens were measured with a colorimeter (CR-508; Minolta Co., Tokyo, Japan). The CIELAB system is an approximately uniform colour space that coordinates for lightness, namely white-black (L*), redness-greenness (a*) and yellowness-blueness (b*)[14]. Colour difference (ΔE) was calculated from the mean ΔL*, Δa* and Δb* values for each specimen with the formula[14,23]:

$$\Delta E = [(L_1-L_0)^2 + (a_1-a_0)^2 + (b_1-b_0)^2]^{1/2}$$

where (L_1-L_0), (a_1-a_0) and (b_1-b_0) are the differences in L*, a* and b* values of a specimen immediately following fabrication and after immersion in beverages and distilled water. Each specimen was measured 3 times by placing each specimen on the measuring head and covering with the black cover. The mean ΔE value of 3 measurements was automatically calculated by the colorimeter and recorded[24].

Surface roughness measurements were made by using profilometer (Miyutoyo Surfest SV-400). The profilometer was calibrated at the beginning of each measuring session. The specimens were rotated through the profilometer clockwise at random angles. 12 transverses of the stylus were made across the diameter for each specimen so that the entire surface of each specimen was evaluated. The mean roughness parameter (Ra in micrometers) for each specimen was recorded as the average of 12 readings. All readings were performed by the same researcher[25]. All the data were calculated with computer software (Excel 7.0; Microsoft) and statistical analysis was performed within each variable with 1 way ANOVA and the Tukey multiple comparison test (α = .05).

Results

In the CIELAB colour system, ΔE value signifies the combination of differences in the 3 dimensions of the colour space. In Meliodent and Lucitone 199 acrylic resin materials, no significant difference was determined between the ΔE values of tea, coffee, orange juice and red wine (Tabs. 2 and 3). SR Ivocap acrylic resin material showed significantly higher E values in tea and orange juice, 1.95±0.22 and 4.74±3.25, respectively (Tab. 4). Ufi Gel Hard material showed clinically unacceptable ΔE values (ΔE > 3.7) in all the solutions except coffee (Tab. 5).

Table 2. The mean values and standard deviations (SD) of the colour changes of Meliodent

Meliodent	ΔE Mean ± SD	ΔE Median	+p
Tea	1.42 ± 1.13	1.32	
Coffee	3.25 ± 4.81	1.55	
Orange juice	2.08 ± 1.46	1.58	0.162
Red wine	1.62 ± 2.16	0.84	
Distilled water	0.99 ± 0.59	0.87	

+ Kruskal Wallis Test ++ Mann Whitney U Test

Table 3. The mean values and standard deviations (SD) of the colour changes of Lucitone 199

Lucitone 199	ΔE Mean ± SD	ΔE Median	+p
Tea	2.25 ± 2.36	1.18	
Coffee	4.09 ± 5.28	1.73	
Orange juice	1.76 ± 1.97	1.15	0.250
Red wine	1.38 ± 0.45	1.33	
Distilled water	2.02 ± 0.85	1.85	

+ Kruskal Wallis Test ++ Mann Whitney U Test

Table 4. The mean values and standard deviations (SD) of the colour changes of SR Ivocap

SR Ivocap	ΔE Mean ± SD	ΔE Median	+p
Tea	1.95 ± 0.22	1.86	
Coffee	3.32 ± 3.02	3.57	
Orange juice	4.74 ± 3.25	4.25	0.034*
Red wine	1.76 ± 0.57	1.70	
Distilled water	1.42 ± 0.87	1.22	
Tea-Coffee ++*p*	0.093		
Tea-Orange juice ++*p*	0.093		
Tea-Red wine ++*p*	0.248		
Tea-D.water ++*p*	**0.021***		
Coffee-Orange juice ++*p*	0.401		
Coffee-Red wine ++*p*	0.753		
Coffee- D.water ++*p*	0.103		
Orange juice-R. wine ++*p*	0.060		
Orange juice-D.water ++*p*	**0.016***		
Red wine-D.water ++*p*	0.093		

+ Kruskal Wallis Test ++ Mann Whitney U Test

Table 5. The mean values and standard deviations (SD) of the colour changes of UfiGel Hard

Ufigel Hard	ΔE Mean ± SD	ΔE Median	+p
Tea	4.06 ± 1.30	3.85	
Coffee	3.02 ± 1.87	2.72	
Orange juice	4.58 ± 1.42	4.23	0.003**
Red wine	5.73 ± 1.30	5.88	
Distilled water	2.60 ± 1.45	2.35	
Tea-Coffee ++*p*	0.103		
Tea-Orange juice ++*p*	0.462		
Tea-Red wine ++*p*	**0.027***		
Tea-D.water ++*p*	0.093		
Coffee-Orange juice ++*p*	**0.036***		
Coffee-Red wine ++*p*	**0.009****		
Coffee- D.water ++*p*	0.529		
Orange juice-R. wine ++*p*	0.127		
Orange juice-D.water ++*p*	**0.027***		
Red wine-D.water ++*p*	**0.002****		

+Kruskal Wallis Test ++ Mann Whitney U Test
* $p<0.05$ ** $p<0.01$

When ΔE was examined in coffee, no significant difference was determined between the Δ values of the materials (Tab. 6). In tea, the greatest mean colour change was determined in Ufi Gel Hard, which had significantly higher E values than all other materials (Tab. 7). In orange juice, SR Ivocap and Ufi Gel Hard showed significantly higher ΔE values than Meliodent and Lucitone 199 (Tab. 8). In red wine, again Ufi Gel Hard showed the highest Δ value than the others (Tab. 9).

Values of mean surface roughness and standard deviations for each material group are given in table 10. The initial and 3rd week surface roughness value of Ufi Gel Hard was higher than all the other materials; initial and 3rd week surface roughness value of Ivocap 199 was lower than all the other materials. No statistically significant difference was determined between the initial and 3rd week surface roughness values of Ufi Gel Hard and Lucitone 199. However, Meliodent and Ivocap 199 3rd week surface roughness values were statistically higher than the initial values (Tab. 10).

Table 6. The mean values and standard deviations (SD) of the colour changes of Meliodent, SR Ivocap, Lucitone 199, and Ufi Gel Hard in coffee

Coffee	ΔE Mean ± SD	ΔE Median	+p
Meliodent	3.25 ± 4.81	1.55	0.677
SR Ivocap	3.32 ± 3.92	1.57	
Lucitone 199	4.09 ± 5.28	1.73	
Ufigel Hard	3.02 ± 1.87	2.72	

+ Kruskal Wallis Test ++ Mann Whitney U Test
* $p<0.05$ ** $p<0.01$

Table 7. The mean values and standard deviations (SD) of the colour changes of Meliodent, SR Ivocap, Lucitone 199 and Ufi Gel Hard in tea

Tea	ΔE Mean ± SD	ΔE Median	+p
Meliodent	1.42 ± 1.13	1.32	0.005**
SR Ivocap	1.95 ± 0.22	1.86	
Lucitone 199	2.25 ± 2.36	1.18	
Ufigel Hard	4.06 ± 1.30	3.85	
Meliodent-Ivocap ++*p*	0.093		
Meliodent-Lucitone ++*p*	0.600		
Meliodent-Ufigel Hard ++*p*	**0.003****		
Ivocap-Lucitone ++*p*	0.248		
Ivocap-Ufigel Hard ++*p*	**0.002****		
Lucitone-Ufigel Hard ++*p*	**0.036***		

+ Kruskal Wallis Test ++ Mann Whitney U Test
* $p<0.05$ ** $p<0.01$

Table 8. The mean values and standard deviations (SD) of the colour changes of Meliodent, SR Ivocap, Lucitone 199 and Ufi Gel Hard in orange juice

Orange Juice	ΔE Mean ± SD	Median	+p
Meliodent	2.08 ± 1.46	1.58	0.007**
SR Ivocap	4.74 ± 3.25	4.25	
Lucitone 199	1.76 ± 1.97	1.15	
Ufigel Hard	4.58 ± 1.42	4.23	
Meliodent-Ivocap ++*p*	**0.036***		
Meliodent-Lucitone ++*p*	0.462		
Meliodent-Ufigel Hard ++*p*	**0.009****		
Ivocap-Lucitone ++*p*	**0.027***		
Ivocap-Ufigel Hard ++*p*	0.753		
Lucitone-Ufigel Hard ++*p*	**0.009****		

$^{+}$ Kruskal Wallis Test $^{++}$ Mann Whitney U Test
* $p<0.05$ ** $p<0.01$

Table 9. The mean values and standard deviations (SD) of the colour changes of Meliodent, SR Ivocap, Lucitone 199 and Ufi Gel Hard in red wine

Red Wine	ΔE Mean ± SD	Median	+p
Meliodent	1.62 ± 2.16	0.84	0.001**
SR Ivocap	1.76 ± 0.57	1.70	
Lucitone 199	1.38 ± 0.45	1.33	
Ufigel Hard	5.73 ± 1.30	5.88	
Meliodent-Ivocap ++*p*	0.093		
Meliodent-Lucitone ++*p*	0.248		
Meliodent-Ufigel Hard ++*p*	**0.006****		
Ivocap-Lucitone ++*p*	0.208		
Ivocap-Ufigel Hard ++*p*	**0.001****		
Lucitone-Ufigel Hard ++*p*	**0.001****		

$^{+}$ Kruskal Wallis Test $^{++}$ Mann Whitney U Test
* $p<0.05$ ** $p<0.01$

Table 10. The surface roughness values and standard deviations (SD) of the colour changes of Meliodent, SR Ivocap, Lucitone 199 and Ufi Gel Hard

	Surface Rougness Initial Mean ± SD	3. Weeks Ort ± SD	+++p
Meliodent	0.26 ± 0.11	0.29 ± 0.10	0.015*
SR Ivocap	0.15 ± 0.04	0.19 ± 0.05	0.001**
Lucitone 199	0.28 ± 0.11	0.31 ± 0.14	0.221
Ufigel Hard	0.78 ± 0.23	0.82 ± 0.16	0.106

+*p*	**0.001****	**0.001****
Meliodent-Ivocap ++*p*	**0.005****	**0.004****
Meliodent-Lucitone ++*p*	0.908	0.855
Meliodent-Ufigel Hard ++*p*	**0.001****	**0.001****
Ivocap-Lucitone ++*p*	**0.001****	**0.001****
Ivocap-Ufigel Hard ++*p*	**0.001****	**0.001****
Lucitone-Ufigel Hard ++*p*	**0.001****	**0.001****

$^{+}$ Oneway ANOVA test $^{++}$ Tukey Test $^{+++}$ Paired Sample t test
* $p<0.05$ ** $p<0.01$

Discussion

Discoloration can be evaluated with various instruments. Since instrument measurements eliminate the subjective interpretation of visual colour comparison, spectrophotometers and colorimeters have been used to measure colour change in dental materials[9,15,26]. Various studies have reported different thresholds of colour difference values above the colour change perceptible by human eye. The values ranges from Δ equal to 1, between 2 and 3, greater than or equal to 3.3 and greater than or equal to 3.7[14]. The value of ΔE represents relative colour changes that an observer might report for the materials after treatment or between the time periods. Thus ΔE is more meaningful than the individual L*, a* and b* values[24,27].

Seghi et al[28] and Um and Ruyter[5] reported that Δ value equal to L* is considered visually detectable 50% of the time, whereas a ΔE value greater than 2 is detectable 100% of the time. A perceptible discoloration that is $\Delta E_{ab*} > 1.0$ will be referred to as acceptable up to value $\Delta E_{ab*} = 3.3$ in subjective visual evaluations made *in vitro* under optimal lighting conditions[29]. Johnston and Kao[30] reported that if ΔE is less than 1, this chromatic value deemed to be slight and the average colour difference between compared teeth rated as "match" in the oral environment was 3.7 (ΔE). Goldstein and Schmitt[31] reported that when ΔE is more than 3.7, it is no longer within the limits of clinical acceptability and it assumes the quality of visual detectability. Yannikakis et al[27] referred discoloration below or above the value ΔE 3.7 as "acceptable" or "unacceptable", respectively. In the present study, as in Yannikakis et al[27], the Δ 3.7 was accepted as clinically acceptable and above this value was considered as clinically unacceptable.

Many resins, including conventional denture base acrylic resins (heat-cured resins), denture base repair acrylic resins and hard denture liners (cold-cured resins), were activated by visible light and microwave, and they were for prosthetic applications[11]. All these materials are known to be affected by food, drink and tobacco[11,13,32]. 4 common used beverages (tea, coffee, orange juice and red wine) were used to measure the colour stability of denture resin materials. They were chosen as the test agents because they have been shown to have greater staining ability on anterior composite resins and natural tooth structure[11,33].

Causative factors that may contribute to the change in colour of aesthetic restorative materials include stain accumulation, dehydration, water sorption, leakage, poor bonding and surface roughness, wear or chemical degradation, oxidation of the reacted carbon-carbon double bonds that produces coloured peroxide compounds, and continuing formation of the coloured degradation products[34,35]. The degree of colour change can be affected by a number of factors, including incomplete polymerization, water sorption, chemical reactivity, diet[2], oral hygiene and surface smoothness of the restoration[15]. According to May et al[32], colour change may be associated with porosity caused by overheating or insufficient pressure during polymerization.

In this study, Meliodent specimens exhibited ΔE values at clinically acceptable levels in all solutions; Lucitone 199 and SR Ivocap also exhibited ΔE values at clinically acceptable levels in 3 of 4 solutions, except in coffee (ΔE=4.09) and orange juice (ΔE=4.74). Ufi Gel Hard exhibited the greatest staining in red wine (ΔE= 5.73). Colour changes exhibited by all specimens after immersion in test solutions were at clinically unacceptable levels, except coffee (ΔE=3.02).

Yannikakis et al[36] and Güler et al[15] used coffee and tea as staining agents and found that coffee stained provisional resin restorative materials more than tea. On the other hand, it is known that tannic acid, which is present in tea and coffee, caused the staining[12]. The study of Crispin and Caputo[37] determined that quality and concentration of tea and coffee products can affect the degree of colour changes. Also the excessive staining in coffee observed with Lucitone may be related to the rubber phase in its structure[38]. There are no studies in the literature which used red wine and orange juice as a staining solution for acrylic resins. Red wine ΔE values were within the limitations of the clinically acceptable levels except for Ufi Gel Hard. Ufi Gel hard is a PMA-based, cold-curing, permanently hard denture liner. Being a hard material, similar to denture acrylic, it can be trimmed and polished in the same way as denture acrylic. Orange juice ΔE values were also within the limitations of the clinically acceptable levels except for Ufi Gel Hard and SR Ivocap. When long term lining is required, the drinking habits of the patients must be considered while choosing the type of lining material.

According to *in vivo* studies by Bollen et al[39] and Quirynen et al[40], clinically acceptable roughness (Ra) of hard surfaces in the oral environment after polishing should not exceed 0.2 µm. In the presented study, SR Ivocap initial and last values were within this limits; Meliodent and Lucitone 199, initial and last values were slightly higher than 0.2 µm; Ufi Gel Hard values were higher than 0.2 µm (0.78±0,23, 0,82±0,16). However, the surface roughness values determined in this study were lower than in Zissis et al[41] study. Zissis et al[41] reported roughness values of 3.2 µm for auto-polymerized resilient liners and values ranging from 3.5 to 4.0 µm for heat-polymerized resilient liners. When evaluating surface properties of denture base materials, a higher variability of Ra values of polished acrylic resin should be expected in clinical practice than in the presented study. Because of polishing of dentures is never performed on completely flat surfaces and the recommended speed and maximum allowable pressure of a rotating polisher are not easy to control, especially at chairside[42].

This *in vitro* study provides information about different types of acrylic resins with respect to colour and surface changes by various solutions. The results may be useful to clinicians when selecting the material to be used for acrylic dentures.

Conclusions

Within limitations of this *in vitro* study, the following conclusions may be drawn: tea, coffee, orange juice and red wine did not cause significant changes in the surface roughness of Ufi Gel Hard liner and Lucitone acrylic resin, but did cause significant changes in the surface roughness of Meliodent and SR Ivocap acrylic resins for the time period tested. ΔE of all 3 heat-cured denture base acrylic resins and cold-curing hard denture liner changed after immersion in all of the staining solutions during the experimental process. Combination of acrylic resins, staining solutions and surface properties are significant factors affecting the colour stability. When choosing the type of lining material and acrylic resin, the drinking habits of the patients should be considered.

References

1. *Lai YL, Lui HF, Lee SY*. In vitro color stability, stain resistance and water sorption of four removable gingival flange materials. *Journal of Prosthetic Dentistry*, 2003; 90:293-300.
2. *Scotti R, Mascellani CS, Forniti F*. The in vitro color stability of acrylic resins for provisional restorations. *International Journal of Prosthodontics*, 1997; 10:164-168.
3. *Lai CP, Tsai MH, Chen M, Chang HS, Tay HH*. Morphology and properties of denture acrylic resins cured by microwave

energy and conventional water bath. *Dental Materials*, 2004; 20:133-141.
4. *Pfeiffer P, Rosenbauer EU*. Residual methyl methacrylate monomer, water sorption and water solubility of hypoallergenic denture base materials. *Journal of Prosthetic Dentistry*, 2004; 92:72-78.
5. *Um CM, Ruyter IE*. Staining of resin based veneering materials with coffee and tea. *Quintessence International*, 1991; 22:377-386.
6. *Wong DM, Cheng LY, Chow TW, Clark RK*. Effect of processing method on the dimensional accuracy and water sorption of acrylic resin dentures. *Journal of Prosthetic Dentistry*, 1999; 81:300-304.
7. *Cucci ALM, Vergani CE, Giampaolo ET, Afonso MCSF*. Water sorption, solubility and bond strength of two auto-polymerizing acrylic resins and one heat polymerizing acrylic resin. *Journal of Prosthetic Dentistry*, 1998; 80:434-438.
8. *Arima T, Murata H, Hamada T*. The effects of cross linking agents on the water sorption and solubility characteristics of denture base resin. *Journal of Oral Rehabilitation*, 1996; 23:476-480.
9. *Satou N, Khan AM, Matsumae I, Satou J, Shintani H*. In vitro color change of composite based resins. *Dental Materials*, 1989; 5:384-387.
10. *Villalta P, Lu H, Okte Z, Godoy FG, Powers JM*. Effects of staining and bleaching on color change of dental composite resins. *Journal of Prosthetic Dentistry*, 2006; 95:137-142.
11. *Keyf F, Etikan I*. Evaluation of gloss changes of two denture acrylic resin materials in four different beverages. *Dental Materials*, 2004; 20:244-251.
12. *Hersek N, Canay Ş, Uzun G, Yıldız F*. Color stability of denture base acrylic resins in three food colorants. *Journal of Prosthetic Dentistry*, 1999; 81:375-379.
13. *Punaveja S. Fletcher AM, Ritchie GM, Amin WM, Moradians S, Dodd AW*. Color stability of two self curing denture base materials. *Biomaterials*, 1982; 3:249-250.
14. *Sham ASK, Chu FCS, Chai J, Chow TW*. Color stability of provisional prosthodontic materials. *Journal of Prosthetic Dentistry*, 2004; 91:447-42.
15. *Güler AU, Yılmaz F, Kulunk T, Güler E, Kurt S*. Effects of different drinks on stainability of resin composite provisional restorative materials. *Journal of Prosthetic Dentistry*, 2005; 94:118-124.
16. *Kuhar M, Funduk N*. Effects of polishing techniques on the surface roughness of acrylic denture base resins. *Journal of Prosthetic Dentistry*, 2005; 93:76-85.
17. *Bollen CM, Lambrechts P, Quirynen M*. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. *Dental Materials*, 1997; 13:258-269.
18. *Radford DR, Sweet SP, Challacombe SJ, Walter JD*. Adherence of Candida albicans to denture-base materials with different surface finishes. *Journal of Dentistry*, 1998; 26:577-583.
19. *Sipahi C, Anil N, Bayramli E*. The effect of acquired salivary pellicle on the surface free energy and wettability of different denture base materials. *Journal of Dentistry*, 2001; 29:197-204.
20. *Radford DR, Challacombe SJ, Walter JD*. Denture plaque and adherence of Candida albicans to denture-base materials in vivo and in vitro. *Critical Reviews in Oral Biology and Medicine*, 1999; 10:99-116.
21. *Puri G, Berzins DW, Dhuru VB, Raj PA, Rambhia SK, Dhir G, Dentino* AR. Effect of phosphate group addition on the properties of denture base resins *Journal of Prosthetic Dentistry*, 2008; 100:302-308
22. *Memon MS, Yunus N, Razak AAA*. Some mechanical properties of a highly cross linked, microwave polymerized, Injection molded denture base polymer. *International Journal of Prosthodontics*, 2001; 14:214-218.
23. *Lee SY, Nathanson D, Giordano R*. Colour stability of a new light-cured ceramic stain system subjected to glazing temperature. *Journal of Oral Rehabilitation*, 2001; 28:457-462.
24. *Türker ŞB, Koçak A, Aktepe E*. Effect of five staining solutions on the color stability of thwo acrylics and three composite resins based provisional restorations. *The European Journal of Prosthodontics and Restorative Dentistry*, 2006; 14(1):2-6.
25. *Türker ŞB, Bişkin T*. Effect of three bleaching agents on the surface properties of three different esthetic restorative materials. *Journal of Prosthetic Dentistry*, 2003; 89:466-473.
26. *Okubo SR, Kanawati A, Richards MW, Childness S*. Evaluation of visual and instrument shade matching. *Journal of Prosthetic Dentistry*, 1998; 80:642-648.
27. *Yannikakis SA, Zissis AJ, Polyzois GL, Caron C*. Color stability of provisional resin restorative materials. *Journal of Prosthetic Dentistry*, 1998; 80:533-539.
28. *Seghi RR, Hewlett ER, Kim J*. Visual and instrumental colorimetric assessments of small color differences on translucent dental porcelain. *Journal of Dental Research*, 1989; 68:1760-1764.
29. *Fay RM, Servos T, Powers JM*. Color of restorative materials after staining and bleaching. *Operative Dentistry*, 1999; 24:292-296.
30. *Johnston WM, Kao EC*. Assessment of appearance match by visual observation and clinical colorimetry. *Journal of Dental Research*, 1989; 68:819-822.
31. *Goldstein GR, Schmitt GW*. Repeatability of a specially designed intraoral colorimeter. *Journal of Prosthetic Dentistry*, 1993; 69:616-619.
32. *May KB, Shotwell JR, Koran A, Wang R*. Color stability: denture base resins processed with the microwave method. *Journal of Prosthetic Dentistry*, 1996; 76:581-589.
33. *Cooley RL, Barkmeier WW, Matis BA, Siok JF*. Staining of posterior resin restorative materials. *Quintessence International*, 1987; 18:823-827.
34. *Ferracane JL, Moser JB, Greener EH*. Ultraviolet light-induced yellowing of dental restorative resins. *Journal of Prosthetic Dentistry*, 1985; 54:483-487.
35. *Anıl N, Hekimoğlu C, Şahin S*. Color stability of heat-polymerized and autopolymerized soft denture liners *Journal of Prosthetic Dentistry*, 1999; 81:481-484.
36. *Yannikakis SA, Zissis AJ, Polyzois GL, Caroni C*. Color stability of provisional resin restorative materials. *Journal of Prosthetic Dentistry*, 1998; 80:533-539.
37. *Crispin BJ, Caputo AA*. Color stability of temporary restorative materials. *Journal of Prosthetic Dentistry*, 1979; 42:27-33.
38. *Stafford GD, Bates JF, Huggett R, Handley RW*. A review of the properties of some denture base polymers. *Journal of Dentistry*, 1980; 8:292-306.

39. *Bollen CM, Papaioannou W, Van Eldere J, Schepers E, Quirynen M, van Steenberghe D*. The influence of abutment surface roughness on plaque accumulation and peri-implant mucositis. *Clinical Oral Implants Research*, 1996; 7:201-211.
40. *Quirynen M, Bollen CM, Papaioannou W, Van Eldere J, van Steenberghe D*. The influence of titanium abutment surface roughness on plaque accumulation and gingivitis: short-term observations. *International Journal of Oral and Maxillofacial Implants*, 1996; 11:169-178.
41. *Zissis AJ, Polyzois GL, Yannikakis SA, Harrison A*. Roughness of denture materials: a comparative study. *Internat5ional Journal of Prosthodontics*, 2000; 13:136-140.
42. *Garcia RCM, Leon BLT, Oliveira VMB, Cury AADB*. Effect of a denture cleanser on weight, surface roughness, and tensile bond strength of two resilient denture liners. *Journal of Prosthetic Dentistry*, 2003; 89:489-494.

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