

Comparative effects of denture cleansers on physical properties of polyamide and polymethyl methacrylate base polymers

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The purpose of this study was to evaluate the effect of denture cleansers on the surface roughness, hardness and color stability of two polyamides (Valpast, Deflex), a butadiene styrene copolymer PMMA (Rodex), and PMMA polymer as a control group (Paladent). Each material was divided into 5 sub-groups ($n=7$) as two control and three test groups. Three test groups were immersed for 20 days in commercially available three denture cleansers (CO-Corega, PR-Protex, VA-Valclean). Two-way analysis of variance and Tukey's *post hoc* HSD test were used to evaluate surface roughness and hardness data ($\alpha=0.05$). ΔE , ΔL^* , Δa^* and Δb^* mean values were used for ANOVA, Tamhane test was used as *post hoc*. Polyamides showed low hardness and high roughness before and after immersion. A significant decrease in hardness was observed for all resins except Rodex after immersion ($p<0.05$). The denture cleansers changed the roughness, hardness and color of some resins.

Keywords: Denture cleansers, Base resins, Physical properties, Polyamide resins, Polystyrene graft copolymer resins

INTRODUCTION

In patients who use fixed and partial removable dentures, hygiene of dentures and maintaining the health of oral mucosa are of great importance^{1,2}. Denture cleansers are used to provide adequate denture plaque control, prevent halitosis, remove discoloring caused by foods and drinks, eliminate *Candida albicans* and *Candida glabrata* and other microorganisms, to dissolve calculus and prevent denture-induced stomatitis³⁻⁵. In patients, particularly those who are very old, have Alzheimer's disease, dementia or low motor capacity, the use of chemical agents may be the only means of denture hygiene^{6,7}. Denture cleansers can be classified according to their chemical composition: enzymes, alkaline hypochlorites, neutral peroxide with enzymes, acids, disinfectants, and alkaline peroxides⁷. Currently, the most common commercial cleansers namely alkaline peroxide, are based upon or require immersion techniques⁸. Gornitsky *et al.*⁹ reported the existence of antimicrobial activity *via* a chemical action of perborate-based denture cleansers on microorganisms that adhered to prostheses. McCabe *et al.*¹⁰ verified these solutions are conducive to prosthesis hygiene and do not contain any abrasive particles. Fernandes *et al.*¹¹ reported that this solution was effective both in acrylic and polyamide-based denture base resins for removing *Candida* biofilms forms.

In recent years, new-generation polyamide thermoplastic resins and butadiene styrene graft PMMA copolymer resins are more widely used than polyethylene methacrylate (PMMA)-based acrylic resins in production of removable dentures^{11,12}.

Polyamide resins (nylon, $(\text{NH}(\text{CH}_2)_m\text{CO})_n$) were produced as denture base material in 1950; however, very few studies were conducted on these resins^{13,14}. Hargreaves¹⁵ reported optimum properties for the use of polyamide in laboratory stages. It was reported that the materials had flexible and semi-flexible structure, low water absorption and solubility, could be injection-molded, did not contain allergic monomer, were biocompatible and had low density. The most important advantages of these resins are that they reflect the color of gingival tissue beneath, due to high light transparency; in other words, they have high-quality esthetic properties; low porosity; they do not cause discoloration and smell formation; and have high impact resistance. In addition, although they have a low rigidity, when compared to acrylic resins, they have extremely tough properties.

Despite all these advantages, they have several important disadvantages, particularly due to their fibrous structure, as follows: difficulty in smoothing and polishing procedures and thus microbial contamination; mechanical retention with acrylic artificial teeth such as diatorics is required; mechanical connection with acrylic liner in nutrition operation¹². Exact indications and contraindications of polyamide thermoplastic resins in clinical use were not determined. However, considering the described properties, they can be particularly appropriate for patients with MMA allergy; bruxism cases, in patients with bone and tuber undercuts, in thin mucosa and excessive bone resorption, in cases where the patient cannot tolerate the force applied by the denture, in production of temporary dentures after implants, and particularly in very old patients with low

motor capacity.

High-impact acrylics have high elastic modulus and impact strength. The rubber-reinforced acrylic contains butadiene styrene rubber substances grafted with methyl methacrylate, which is dispersed in a poly methyl methacrylate matrix. The rubber inclusions serve to prevent crack propagation. A wide range of denture base resins is available, often marketed as high strength materials. These materials are often expensive options to conventional heat-cured acrylic resin^{16,17}.

However, the present concern about these materials is that there is insufficient scientific evidence regarding the properties of the high-impact acrylics and polyamide resins due to the small number of studies comparing the PMMA-based resins^{18,19}.

Previous studies investigated the influence of denture cleansers on the surface conditions and color stability of PMMA acrylic resins. Surface quality, which is assessed by both surface roughness and surface hardness, is one of the most important factors with regard to the efficacy of the components of resin materials. However, no information is available for the surface properties and color stability values of polyamide and high-impact resins immersed in denture cleansers²⁰⁻²².

The purpose of the present study was to evaluate the influence of three commercially available denture cleansers on the surface quality and color of two different polyamide-based denture base polymers, one butadiene styrene copolymer and one PMMA-based control group. The hypothesis tested was that immersion in denture cleansers would not influence the surface roughness,

hardness or color stability of denture base resins.

MATERIALS AND METHODS

Two commercially available thermoplastic polyamide resins and a high-impact polystyrene copolymer PMMA resin were tested in this study (Table 1), with polymethyl methacrylate specimens prepared as a control. All the materials tested were a shade of pink due to its common use in prosthodontic practice, although each material has its own shade system. All the materials used in this study were Type 3 denture base resins.

Specimen preparation

Metal molds and/or wax patterns were prepared in 3 mm thickness and 20 mm diameter for each specimen. The specimens were fabricated by the manufacturers' recommended laboratories.

The polyamide specimens were flaked according to the manufacturers' instructions with a positioned sprue. After the boil out, a cylinder containing the polyamide was plasticized for 11 min at 270–288°C before injecting into the flask. The levers of the press were turned rapidly to apply firm pressure until the springs of the press were fully compressed. The pressure was maintained for 3 min. The pressure was then relived and the flask was allowed to bench cool for 2 h before opening.

Butadiene styrene graft PMMA copolymer specimens were fabricated using a conventional flasking and pressure-pack technique and a 9 h water bath process at 74°C. The conventional heat polymerized resin

Table 1 Materials used in this study

Materials	Groups	Type	Color	Manufacturer
Rodex	Rdx	Butadien-styrenegreft PMMA copolymer	Live pink	Denture material Povere Milano, Italy
Paladent	Pld	Ethyl hexyl acrylate N-octylmethacrylate PMMA	Pear pink	Heraeus Kulzer GmbH, Wehrheim, Germany
Deflex	Dfl	Polyamide/nylon	Light pink	Nuxen SRL, Buenos Aires, Argentina
Valplast	Vlp	Polyamide/nylon	Original pink	Valplast International Corp., New York, USA
Corega Tabs	CO	Potassium Monopersulfate; Sodium Bicarbonate; Sodium Lauryl Sulfoacetate; Sodium Perborate Monohydrate; Sodium Polyphosphate	white	Block Drug Company, Inc., Jersey City, New Jersey-NJ, USA
Protefix	PR	Sodium bicarbonate, Potassium caroate, Sodium perborate, Citric acid, Sodium laurly sulphate, Aroma	white	Queisser Pharma, Flensburg, Germany
Valclean	VA	Potassium caroate, Magnesium carbonate	white	Valplast International Corp., New York, USA

specimens were fabricated in the conventional manner, as polymerization in water bath at 100°C for 30 min. The flask was then allowed to bench cool for 2 h before opening.

One of the surfaces was finished using 200–800 grit and with waterproof carbide papers using an automatic polishing machine (Grin PO 2V grinder-polisher, Metkon A.Ş, Bursa, Turkey) and polished on a wet rag wheel with a slurry of pumice, followed by calcium carbonate to standardize surface roughness.

Immersion procedures

A total of 35 specimens were produced for each base resin/denture cleanser combination, which resulted in 7 specimens for each combination and time period of immersion. The denture cleansers were prepared according to the manufacturers' directions, ensuring that the solutions covered all specimens. Specimens were immersed into each of the 3 denture cleansers for 15 min at 50 °C, washed with tap water and distilled water, then immersed in distilled water after the other period time at room temperature. Fresh denture cleanser solution was prepared each time/day. This procedure represents standard hygiene recommendations for patients using removable prosthetic restorations. These processes were repeated daily for 20 d. Distilled water was employed as a control solution (Table 2).

Surface roughness of denture base materials

The surface roughness (Ra) of the test samples was measured with a profilometer (SJ-201P, Mitutoya Corp, Kawasaki, Japan), using a 0.4-gf load for 5 s, where a stylus traverses the surface, and an amplified trace of the profile is provided. The resolution of the data was 0.01 µm. Surface roughness was standardized for all resins before immersion in solutions, but all of them were standardized in their own group. The Ra value is the arithmetic average of all samples of the profile through the mean sample length. In total, 140 samples (420 roughness measurements) were evaluated. All measurements were recorded by one operator.

Vickers hardness of denture base materials

The Vickers hardness (VHN) of the test samples was measured with a Vickers Hardness Tester (Struers A/S, Balerup, Denmark) using a 100-gf load for 30 s. The diagonals of the pyramid impressed on the specimen by the Vickers diamond indenter were measured and noted. The VHN value is the arithmetic average of the three measurements taken for each sample. In total, 140 samples (420 hardness measurements) were evaluated. All measurements were recorded by one operator. The mean Vickers hardness number was then calculated for each sample, and the average value was used to provide an overall mean value representative of the materials after immersion in cleaning solutions.

Color stability test

The color of the specimens was measured using a portable colorimeter (Shade Eye- ex, Shofu, Japan) against a gray background with a lightness level of 5 Gray background was selected to make a standard for color measurements as performed in a previous study¹²⁾. The diameter of the measurement window was 3 mm; the illumination and light beam angle was 90°. Color changes were examined for each specimen based on color specification using the CIEL*a*b* color space system. The CIEL*a*b* system represents three-dimensional color space with components of (*L*) lightness, (*a*) red-green, and (*b*) yellow-blue²³⁾. Measurements were performed at three points for each specimen to obtain a mean value. The differences in the *L*a*b** values of the specimens in each group before and after immersion were compared through post-polymerization as a control group. The color differences (ΔE) resulting from immersion were calculated using the following equation: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^{*2})]^{1/2}$ for $\Delta L^* = L_1 - L_0$, $\Delta a^* = a_1 - a_0$, $\Delta b^* = b_1 - b_0$. L_0, a_0, b_0 =immediate polymerization/before immersion, L_1, a_1, b_1 =after immersion/20 days cleaning. To relate the color differences (ΔE) to clinical environment, the color data were quantified by the National Bureau of Standards (NBS) units²⁴⁾ through the Formula NBS units= $\Delta E \times 0.92$.

Table 2 Group codes of denture cleaning methods tested

Group Codes	Cleaning methods
Control ND	Not immersed in any solution
Control IW20	Distilled Water—at room temperature—20 days
CO	Corega Tab—at 50°C for 15 min—20 days after distilled water at room temperature for other time of day
PR	Protefix Tab—at 50°C for 15 min—20 days after distilled water at room temperature for other time of day
VA	Valclean Powder—at 50°C for 15 min—20 days after distilled water at room temperature for other time of day

SEM analysis

Scanning electron microscopy images (Carl Zeiss Evo Ls10, USA) were taken to observe the surface topography of the some samples after immersion in solutions. The samples were sputter coated with Au-Pd to a thickness of approximately 5 nm (500× magnification).

Statistical analysis

Statistical analysis was performed using statistical software (SPSS version 16.0, SPSS, Chicago, IL, USA). Vickers hardness (VHN) and surface roughness (Ra, μm) data were evaluated with using two-way analysis of variance (ANOVA). Since significant differences were found between or within groups, Tukey's HSD was used to determine the differences.

One-way analysis of variance (ANOVA) was performed for each resin to compare discolorations according to the solutions used for ΔE , ΔL^* , Δa^* and Δb^* . To compare the statistically significant discolorations for each solution in terms of resin materials, Tamhane test was used as post hoc for ΔE and ΔL^* in Rodex group. In all comparisons, statistical significance was determined by a $p < 0.05$.

RESULTS

Surface roughness

The results are presented as average surface roughness

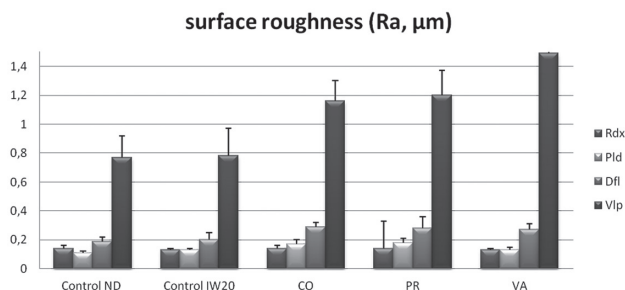


Fig. 1 Roughness of denture bases in different denture cleansers.

values (Ra) of denture base materials-cleansing solutions in Fig. 1. There was not any difference between the control groups ($p > 0.05$). When the solutions were not taken into account, there was statistical difference between all groups except Rdx and Pld. The Rdx and Pld acrylic resins showed less surface roughness than the other two resins among control and solution groups. The highest roughness was observed in Vlp (Fig. 1).

In terms of the solutions, there was no statistical difference between CO-PR-VA for their effect on the samples ($p > 0.05$). Surface roughness remained unchanged in Rdx and increased in all cleaning solutions in Pld, Dfl, and Vlp (Fig. 1).

Vickers hardness

The results are presented as average Vickers hardness values (VHN) of denture base materials-cleansing solutions in Table 3. There was not any difference between the control groups ($p > 0.05$). In terms of each cleansing solution, there was a statistical difference between all groups of resins except Rdx and Pld ($p < 0.05$). Rdx and Pld acrylic resins showed higher hardness values than other two resins for the control and solution groups. The lowest hardness was observed in Vlp.

When the resins were not taken into account, there was no statistical difference between CO-PR-VA ($p > 0.05$). In terms of the solutions, while hardness remained unchanged in Rdx, hardness decreased in solutions in Pld, Dfl, and Vlp (Table 3).

Color stability

According to the comparison of discoloration for each resin in terms of cleansers, (Tables 4 and 5) and one-way ANOVA, there was no statistical difference between Dfl, Vlp, and Pld groups in terms of ΔE , ΔL^* , Δa^* , Δb^* ($p > 0.05$). There was also no difference in terms Δa^* and Δb^* in Rdx groups ($p > 0.05$); however in Rdx groups, (ΔE) values of PR cleansers were different than the control group ($p < 0.05$) but there was no difference between CO, PR and VA solutions in terms of ΔE ($p > 0.05$). Tamhane test showed that the ΔL^* value for Rdx after the immersion of PR was smaller than the control group but this positive ΔL^* value also indicated that the slightly increase of lightness. NBS units of the Rdx group in

Table 3 Mean (SD) hardness values (kg/mm^2) and standard deviations of materials evaluated

Materials	Cleansing Methods				
	Control ND	Control WI20	CO	PR	VA
Rdx	15.29(0.38) ^{aA}	15.14(0.35) ^{aA}	15.24(0.35) ^{aA}	15.26(0.32) ^{aA}	15.3(0.29) ^{aA}
Pld	15.41(0.39) ^{aA}	15.41(0.25) ^{aA}	14.74(0.41) ^{bA}	14.64(0.41) ^{bA}	15.33(0.30) ^{bA}
Dfl	9.07(0.42) ^{aB}	9.07(0.68) ^{aB}	7.9(0.41) ^{bB}	8.07(0.41) ^{bB}	9.19(0.38) ^{bB}
Vlp	8.27(0.93) ^{aC}	8.07(0.79) ^{aC}	6.64(0.45) ^{bC}	7.09(0.22) ^{bC}	7.89(0.55) ^{bC}

Horizontally, means with same supercript lowercase letters are not statistically significant ($p > 0.05$).

Vertically, means with same supercript uppercase letters are not statistically significant ($p > 0.05$).

Table 4 Mean (SD) color differences of ΔE materials in cleansing solutions

Material	Cleansing Methods			
	Control WI20	CO	PR	VA
Rdx	5.89(0.91) ^{aA}	2.40(1.86) ^{abA}	0.53(1.06) ^{bB}	1.36(2.07) ^{abA}
Pld	0.59(0.47) ^{aBCD}	0.81(0.25) ^{aA}	0.97(0.35) ^{aBC}	0.79(0.21) ^{aB}
Dfl	1.20(1.55) ^{aBCD}	2.14(1.59) ^{aA}	1.99(0.95) ^{aC}	1.09(1.01) ^{aAB}
Vlp	1.15(0.68) ^{aBCD}	1.81(0.94) ^{aA}	1.53(0.79) ^{aBC}	0.79(0.93) ^{aB}

Horizontally, means with same supercript lowercase letters are not statistically significant ($p>0.05$).

Vertically, means with same supercript uppercase letters are not statistically significant ($p>0.05$).

Table 5 Changes of ΔLab values of denture base materials in cleansing solutions

Material	ΔLab	Control WI20	CO	PR	VA
Rdx	ΔL^*	-5.78(0.89) ^{aA}	-2.36(2.60) ^{abA}	0.52(2.74) ^{bA}	-1.10(3.81) ^{abA}
	Δa^*	-1.04(0.38) ^{aA}	-0.24(0.63) ^{aA}	-0.04(0.83) ^{aA}	-0.68(0.64) ^{aA}
	Δb^*	-0.42(0.40) ^{aA}	-0.38(0.45) ^{aA}	-0.10(0.51) ^{aABD}	-0.42(0.59) ^{aA}
Pld	ΔL^*	0.54(0.98) ^{aAB}	0.80(0.24) ^{aA}	0.92(0.36) ^{aA}	0.74(0.23) ^{aB}
	Δa^*	0.04(0.34) ^{aA}	0.06(0.40) ^{aA}	0.28(0.38) ^{aA}	0.26(0.89) ^{aA}
	Δb^*	0.24(0.13) ^{aA}	-0.08(0.23) ^{aA}	-0.02(0.37) ^{aAB}	-0.06(0.15) ^{aA}
Dfl	ΔL^*	1.08(2.90) ^{aB}	2.08(1.99) ^{aA}	1.38(1.84) ^{aA}	1.08(1.30) ^{aA}
	Δa^*	-0.14(1.18) ^{aA}	-0.40(1.13) ^{aA}	1.02(0.49) ^{aA}	0.00(1.64) ^{aA}
	Δb^*	-0.50(1.01) ^{aA}	-0.30(1.03) ^{aA}	1.00(1.05) ^{aAC}	-0.10(1.13) ^{aA}
Vlp	ΔL^*	0.84(1.46) ^{aB}	1.78(0.87) ^{aA}	1.36(1.44) ^{aA}	-0.30(1.07) ^{aB}
	Δa^*	0.06(1.45) ^{aA}	-0.16(2.03) ^{aA}	-0.68(0.58) ^{aA}	0.20(0.82) ^{aA}
	Δb^*	0.78(1.03) ^{aA}	-0.26(0.74) ^{aA}	-0.18(1.03) ^{aA}	0.70(0.75) ^{aA}

Horizontally, means with same supercript lowercase letters are not statistically significant ($p>0.05$).

Vertically, means with same supercript uppercase letters are not statistically significant ($p>0.05$).

Table 6 NBS units for all materials (Critical Marks of Color Differences)

Material	Control WI20	CO	PR	VA
Rdx	5.42(A)	2.21(N)	0.49(T)	1.25(S)
Pld	0.54(S)	0.75(S)	0.89(S)	0.73(S)
Dfl	1.10(S)	1.97(N)	1.83(N)	1.00(S)
Vlp	1.06(S)	1.67(N)	1.41(S)	0.73(S)

Critical Marks of Color Differences according to the NBS are classified as

Trace (T): 0.0–0.5; Slight(S): 0.5–1.5; Noticeable(N): 1.5–3.0;

Appreciable(A): 3.0–6.0; Much(M): 6.0–12.0; Very much(V): >12.0

Control IW20, CO, PR, VA were respectively: 5.42; 2.21; 0.49; 1.25. All of the test groups showed predominately similar results and classified as: slight. All of the Pld groups were classified as: slight (Table 6).

SEM

SEM images of the specimens also confirm the results of this study. The lowest roughness was observed in copolymer groups and the surface roughness of this group (Rdx) did not change after the immersion of the cleansers. Figure 2 represents the low surface roughness and similar surface property of the specimen

after immersion in VA cleanser. Except Rdx groups, surface roughnesses of the samples were increased after immersion of the cleansers. Figure 3 represents the highest roughness which was found in the Vlp polyamide in the control group and increased roughness after the immersion of the tested cleansers.

DISCUSSION

This study evaluated the effects of three commercial denture cleansers on surface roughness, hardness and color stability of two polyamides, one butadiene styrene

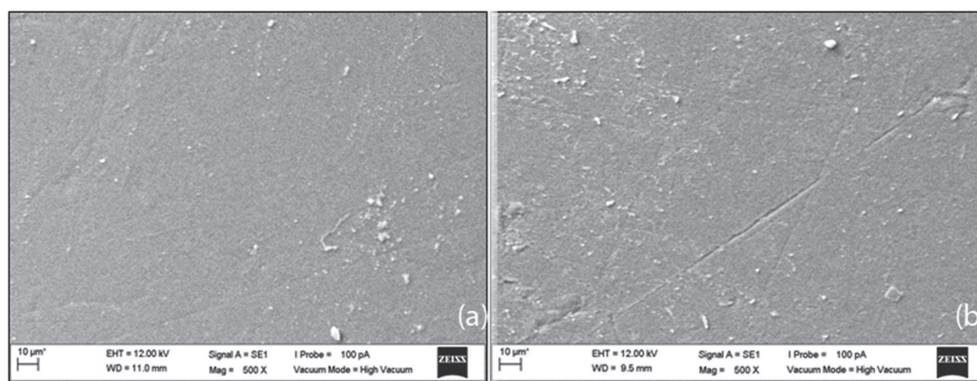


Fig. 2 SEM micrographs of Rdx surfaces (500× original magnification). (a) Control IW20, (b)VA. Surface roughness of Rdx did not change after the immersion of solutions.

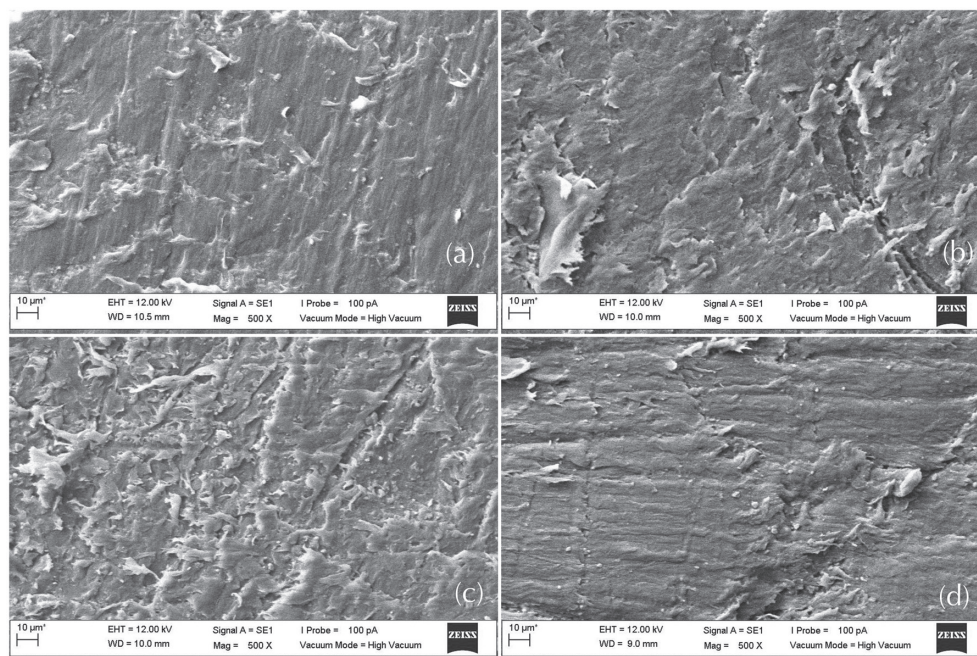


Fig. 3 SEM images of Vlp surfaces (500×). (a) Control IW20, (b)CO, (c)PR, (d)VA. Surface roughness was increased after the immersion of the solutions.

graft PMMA copolymer and a conventional PMMA resin base material.

Considering the cleaning methods used by the patients on the dentures, resin materials were immersed in 50°C warm solutions for 15 min per day for a period of 20 days. Denture cleansers were prepared according to the manufacturers' recommendations. The hypothesis that denture cleansers would not influence the surface roughness, hardness or color stability of denture base resins was partially rejected.

The surface roughness of the Rdx denture base resin specimens was not affected by the denture cleansers evaluated. This may be the strong surface character due to its crosslinking structure^{16,17}. Since Vlp polyamide resin had a higher initial surface roughness, roughness increased after the immersion. The surface roughness of the polyamide and a conventional acrylic resin increased after 20 days of repeated immersion, regardless of the solution type used.

One possible explanation for the increase in roughness observed for resin specimens may be that the high water temperature and the oxygen-liberating solution used during the disinfection procedure led to alterations in the surface of the resins. In all the resins, the surface roughness of all samples was previously standardized by smoothing and polishing procedures. Bollen *et al.*²⁵ reported that the surface roughness of acrylic resin depended on the polishing grit used. Since copolymer and conventional PMMA resins have good polishing properties, they have low initial roughness. However, since polyamide-based resins have fibrous structure, semi-flexible structure and low surface hardness.

SEM images also confirmed that polyamide-based resins had higher roughness than control groups. The smoothing and polishing procedures were quite difficult with these materials. Surface structure of these polyamide-based resins should be analyzed for the content and distribution of the material after the setting in the further studies.

Peracini *et al.*¹ immersed acrylic resin samples in alkaline peroxide solution for 6 days and reported that surface roughness of the resins were increased. This finding is consistent with the results of our study.

The current study is also consistent with the findings of Machado *et al.*², who showed that sodium perborate solution increased surface roughness of acrylic resins. All of the three solutions used in the present study showed similar effects. It was thought that these similar effects occurred as the solutions had the same basic structure. SEM results were consistent with surface roughness values.

Surface roughness is an important factor, which affects the clinical life of materials and resistance to plaque formation. Surface roughness is related to the abrasion of materials^{8,20}.

Some *in vivo* studies suggested rough denture surface makes accumulation of microorganisms easier and a higher level of biofilm formation occurs compared to smooth surfaces. Rough surfaces also affect staining

resistance, health of oral tissue, comfort of the patient, aesthetics and retention of the dentures directly or indirectly^{2,26}. In this study, the surface roughness of the Rdx, butadiene styrene graft copolymer specimens, was not affected by the cleaning procedures evaluated.

In this study it was found that control group samples of conventional PMMA resin had higher hardness than polyamide-based resins. This difference stems from the differing structural properties of the materials. According to the manufacturers, polyamide resins had higher fibrous content and lower modulus of elasticity.

The hardness of the polyamide resins and PMMA resin decreased after repeated immersion, regardless of the solution type used. Rdx resin has a butadiene styrene graft copolymer structure and is polymerized for a long time, it has a high hardness. Since the literature contains no study on the hardness of this resin in alkaline peroxide solution, it is not possible to compare the results; therefore, further studies should be carried out. But we may consider that the hardness test suggested that high impact resin can withstand stress through a considerable degree of indentation, indicating that they have sufficient longevity for insertion and removal from the denture cleansers.

Pinto *et al.*²⁷ reported that polyamide resins had a higher mechanical resistance than acrylic resins. In the present study, although the hardness of the polyamides as the control group was lower, when they were immersed in solutions, the decrease in hardness was lower than that observed in the PMMA resins.

Neppelenbroek *et al.*²⁸ and Machado *et al.*² reported significantly reduced hardness for acrylic resins tested with sodium perborate solution. Similarly, in the present study, hardness decreased in the PMMA resin. Hardness can decrease due to continuing polymerization reaction, monomer release, and combinations of these monomers with free active radicals by bonding with oxygen.

Different alkaline peroxide-based denture cleansers were selected with the idea that some possible differences in their structure would cause a different effect; however, no difference was found in terms of hardness. Resins are cleaned with alkaline peroxide by decomposition of peroxide into free radicals. These free radicals convert large molecules into small molecules through reduction and oxidation processes²⁹.

When immersed in hot water, hydrogen peroxide is heated, and thus the oxygen in its structure is decomposed to free oxygen radicals and thus water molecules are removed. Oxygen might cause a chemical softening of the resin surface by damaging interchain forces in the polymer. Nikawa *et al.*³ reported that the high peroxide content and level of oxygenation in the strongly alkaline solution is the damaging factor for denture base materials. In the current study, specimens were immersed into each of the 3 denture cleansers for 15 min at 50°C. The increase of the temperature may be an activating agent for these cleansers.

The hypothesis that denture cleansers could influence the color stability of the denture base materials

was accepted. In the present study, color changes were performed using the CIE $L^*a^*b^*$ colorimetric system and NBS units color comparison parameters. No difference was observed in ΔE values of the resins after immersion in denture cleansers for 20 days except Rdx. The reason for this might be that the materials were immersed in solution for a short daily period and that they were immersed in distilled pure water again after the immersion procedure. But color values of Rdx group changed after immersion of the solutions.

The result of this study is consistent from those of Ünlü *et al.*¹⁹⁾ and Peracini *et al.*¹⁾, who also detected a significant whitening effect on heat polymerized acrylic resins with perborate cleansing agents. However, Sato *et al.*³⁰⁾ did not detect color changes in the PMMA based acrylic resins with the use of three different denture cleansers.

Hong *et al.*²²⁾ reported that color change level was high in acrylic resins following immersion in alkaline peroxide denture cleanser solutions for 365 days. In the present study the samples were immersed with denture cleansers for 20 days. Long terms effects of these cleansers might be more strong.

The color values (ΔL^* , Δa^* and Δb^*) of most of the tested materials were not changed statistically after the immersion of any denture cleansers. The only ΔL^* values of Rdx group was statistically different than the control group after immersion of PR solution. The results of this study may be explained that the denture cleansers have similar effects on the denture resins for Δa^* and Δb^* values comparing to other groups including control group which is distilled water. It may also be explained that, the lightness for copolymer resin after the immersion of PR solution was increased comparing the control group.

Discoloration of the materials after the immersion of denture cleansers is similar and they are predominantly slight. Rdx after immersion of CO, Dfl after CO and PR, Vlp after CO are classified as noticeable.

Besides the NBS units, other evaluation in the literature about evaluation of discoloration of the materials, is according to the ΔE values and O'Brien³¹⁾ had reported that; based on clinical studies the ΔE values below 3.5 unit is unacceptable. According to O'Brein, only control WI20 group of Rdx is over the limit.

In addition, further studies can be carried out over longer periods using different denture cleansing solutions. The chemical and thermal properties of denture base materials with different polymeric structures can be investigated after denture cleansers.

CONCLUSIONS

After conducting surface roughness, hardness and color stability tests on two thermoplastic polyamide resins, a polystyrene-graft copolymer high impact PMMA resin and a conventional PMMA acrylic resin in different denture cleansers for 20 days, the following conclusions can be drawn:

1. All three sodium perborate-containing denture

cleansers increased surface roughness of the materials except for the graft copolymer PMMA acrylic resin. However, there was no difference between the three solutions.

2. The highest surface roughness was observed in Vlp polyamide resin. No difference was observed in PMMA resins.
3. Polyamide resins demonstrated low Vickers hardness before and after immersion in the denture cleansers.
4. The slightly increase of lightness for copolymer resin after the immersion of PR solution was noticed comparing the control group, which the immersion solution is, distilled water.

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