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## Effect of Denture Cleansers on Flexural Strength, Color Stability and Surface Roughness of Flexible and Microwave cured Acrylic Resin

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## Effect of Denture Cleansers on Flexural Strength, Color Stability and Surface Roughness of Flexible and Microwave cured Acrylic Resin

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### ABSTRACT

**Purpose:** The aim of the present study was to evaluate the effect of denture cleansers on the flexural strength, color stability and surface roughness of flexible denture base resin as well as micro wave cured denture base resin. **Materials and Methods:** A total of 144 specimens were fabricated. Seventy two specimens were constructed from each type of resin and were further subdivided into 3 subgroups (n=24) according to their immersion in different types of denture cleansers. Subgroup1: distilled water (control), subgroup 2: 5% sodium hypochlorite and subgroup 3: effervescent alkaline tablets (Corega tabs). The color changes and surface roughness were measured for each subgroup before (baseline) and after immersion in the solutions. The flexural strength was also measured after their immersion. **Results:** For both groups (flexible denture base resin and microwave cured denture resin groups); control subgroup showed the statistically significant higher flexural strength values, while subgroup treated with Corega Tabs recorded the statistically significant lowest flexural strength values. Regarding the color changes, for both groups (flexible denture base resin and microwave cured denture resin groups); subgroup treated with Corega Tabs recorded statistically significant highest ( $\Delta E$ ) mean values, followed by subgroup treated with sodium hypochlorite then the control subgroup. However, there was a statistically non-significant difference of the Ra values between the tested groups and subgroups. **Conclusions:** Within the limitations of the study, it was concluded that the tested denture cleansers had no effect on the surface roughness of flexible and microwave cured acrylic resin, however, significantly influenced their flexural strength. Moreover, denture base polymers are susceptible to color change on immersion in Corega Tabs.

### INTRODUCTION

During delivery of a dental prosthesis, patients are advised and given instructions on denture care. Apart from directions on regular brushing of the dentures, it is generally recommended that patients immerse the

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prosthesis in denture cleansers for variable periods of time<sup>1</sup>. Denture care is indispensable for general health, especially in elderly patients who can't adequately brush their dentures because of disease, dementia and poor dexterity. Beyond the concern for esthetics, the lack of adequate denture hygiene can cause biofilm accumulation and oral infections such as denture stomatitis<sup>2,3</sup>. It is a common infection characterized by inflammation of oral tissues and colonization of the fitting surface of prostheses by micro-organisms<sup>4</sup>.

Mechanical methods are the most common and effective procedures for biofilm removal on prosthesis surfaces. The use of chemical cleansers is usually associated to mechanical methods, and their efficacy in removing stains and reducing biofilm formation on the surface irregularities of dentures have been reported<sup>5,6</sup>. Nevertheless, the factors contributing to the infrequent use of denture cleansers include insufficient information provided to the patient, high cost and restricted market access. The best disinfectant should fulfill most of the requirements of the ideal agent while not causing any kind of alteration in the structure of the denture.

Denture cleansers can be classified according to their chemical composition: enzymes, alkaline hypochlorites, neutral peroxide with enzymes, acids, disinfectants, and alkaline peroxides<sup>7</sup>. Currently, the most common commercial cleansers namely alkaline peroxide, are based upon or require immersion techniques<sup>8</sup>. Gornitsky et al.<sup>9</sup> reported the existence of antimicrobial activity *via* a chemical action of perborate-based denture cleansers on microorganisms that adhere to the prostheses. Fernandes et al.<sup>10</sup> reported that this solution was effective both in acrylic and polyamide-based denture base resins for removing *Candida* biofilms forms.

The effervescent tablets are classified as chemical soak-type products, and when dissolved in water the sodium perborate readily decomposes to form an alkaline peroxide solution. This peroxide solution subsequently releases oxygen, thereby enabling

a mechanical cleaning by the oxygen bubbles in addition to the chemical cleaning. With regard to the available denture cleansers, sodium hypochlorite is one of the oldest and most widely used disinfectants<sup>10</sup>. It has both bactericidal and fungicidal properties, because it acts directly on the organic matrix of the plaque. However, this solution has several disadvantages, such as bad odor, bad taste and it whitens the denture base<sup>11</sup>.

The choice of denture cleanser for different denture base resins should be based on the chemistry of resin and cleanser, denture cleanser concentration, and duration of immersion. In addition to appropriate choice of denture cleanser, proper use of denture cleanser as prescribed by the manufacturer should be strictly followed by the patients with reference to the concentration of denture cleanser, temperature of solution, and duration of immersion<sup>12</sup>.

In recent years, new-generation polyamide thermoplastic resins (nylon) based material are more widely used than polyethylene methacrylate (PMMA)-based acrylic resins in production of removable dentures<sup>10,13</sup>. Nylon polymer has been attracting attention as a denture base material because of multiple advantages like favorable esthetic outcome, it does not contain allergic monomer, higher elasticity than conventional heat polymerized resins and sufficient strength for use as a denture base material and has low density<sup>14</sup>.

Microwave polymerization of acrylic resin was introduced in Japan. Polymerization by microwave irradiation has several advantages: a denture base can be fully polymerized in only 3 min, much faster when compared to the polymerization time of 9 h normally used for water-bath polymerization; a simpler equipment is required; only a fraction of the energy needed by conventional methods is required for microwave-activated polymerization; and less residual monomer remains in microwave-polymerized resins<sup>15</sup>.

It is of clinical importance to determine whether denture cleansers alter the properties of acrylic

resins. Some authors have concluded that the daily use of denture cleansers can affect the properties of denture acrylic resin <sup>16</sup>. Denture base polymers are susceptible to color change if the cleaning solutions are not correctly used <sup>17</sup>. The surface roughness is of great clinical relevance since it can affect biofilm formation and make it difficult to remove <sup>18</sup>. Therefore, the choice of appropriate methods for denture cleaning is clinically important, when the objective of the procedures is not to cause surface damage of the denture base, and for daily use to prevent microbial adhesion. Moreover, fracture of an acrylic denture base is a common problem and occurs during masticatory function because of base deformation and consequent resin fatigue <sup>19</sup>. Immersion in denture cleansers and disinfecting solutions may decrease the flexural strength of acrylic resins <sup>20,21</sup>.

The aim of the present study was to evaluate the effect of denture cleansers on the flexural strength, color stability, and surface roughness of flexible denture base resin, as well as micro wave cured denture base resin.

## MATERIALS AND METHODS

Two types of denture base materials were used in this study; flexible denture base resin (Group I) and microwave-polymerized acrylic resin (Group II). A total of 144 specimens were fabricated. Seventy

two specimens were constructed from each type of resin and were further subdivided into 3 subgroups (n=24) according to their immersion in different types of denture cleansers. Subgroup 1: distilled water (control), subgroup 2: 5% sodium hypochlorite and subgroup 3: effervescent alkaline tablets (Corega tabs). The color changes and surface roughness were measured for each subgroup before (baseline) and after immersion in the solutions. The flexural strength was also measured after their immersion. The types of denture resin, chemical composition and denture disinfectants used in this study are presented in table (1).

### Specimen fabrication

A total of 72 specimens were constructed for each type of resin. Rectangular specimens with dimensions 65x10x3 mm were used for testing the color changes, the surface roughness and the flexural strength, complying with the ADA specification number 12 for denture base polymers<sup>22</sup>.

### Flexible denture base resin

A wax pattern with dimensions 65x10x3 mm was constructed to create the mold into which the resin was injected. The flexible resin material was supplied in the form of granules in metallic cartridges of varying sizes. The cartridges containing thermoplastic grains were heated to plasticize the resin. Then

**Table (1):** Types of denture resin, chemical composition and denture disinfectants used in the present study

Product	Composition	Manufacturer
Flexible thermoplastic resin (bre-flex)	A thermoplastic polyamide resin (nylon) based material	Bredent-Germany
Microwave resin	PMMA	GC Dental Industrial Corp., Tokyo, Japan.
Alkaline peroxide (Corega Tabs)	Sodium carbonate, potassium carbonate, citric acid, sodium carbonate peroxide, sodium bicarbonate, sodium benzoate, PEG-180, sodium lauryl sulfoacetate, subtilisin, PBP, aroma, CL44090	GlaxoSmithKline, Brentford, United Kingdom
Alkaline hypochlorite	Sodium hypochlorite %5	Injectcenter, Ribeirão Preto, SP, Brazil.

the material was suited for thermoplastic processing by injection molding technique (Thermopress 400, Bredent GmbH & Co.KG, Germany). The resin was injected into the hollow mold under very high pressure. The resin was plasticized under 220-265 °C and preheated for 15 min <sup>23</sup>.

#### ***Microwave cured denture resin***

Similarly, a wax pattern with same dimensions (65x10x3 mm) was constructed and flaked into a special microwave curing flask made of fiber reinforced plastic. Wax elimination was carried out to create a mold for packing the resin. The microwave denture base resin was mixed, packed and processed according to the manufacturer's instructions. After packing, the flask was fitted by applying pressure using the flask press and then tightening the bolts. The flasks were then placed in a microwave oven (EM-M 535T, Sanyo Electric, Osaka, Japan) for a 3min cycle at 900W. After the end of the polymerization cycle, the flasks were allowed to slowly cool in a water bath at room temperature before deflasking. All acrylic specimens were trimmed with a tungsten bur and ground wet to the final dimensions with 320-, 400-, 600-, 1000-grit silicon carbide papers. Pumice and whiting were used for final polishing.

#### **Immersion period**

After testing the color and roughness of the specimens (baseline). The specimens were then immersed in each of the three solutions for 15 days continuously, which simulated 3 years of use, following the regime of daily immersion for 20 minutes. After this period, the color change, roughness and flexural strength tests were performed. The calculation of these immersion periods was done by the following method <sup>24</sup>.

One hour represented 3 immersions of 20 min and each 24 h (one day) corresponded to 72 immersions of 20 min per day. Therefore, to complete a 3-year immersion simulation (1095 days), 15 days were required.

### **Testing Procedures**

#### **Flexural strength test**

All specimens were individually and horizontally mounted in a custom made loading fixture [three point bend test assembly; two parallel stainless steel rods with span length 50 mm supporting the specimen, with the damage site centrally located on the tensile side] on a computer controlled materials testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a load cell of 5 KN and data were recorded using computer software (Instron Bluehill Lite Software). Then the specimens were subjected to statically compression loading until fracture at a crosshead speed of 5 mm/min. The Stress-strain curves were recorded with computer software (Instron Bluehill Lite Software). The flexural strength (S) of each rectangular specimen was calculated using the following formula:

$$S = 3P (L) / 2bd^2$$

Where, P is the maximum load, L is the distance between the supports, b is the specimen width, and d is the specimen thickness. Mean flexural strengths were calculated in MPa.

#### **Color measurement**

The specimens' colors were measured using a portable Reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany). The aperture size was set to 4 mm and the specimens were exactly aligned with the device. A white background was selected and measurements were made according to the CIE L\*a\*b\* color space relative to the CIE standard illuminant D65. The color changes ( $\Delta E$ ) of the specimens were evaluated using the following formula:

$$\Delta E = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$$

Where: L\* = lightness (0-100), a\* = (change the color of the axis red/green) and b\* = (color variation axis yellow/blue ).

To determine the color difference, it is necessary to compute and record the difference in all three color space values,  $L^*$ ,  $a^*$ ,  $b^*$ . These differences are then assigned as:

$\Delta L = L_2 - L_1$  Where +ve values denote “lighter” and -ve values “darker”

$\Delta a = a_2 - a_1$  Where +ve values denote “less green” and -ve values denote “less red”

$\Delta b = b_2 - b_1$  Where +ve values denote “less blue” and -ve values denote “less yellow”

Therefore, this formula provides numeric data that represent the differences in color perceived between two objects.

To relate the color alterations ( $\Delta E$ ) to the clinical environment, data were quantified by the National Bureau of Standards (NBS) units <sup>(17)</sup> through the formula: NBS units =  $\Delta E \times 0.92$  and then classified according to the scale: 1) Trace: 0.0-0.5; 2) Slight: 0.5-1.5; 3) Noticeable: 1.5-3.0; 4) Considerable: 3.0-6.0; 5), much: 6.0-12.0; 6) very much: +12.0.

### Surface Roughness

Surface roughness ( $R_a$ ) was measured with USB digital surface profile gauge, cut-off – 0.25 mm (Ecometer 224/2, Elcometer Instruments, Great Britain) and data were recorded using computer software (Elcomaster 2, Elcometer Instruments). The surface profile needle (radius of  $2.5 \mu\text{m}$ ) was positioned perpendicular over each test specimen performing five readings in different locations of the sample surface. After the five readings, the mean surface roughness values were obtained. Moreover, an optical method was used to fulfill the need for quantitative characterization of surface topography without contact. Specimens were photographed using USB Digital microscope with a built-in camera (Scope Capture Digital Microscope, Guangdong, China) connected with an IBM compatible personal computer using a fixed magnification of 90X. The images were recorded with a resolution of  $1280 \times 1024$  pixels per image. Digital microscope images

were cropped to  $350 \times 400$  pixels using Microsoft office picture manager to specify/standardize area of roughness measurement. The cropped images were analyzed using WSxM software (Ver 5 develop 4.1, Nanotec, Electronica, SL). Within the WSxM software, all limits, sizes, frames and measured parameters are expressed in pixels. Therefore, system calibration was done to convert the pixels into absolute real world units. Calibration was made by comparing an object of known size (a ruler in this study) with a scale generated by the software.

Subsequently, a 3D image of the surface profile of the specimens was created. Three 3D images were collected for each specimen, both in the central area and in the sides at area of  $10 \mu\text{m} \times 10 \mu\text{m}$ . WSxM software was used to calculate average roughness expressed in  $\mu\text{m}$  which can be assumed as a reliable indices of surface roughness <sup>25</sup>.

### Statistical analysis

Analysis of data was performed using Statistical software (IBM SPSS, v.21, IBM Corp, Armona, NY, USA). Data analysis was presented as mean and standard deviations for the quantitative data with parametric distribution. Independent sample t-test was used for comparison between the groups. One way analysis of variance (ANOVA), followed by post hoc analysis using LSD test for comparison between subgroups. Results were considered statistically significant when p-value was  $\leq 0.05$ . Pearson correlation test was used to study the correlation between the values of the color change and surface roughness.

## RESULTS

### Flexural strength

Results showed a statistically significant difference between flexible denture base resin and microwave cured denture resin groups ( $P \leq 0.05$ ), as shown in table (2) and figure (1). Flexible denture base resin group showed statistically significant lower flexural strength values than Microwave cured denture resin.

For both groups (flexible denture base resin and microwave cured denture resin groups); control Subgroup showed the statistically significant higher flexural strength values ( $54.42 \pm 2.86$ ,  $75.67 \pm 3.48$  respectively), while subgroup treated with Corega Tabs recorded the statistically significant lowest flexural strength values ( $53.78 \pm 1.38$ ,  $60.23 \pm 1.49$  respectively).

Regarding flexible denture base resin; there was a statistically non-significant difference between all subgroups ( $p=0.9311$ ). Whereas for the microwave cured denture resin group, there was a significantly lower flexural strength values for Corega Tabs than for the control subgroup (distilled water) and the subgroup treated with sodium hypochlorite.

**Table (2):** Statistical analysis (mean, standard deviation) of flexural strength for denture base materials after immersion in different denture cleansers

Denture base material Denture cleanser	Flexible denture base resin	Microwave cured denture resin	P-value
Control (distilled water)	$54.42^B \pm 2.86$	$75.67^A \pm 3.48$	$<0.0001^*$
Sodium hypochlorite	$54.27^B \pm 1.2$	$69.19^A \pm 6.51$	$0.0075^*$
Corega Tabs	$53.78^B \pm 1.38$	$60.23^A \pm 1.49$	$0.0012^*$
P-value	$0.9311$ ns	$0.0058^*$	

Values with identical letters indicate no statistically significant difference ( $P > 0.05$ ).

\*=Significant, ns=Non Significant

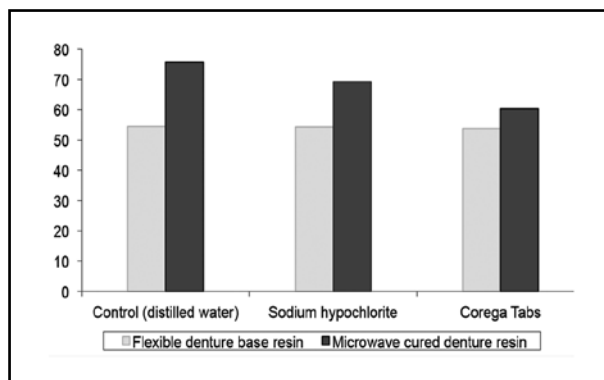


Fig. (1) Bar chart showing flexural strength mean values for denture base materials after immersion in different denture cleansers

### Color measurement:

The mean  $\Delta E$  values for the flexible denture base resin and microwave cured denture resin are summarized in Table (3) and graphically represented in Figure (2). For both groups (flexible denture base resin and microwave cured denture resin groups); subgroup treated with Corega Tabs recorded statistically significant highest ( $\Delta E$ ) mean values, followed by subgroup treated with sodium hypochlorite then the control subgroup.

Table (4), shows the results in NBS units. The color changes in the control and Sodium hypochlorite subgroups were classified as "slight" ( $<1.5$ ). However, for effervescent tablets (Corega Tabs) subgroup, the color changes was classified as "noticeable": ( $1.5-3.0$ ; 4).

**Table (3):** Statistical analysis (mean, standard deviation) of  $\Delta E$  for denture base materials after immersion in different denture cleansers

Denture base material Denture cleanser	Flexible denture base resin	Microwave cured denture resin	P-value
Control (distilled water)	$1.37 \pm 0.42$	$1.43 \pm 0.042$	$0.115$ ns
Sodium hypochlorite	$1.332 \pm 0.158$	$1.594 \pm 0.078$	$0.074$ ns
Corega Tabs	$1.76 \pm 0.276$	$1.777 \pm 0.284$	$0.893$ ns
P-value	$0.007^*$	$<0.001^*$	

\*=Significant, ns=Non Significant

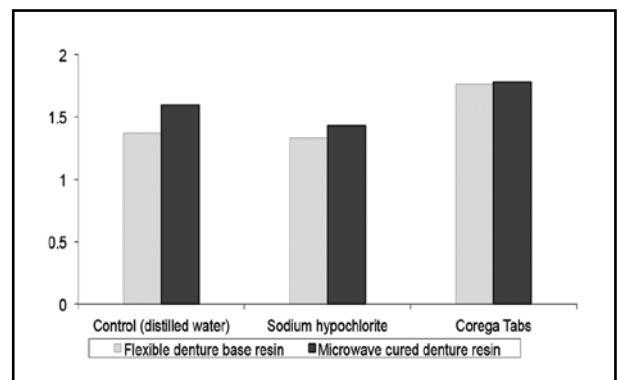


Fig. (2) Bar chart showing mean  $\Delta E$  values for denture base materials after immersion in different denture cleansers

**Table (4):** NBS units for different denture cleansers (Critical Marks of Color Differences)

Denture base Denture cleanser	Flexible denture base resin	Microwave cured denture Resin	NBS units = $\Delta E \times 0.92$ and then classified according to the scale: 1) Trace: 0.0-0.5; 2) Slight: 0.5-1.5; 3) Noticeable: 1.5-3.0; 4) Considerable: 3.0-6.0; 5) much: 6.0-12.0; 6) very much: +12.0.
Control (distilled water)	1.26	1.46	
Sodium hypochlorite	1.31	1.22	
Effervescent tablets (Corega Tabs)	1.61	1.62	

**Surface roughness:**

Results showed a statistically non-significant difference between groups (flexible denture base resin and microwave cured denture resin) and also

no significant difference between subgroups as shown in table (5) and figure (3). Figures (4 and 5) show the 3D profiler photographs of the surface configuration of the study groups.

**Table (5):** Statistical analysis (mean, standard deviation) of  $\Delta Ra$  for the tested denture base materials before and after immersion in different denture cleansers

Denture base material Denture cleanser	Flexible denture base resin			Microwave cured denture resin		
	Before	After	$\Delta Ra$	Before	After	$\Delta Ra$
Control (distilled water)	0.2563 $\pm$ 0.0009	0.256933 $\pm$ 0.0013	0.00063	0.25695 $\pm$ 0.001	0.2573 $\pm$ 0.0008	0.00038
Sodium hypochlorite	0.255117 $\pm$ 0.0008	0.257333 $\pm$ 0.001	0.002217	0.256567 $\pm$ 0.0008	0.257533 $\pm$ 0.001	0.000967
Corega Tabs	0.256183 $\pm$ 0.0007	0.257633 $\pm$ 0.001	0.00145	0.256433 $\pm$ 0.0005	0.257567 $\pm$ 0.0007	0.001133
P-value	0.1552 ns	0.7073*	0.0543 ns	0.6846ns	0.9198 ns	0.1768 ns

\*=Significant, ns=Non Significant

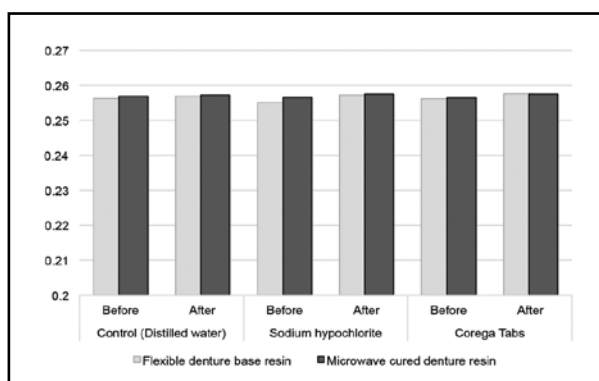


Fig. (3) Bar chart showing roughness mean values for the tested denture base materials before and after immersion in different denture cleansers.



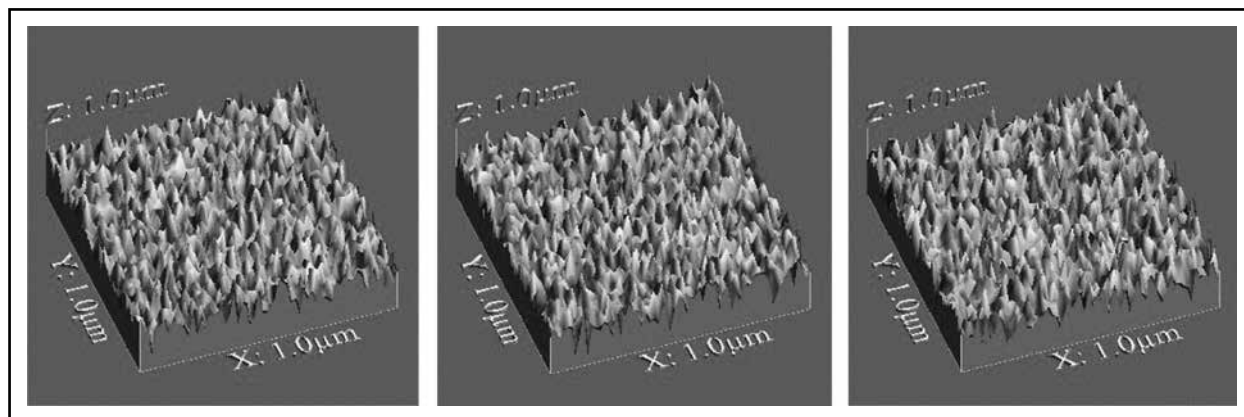


Fig. (4) 3D profiler photographs of flexible denture base resin after immersion in a) distilled water; b) sodium hypochlorite; c) Corega Tabs.

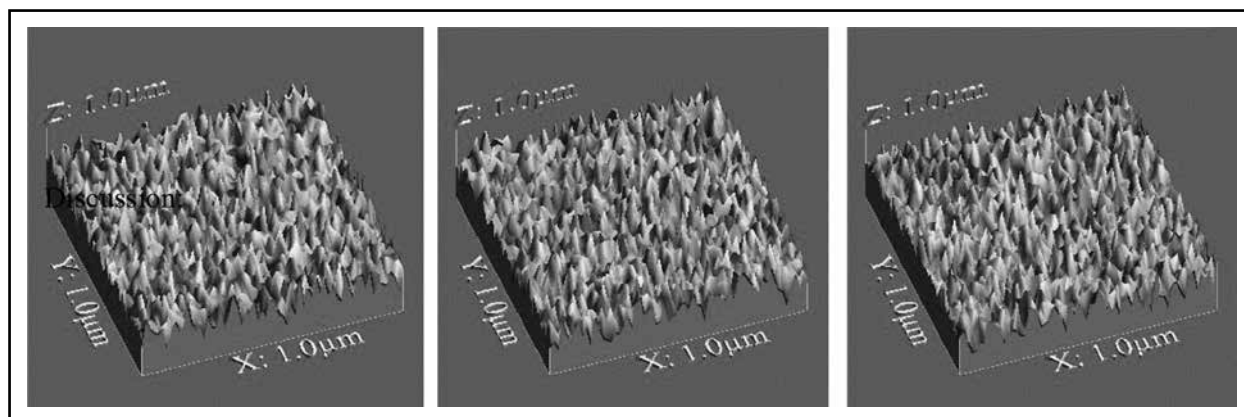


Fig. (5) 3D profiler photographs of microwave cured denture base resin after immersion in a) distilled water; b) sodium hypochlorite; c) Corega Tabs.

*There was a non-significant direct correlation between color change and surface roughness as indicated by Pearson linear correlation (Correlation coefficient ( $r$ ) = 0.1483,  $r^2$  = 0.02199 and  $p$  = 0.577).*

## DISCUSSION

In patients who use fixed and partial removable dentures, hygiene of dentures and maintaining the health of oral mucosa are of great importance<sup>26</sup>. The effect of long term immersion in disinfectants was evaluated. In the current study, sodium hypochlorite and alkaline peroxide were chosen as denture cleansers. The literature has shown that sodium hypochlorite and alkaline peroxides are the two main classes of immersion denture cleansers<sup>27</sup>. Sodium hypochlorite is inexpensive, presents bactericidal and fungicidal action, as

well as stain removal properties, requires a short period of disinfection, and have been suggested as effective denture cleansers<sup>28-30</sup>. Moreover, alkaline hypochlorite cleansers contain 5% sodium hypochlorite act directly on organic matrix of plaque causing dissolution of polymer structure. They can transform the chromophores and have the ability to remove stains<sup>31</sup>.

Alkaline peroxide cleansers contain combination of oxidizing agent along with oxygen generating compound. They form alkaline solution of hydrogen peroxide when dissolved in water which further

decomposes to liberate oxygen. This bubbling action of oxygen exerts mechanical cleaning and antimicrobial effect. Alkaline peroxide solutions present good antimicrobial activity against denture biofilm, comparable with that of sodium hypochlorite solutions<sup>32</sup>. This property, in addition to the absence of odor and aftertaste, makes peroxide solutions good choices for denture cleansing<sup>31</sup>.

These solutions can be employed alone or associated with mechanical methods and the immersion procedures can be performed for 3 to 20 min, or for 8 h<sup>27</sup>. Corega Tabs, for example, is indicated to be immersed from 5 min until 8 h. In order to standardize the immersions, allowing comparison of the results, all solutions were immersed for 20 min<sup>30,33</sup>. The effect of denture cleansers on acrylic resin properties after long periods of immersion has not been widely studied. The hygiene procedures used for a long time because the durability of a denture is about 5 to 7 years<sup>2</sup>. The denture hygiene regime used was immersion for 20 minutes daily for 3 years. According to Furukawa<sup>34</sup> these periods can lead to penetration of the cleanser into the acrylic resin pores, which is responsible for microorganism destruction.

Denture cleaning by immersion in chemical solution should not involve any physical, mechanical or chemical change in the acrylic resin. The decontamination process may result in alterations of the surface morphology and changes in the flexural strength. It was suggested that immersion in certain cleansing solutions can affect the strength and the structure of denture base resins. If denture cleansers affect negatively the resins decreasing the strength, greater incidence of denture fractures. Midline fracture of the denture, for example, may occur as a consequence of flexural fatigue, resulting from cyclic deformation of the base during function. An increased frequency of this type of failure, due to use of denture cleansers, can be demonstrated by the flexural strength testing<sup>21</sup>.

Flexural strength is a simultaneous measurement of tensile, compressive and shear bond strengths<sup>35</sup>. This flexural strength represents the loading that occurs on the denture in the mouth during the masticatory process. The longevity of dentures depends in part on the flexural strength of the acrylic resin after immersion in denture cleansers<sup>31</sup>. In the present study, flexible denture base resin recorded statistically significant lower flexural strength mean values than microwave cured denture resin, as shown in table (2) and figure (1). The difference in flexural strength between the two polymers could be explained in relation to the strength and number of primary bonds between the atoms and secondary (hydrogen bonds) between adjacent chains, the weaker the bond the weaker the material<sup>36</sup>. The weak nylon secondary bonds allow these chains to slide past one another at much lower stresses within polymer mass, in addition to that acrylic resin is polymerized with partial cross linking so it is more rigid than nylon<sup>37</sup>.

This result could also be related to the nature of the resin material, bre-flex is a thermoplastic polyamide resin (nylon) based material. Nylon is a generic designation for a family of synthetic polymers, more specifically aliphatic or semi-aromatic polyamides. They can be melt processed into fibers, films or shapes. Nylons absorb moisture in equilibrium with the relative humidity of their immediate surroundings<sup>38,39</sup>. This finding is in accordance with Ragain et al<sup>40</sup> who concluded that decrease in flexural strength is perhaps related to water sorption.

The results of the present study were consistent with Hamanaka et al.<sup>41</sup>, who reported that polyamide (nylon) denture base material showed lower flexural strength values. Paper polyamide as a denture base. Moreover, this result is in compliance with a study made by Salman and Saleem<sup>37</sup> which revealed that denture cleansers decreased the flexural strength of nylon denture base materials. On the contrary to our study, Soygun et al.<sup>42</sup>, found that polyamide based

denture base material (Valplast) had higher flexural strength compared with the conventional PMMA.

For both groups (flexible denture base resin and microwave cured denture resin groups); Corega Tabs recorded the statistically significant lowest flexural strength values ( $53.78 \pm 1.38, 60.23 \pm 1.49$  respectively). This was attributed to the fact that peroxide radical formed from alkaline peroxide denture cleanser might attack the polymer chain backbone causing polymer degradation producing decrease in strength<sup>31</sup>.

In the present study, color changes were performed using the CIE L\*a\*b\* colorimetric system and NBS units color comparison parameters. In the present study, a portable Reflective spectrophotometer was used to measure the color changes. Instrumental color analysis offers a potential advantage over visual color determination, because instrumental readings are objective, can be quantified, and are more rapidly obtained<sup>43</sup>.

The color stability of a prosthesis may be the most important factor for determining the patient acceptance<sup>6</sup>. The color changes of all acrylic resins increases as immersion time increases. It has been reported that denture cleansers can cause whitening, color fainting or even bleaching, loss of soluble components, and water absorption in acrylic resin materials. In the present study, the microwave resin showed higher color change values than the flexible denture resin. This could be explained on the basis that the higher the value, the more is the consistency of the material with less translucency of it, so it will absorb more light before it can pass through it resulting in more color change<sup>44</sup>. Moreover, acrylic absorb more light than nylon, this is due to the unsaturation is more in the PMMA polymer than polyamide (nylon polymer)<sup>37</sup>. This was in agreement with Sarac et al.<sup>6</sup> who reported that the color change values were different from each other according to difference in denture base materials.

For both groups (flexible denture base resin and

microwave cured denture resin groups); subgroup treated with corega tabs recorded statistically significant highest (DE) mean values. The results of this study were in accordance with Unlu et al.<sup>45</sup>, Peracini et al.<sup>26</sup> and Porwal et al.<sup>12</sup> who detected a significant whitening effect with Corega Tabs relative to the other tested cleansing agents. This may be related to the deleterious combination of oxidation and strong alkaline solution. Peroxide denture cleansers include an effervescent component such as sodium perborate or sodium bicarbonate, when these tablets dissolve in water, sodium perborate decomposes to form an alkaline peroxide solution. This peroxide solution subsequently release oxygen and loosen debris by mechanical means<sup>6,46</sup>. Therefore, the use of these denture cleansers may cause hydrolysis and decomposition of the polymerized acrylic resin itself, this observation may explain why these cleansers had a greater influence on color stability of denture base.

However, Sato et al.<sup>21</sup> did not detect color changes in the acrylic resins with the use of chemical agents. The result found in this research may be due to the short simulation period and visual comparisons made by photographs.

The current study showed that the color changes in the control and Sodium hypochlorite subgroups were classified as "slight" ( $<1.5$ ). However, for effervescent tablets (Corega Tabs) subgroup, the color changes was classified as "noticeable" (1.5-3.0). These values are considered as non-perceptible and acceptable by clinical parameters<sup>45</sup>. Besides the NBS units, other evaluation in the literature about discoloration of the materials, is according to the  $\Delta E$  values and O'Brien<sup>47</sup> had reported that; based on clinical studies the  $\Delta E$  values greater than 3.5 unit is unacceptable. Accordingly the denture cleansers used in the present study are acceptable.

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<sup>8,48</sup>. 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<sup>49</sup>. In the present study, there was no significant difference between the surface roughness of the control and study groups (flexible denture base resin and microwave cured denture resin). In other words, the denture cleansers used in this study had almost no effect on the surface roughness tested acrylic resin materials. This finding was in accordance with a previous study<sup>37</sup> that investigated the effect of different denture cleanser solutions on the surface roughness of nylon and acrylic denture base materials and reported no significant changes in the surface roughness values between nylon and acrylic denture base materials.

Moreover, Arruda et al<sup>50</sup>, evaluated color stability, surface roughness and flexural strength of acrylic resin after immersion in alkaline peroxide and alkaline hypochlorite solutions, simulating a five-year-period of use. They found that Corega Tabs did not change the surface roughness. These results were also consistent with the findings of Peracini et al.<sup>26</sup> in a simulated 180 days of use period. The authors discussed that sodium perborate was unable to remove the debris film on the acrylic resins, which could increase the surface roughness. However, other study showed that sodium perborate solution increased surface roughness of acrylic resins<sup>51</sup>. Different surface roughness values in the literature can be attributed to different immersion times, test materials and application procedures.

Based on a previous research, the surface roughness for acrylic resins to be 0.2  $\mu\text{m}$ , under which no significant decrease in bacterial colonization would occur. Dramatic bacteria colonization would occur, beginning at 2  $\mu\text{m}$ . Also researchers cited 0.12  $\mu\text{m}$  as the characteristic of a smooth acrylic surface<sup>52</sup>.

In the current study the tested groups showed lower values (ranged from 0.000 to – 0.002) from the critical surface roughness value of 2  $\mu\text{m}$  and were at clinically acceptable levels.

## CONCLUSIONS

Within the limitations of the study, it was concluded that the tested denture cleansers had no effect on the surface roughness of flexible and microwave cured acrylic resin, however, significantly influenced their flexural strength. Moreover, denture base polymers are susceptible to color change on immersion in Corega Tabs.

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