

Original Research Article

Effect of Different Denture Cleansers on Surface Roughness of Acrylic Denture Base Materials

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Abstract: The purpose of this investigation was to evaluate the effect of different denture cleansers and distilled water on surface roughness of self- and heat-polymerized acrylic denture base materials. Specimens were prepared from self- and heat-polymerized acrylic resin denture base materials and distributed into different groups of 15 each. Specimens of each group were immersed in distilled water as control and in three different denture cleansers according to the manufacturer's instructions and immersion was repeated 7 times over 7 days. The reading of surface roughness was recorded for all the specimens using a 3D optical noncontact surface profiler based on noncontact scanning interferometry to evaluate roughness. No significant difference was found in the average surface roughness of heat-polymerized resins after immersion in denture cleansers ($P > 0.05$). One-way ANOVA revealed significant difference in self-polymerized acrylic resin base material among different cleansers. Tukey Post Hoc test for multiple comparison showed that the mean of surface roughness of self-polymerized resin base immersed in Corega was significantly greater than the control group ($P = 0.007$). Significant difference was noticed in the interaction between the materials and the solutions ($P = 0.027$). Self-polymerized resins immersed in distilled water had a significant decrease in surface roughness compared with the heat-polymerized resins ($P < 0.05$). Immersion of acrylic denture base materials in the tested denture cleansers had no significant effect on the surface roughness of the denture base materials except for self-polymerized resins, which immersed in Corega.

Keywords: Denture cleansers, Surface roughness, Denture bases, Acrylic resins

INTRODUCTION

Acrylic resin (PMMA- Polymethyl-methacrylate) is extensively used material in different branches of dentistry [1, 2]. Globally, most dentures are made-up from acrylic resins because of its ease of handling and low cost [1]. In spite of its advantages, acrylic resin is not an ideal material, with surface roughness and discoloration being two disadvantages [3, 4].

Appropriate cleaning of dentures is crucial for keeping a healthy mucosa of the oral cavity [5]. Microbial biofilm on oral tissues and surface of acrylic resin denture base is a significant part in the development of denture stomatitis [5]. Denture cleansing is essential part in preventing cross contamination and improves oral health of the patients, longevity of the dentures and quality of life [6, 7]. Several products are designated for removal of denture biofilm and categorized into chemical and mechanical products [7]. Cleaning using chemical products consists of placing the denture in liquids with solvent,

antifungal, detergent, and antibacterial activities with or without use of brushing or ultrasonic devices [8, 9]. The efficacy of denture cleansers is well known; nevertheless, it is critical that continuing use for long time should not cause any negative effect on the acrylic resin denture base and their mechanical and physical properties should remain unchanged [10,11].

Roughness of the denture base acrylic resin after immersion in denture cleansers has been extensively reported [12, 13]. Studies of the surface roughness of acrylic resins have reported no changes in the roughness after immersion in denture cleansers [8, 14]. Other studies showed that surface roughness might add to the increased rate of colonization, adhesion, and maturation of microbial biofilm on surfaces [15, 16]. The roughness of the surfaces of acrylic resin is an imperative aspect, since the adhesion of microorganisms to a surface is a precondition for the colonization of that surface [5]. Irregularities of the surface intensify the probability of microorganisms

staying on the surface of the denture after has been cleaned [17].

One of ultimate properties of denture cleanser is not to produce damaging effects to the denture base materials. Therefore, the purpose of this in vitro study was to determine the effect of different denture cleansers and distilled water on surface roughness of the self- and heat-curing acrylic denture base materials. The null hypothesis tested was that there is no effect of the different denture cleansers on surface roughness of the self- and heat-curing acrylic denture base materials.

MATERIALS/METHODS

Fabrication of Specimens

Sixty specimens of self-polymerized acrylic resins (Rapid Repair, Dentsply, Salzburg, Austria) were produced using silicon molds prepared by investing the discs of wax pattern with standardized dimensions (10 x 10 x 4 mm). The resin material was inserted in the molds and polymerized according to the instructions of the manufacturer. The other 60 specimens of heat-polymerized acrylic resins (Lucitone 199, Dentsply, and Salzburg, Austria) were packed and pressed into silicon molds invested with dental stone inside denture flasks. Then, cured according to the instructions of the manufacturer in Hanau curing unit (Teledyne Hanau Buffalo, NY, U.S.A). Specimens were stored in distilled water at 25°C for 50±2 hours, to eliminate the residual monomer [18]. Then, one surface of each specimen was finished first using metal burs (DFS Daimon, Reidenburg, Germany) mounted on slow speed hand piece followed by a stone wheel finishing burs (Shofu, San Marcos, U.S.A). Later, it was polished using poly buffs brushes and polishing paste (Hatho, Freiburg, Germany) followed by a wet rag wheel with slurry of pumice then by the use of rouge applied on a dry wheel. The other surface was marked with letter N and left unfinished to distinguish the experimental surface used to measure surface roughness.

Immersion Procedures

Specimens of the self- and heat-polymerized acrylic resin denture base materials were distributed into different groups of 15 each. Specimens of each group were immersed in distilled water (200 mL) as control and in three different denture cleansers according to the instructions of the manufacturer. Following each immersion, the specimens in all groups were rinsed in running water for 10 s, dried, immersed in a new solution and the procedure repeated 7 times over 7 days. Table 1 showed denture materials, denture cleansers, and immersion procedures.

Measurement of Surface Roughness

The reading of surface roughness was recorded for all the specimens using a 3D optical noncontact surface profiler (Contour Gt-K1 optical profiler, Bruker

Nano, Inc., Tucson, AZ, USA) based on noncontact scanning interferometry to evaluate roughness. The surface roughness {Sa = Arithmetic mean height} was measured for each surface. The objective standard camera has a magnification 5X. For each specimen, the profile meter scanned area (3 measurements in different directions) was approximately 1.3 x 1.0 mm² and had situated at the center of each surface. Multi-Core Processor with Vision64™ software for accelerated 3D surface measurement and analyses were used for image transfer (Bruker Nano Surface Division, Inc., Tucson, AZ, USA). Multi-Core Processor with Vision64™ Software for Accelerated 3D Surface Measurement and Analyses were used for image transfer (Bruker Nano Surface Division, Inc., Tucson, AZ, USA).

Statistical Analysis

Statistical analyses were performed using one- and two-way analysis of variance (ANOVA), and t-test to compare and evaluate interactions between different groups. All statistical analyses were set at a significance level of $p < 0.05$. The statistical tests were completed using the SPSS 16.0 program (SPSS Inc., Chicago, IL, USA).

RESULTS

Table 2 shows the mean, standard deviation and standard error of surface roughness for each denture base resin material after immersion in different denture cleansers. For heat-polymerized acrylic resins, the highest mean of surface roughness was noticed in the control group (0.126 µm) while the lowest was detected after immersion in Corega (0.118 µm) (Fig. 1). On the other hand, the highest mean in self-polymerized acrylic resins was recorded for Corega (0.130 µm) while the lowest was recorded for the control group (0.113 µm) (Fig. 1). There was statistically significant difference in the surface roughness of self-polymerized acrylic base material after immersion in denture cleansers ($p < 0.05$).

One-way ANOVA revealed significant difference in self-polymerized acrylic resin base material among different cleansers. Tukey Post Hoc test for multiple comparison showed that the mean of surface roughness of self-polymerized resin base immersed in Corega was significantly greater than the control group ($P = 0.007$).

Two-way ANOVA (Table 3) shows no significant difference in surface roughness between heat-polymerized and self-polymerized resins ($P > 0.05$). However, significant difference was found in the interaction between the materials and the solutions ($P = 0.027$). Independent sample t-test demonstrated a statistically significant decrease in surface roughness of self-polymerized resins immersed in distilled water compared with the heat-polymerized resins ($P < 0.05$).

Table-1: Denture materials, denture cleansers, and immersion procedures

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

Table-2: Mean ($\pm$ SD) and std. error of surface roughness for each acrylic denture base material after immersion in different denture cleansers.

Denture Base Material	Denture Cleansers and Control	Mean $\pm$ SD	Std. Error
Heat-Polymerized Acrylic Resin	Corega	0.118 ($\pm$ 0.02)	0.005
	Polident	0.120 ($\pm$ 0.01)	0.004
	Stain Away Plus	0.125 ($\pm$ 0.02)	0.005
	Distilled Water	0.126 ($\pm$ 0.03)	0.007
Self-polymerized Acrylic Resin	Corega	0.130 ($\pm$ 0.01)	0.004
	Polident	0.125 ($\pm$ 0.01)	0.003
	Stain Away Plus	0.120 ($\pm$ 0.02)	0.004
	Distilled Water	0.113 ($\pm$ 0.01)	0.004

Table-3: Two-way ANOVA results for surface roughness of acrylic denture base materials.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.003	7	0.000	1.505	0.173
Intercept	1.788	1	1.788	6241.581	0.000
Material	6.533	1	6.533	0.023	0.880
Solution	0.000	3	9.514	0.332	0.802
Material * Solution	0.003	3	0.001	3.172	0.027
Error	0.032	112	0.000		
Total	1.823	120			
Corrected Total	0.035	119			

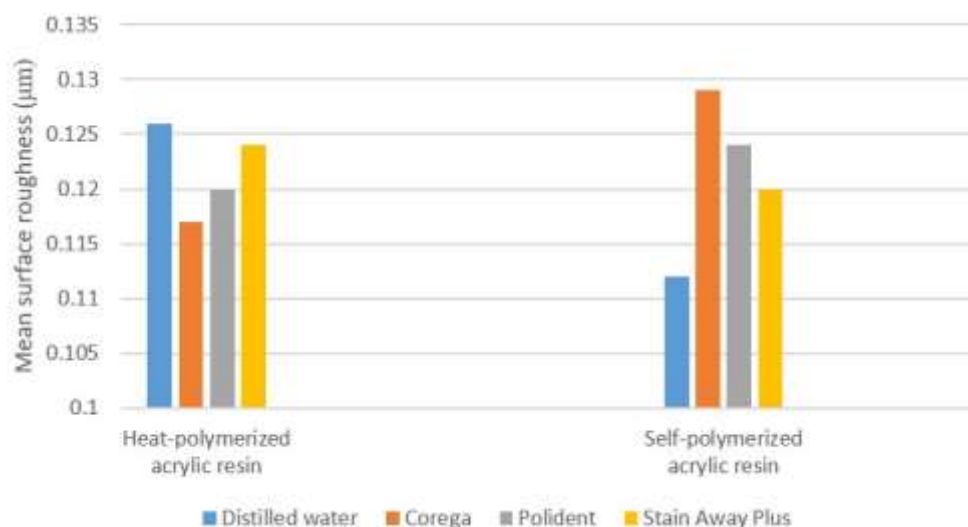


Fig-1: Mean of surface roughness following immersion in different denture cleansers.

DISCUSSION

The null hypothesis tested in the present study was rejected since statistically significant difference was found in the surface roughness of self-polymerized acrylic base material after immersion in denture cleansers. In the present study, immersion of self-polymerized resins in Corega showed a significant increase in surface roughness compared to distilled water. This could be explained by the mechanism of action of the solution. When Corega tablets placed in water, the sodium perborate decomposes to form an alkaline peroxide solution, which then releases oxygen, thus resulting in both mechanical and chemical cleaning action by the bubbles of oxygen [6].

This study evaluated the effect of different denture cleansers on surface roughness of two types of denture base materials: heat-polymerized resin (Lucitone 199) which is commonly used for construction of removable prosthesis and self-polymerized resin (Rapid repair) that considered as a hard relining material used to improve denture's fitting surface for better retention and stability. Routine denture cleaning is an important factor to reduce bacterial and plaque accumulation, staining, bad odor and incidence of inflammation of the supporting tissue [19]. This can be accomplished by chemical and mechanical methods. Brushing is one of the most common mechanical methods for removing plaque deposits from prosthesis surfaces. However, in geriatric patients with poor manual dexterity, chemical methods must be used as adjunctive measures [19]. In the present investigation; the denture base materials have been immersed in different chemical cleansers and brushed five strokes to simulate the effect of chemical and mechanical cleaning protocol. This combination improves the effectiveness in removing stains and decreasing biofilm formation on the denture surfaces [20].

Chemical denture cleansers are classified into five groups: the alkaline peroxides (Percarbonate or perborate), alkaline hypochlorites, enzymes, diluted acids and disinfecting agents [21,22]. All the cleansers evaluated in this study (Corega, Polident and Stain Away Plus) are considered alkaline peroxides (Sodium perborate denture cleansers). Enzymes are also one of the composition in Corega and Polident. Peroxides include alkaline detergents and oxygen release agents such as sodium perborate or percarbonate, which loosens debris and removes light stains [12]. Enzymes act on glycoprotein, mucoprotein, and extracellular polysaccharide structures, causing the breakdown of macromolecules into less-adhesive, smaller units [12].

In this study, there were no significant differences between cleaning solutions in both self- and heat-polymerized materials. This indicates that slight differences in the compositions of the tested cleansers which were selected from one class (Alkaline peroxides) did not cause any significant change in the roughness of the acrylic denture bases. This was in agreement with another study that evaluated the effect of different disinfectants including Corega Tabs, Cepacol and Polident on removable partial denture cleaning by mimicking 180 successive hygiene immersion trials [23]. The authors found a greater roughness of the heat-polymerized acrylic resin after immersion with Cepacol but no differences in the effect between Corega, Polident and water [23]. Another study reported increase roughness of different types of acrylic resin except for the graft copolymer PMMA after immersion in different sodium perborate-containing denture cleansers for 20 days [24]. However, there was no difference between denture cleansers [24]. For the best of authors' knowledge, no study was found on the effect of the commercial cleaner (Stain Away

Plus) on the physical properties of acrylic denture base materials to compare the results.

The results of this investigation revealed that the surface roughness of self-polymerized resins immersed in distilled water was lower than heat-polymerized resins. This could be mainly due to differences in the structure and polymerization process between both materials. The acrylic denture base materials composed of poly methyl methacrylate polymer, initiator such as benzoyl peroxide and pigments (salts of cadmium or iron or organic dyes). The liquid contains methyl methacrylate monomer, cross-linking agent (ethylene glycol dimethacrylate), inhibitor (hydroquinone) and a chemical activator such as N N'-dimethyl-p-toluidine. The last is only presented in self-polymerized resins [25]. Polymerization process results in the conversion of the monomer molecules into polymers. During this process, some unreacted residual monomers remain unpolymerized [25]. Self-polymerized denture base materials demonstrated up to seven times the level of residual monomer found in heat-polymerized materials [26]. Diffusion of the unreacted molecules out of the resin [27] and further polymerization reaction at the sites of active radicals [28] reduce the residual monomer. Studies showed that water storage of heat and self-polymerized acrylic resins reduces the level of residual monomer significantly [29, 30]. On the other hand, water molecules may act as plasticizers that diffuse into the polymer and progressively cause relaxing the polymer chains and interfere with the mechanical properties of the polymerized material [31, 32]. However, storage of the samples after polymerization and the immersion of the control groups in distilled water for the whole testing period increase the leaching of residual monomer from the resin which overcome the plasticizing effect of the water.

In this study, all the self- as well as the heat-polymerized resin materials have been finished and polished. Although hard relining material should not be polished in the clinical condition, this was accomplished for standardization between both tested materials. The finishing technique utilized to produce smooth acrylic surfaces was similar to the clinical and laboratory procedures used during finishing and polishing of dentures. This was different than other studies who reported the use of carbide or sand papers with different grits for finishing the acrylic resin materials [5,8,24]. It was reported that the surface roughness of acrylic resin depend on the polishing grit [17]. A study concluded that self-polymerized acrylic resins had the least favorable surface roughness, regardless of the polishing method used: Axis, Brasseler, Shofu, and conventional polishing with different grits of pumice and polishing compound and the latter produced a smoother surface compared to the polishing kits [16]. In this study, the combination of the

conventional polishing method and the use of polishing kits could be another possible explanation for the decrease in surface roughness for the self-polymerized resins compared to heat-polymerized resins in the control groups.

In the current study, there was a decrease in surface roughness of heat-polymerized resins after immersion in the cleaning solutions compared to the control group. This was in agreement with another study, which reported no significant change in the roughness after immersion of heat-cure acrylic resin denture base materials in sodium perborate solution, 0.2% chlorhexidine gluconate, and 1% sodium hypochlorite up to 240 hours [33]. A study evaluated the effect of immersion of heat-polymerized acrylic resin in Corega Tabs and Bony Plus simulating a 180-day use found that Bony Plus significantly increased the surface roughness of the heat-polymerized acrylic resin but no significant changes was found with Corega Tabs [34]. On the other hand, a study reported that immersion of 1 heat-polymerizing denture base resin (Lucitone 550) and 2 hard chairside relining resins (Kooliner and DuraLiner II) in sodium perborate solution and microwave disinfection may increase the roughness and their effect varied among the materials [13]. Comparing the results with previous studies was difficult due to various immersion periods, the use of different cleaning solutions and resin materials.

The highest means of surface roughness for denture base materials after immersion with denture cleansers and distilled water was 0.130 μm for self-polymerized and 0.126 μm for heat-polymerized resins. A review evaluated the roughness of 20 commercially available denture base and lining materials reported that the roughness values of denture base materials ranged from 3.4 to 7.6 μm , whereas for the hard liners ranged from 0.7 to 4.4 μm [35]. The results in this study were lower than those reported by Zissis *et al* [35]. Previous studies used different measurement methods to measure surface roughness. In this study, non-contact optical profiler analysis was used to analyze the surface roughness (Sa) in micrometer. There is no agreement about reference data on the limit roughness below which the bacteria would not adhere [36]. The most commonly mentioned limit of surface roughness (Ra) is below 0.2 μm for adherence of dental biofilm [37, 38] and increase of roughness above this value lead to accumulation of bacteria [39]. However, the aforementioned investigations were performed on artificial materials such as cellulose acetate. May be it is most accurate to say, that the number depends on the species of bacteria. Thus, comparisons between surface roughness data of different studies have to be taken with thoughtfulness due to differences in methods and settings of surface analysis as well as tested surfaces. This study reported the three-dimensional roughness measured at a similar magnification, which may not be

easy to compare to other studies. Furthermore, it is not possible to compare roughness values obtained with contact profilometer along one line of the specimen with those values obtained with the non-contact optical interferometers as surface area. In this study, the optical interferometry noncontact profilometer was used to measure surface roughness. Compared with a stylus profilometer, the optical interferometry noncontact profilometer is faster, nondestructive, and allow repeatability [40]. Optical profilers measure roughness (Sa) of a selected micro area at a high spatial resolution with no contact with the specimen. In addition, preparation of the specimen is not required [40]. Sa is a surface roughness and for technical surfaces, the relationship between Ra and Sa is 1.25; however, this rule does not have to apply to biological specimen [40].

Study limitations

The results of this investigation should consider the limitations of the study, including its *in vitro* setting and application of the tested materials for 7 times over 7 days, which may not be enough to simulate the cumulative long-term effect *in vivo*. In addition, operator variables during the finishing and polishing procedure of each sample, applied pressure during brushing, the lack of simulation of oral conditions such as the influence of saliva and biofilm accumulation. In addition, the clinical condition in the mouth is not easy to mimic in the laboratory [41]. Surface roughness *in vitro* may be different when compared to the dynamic system in the oral cavity *in vivo* and therefore, direct extrapolations to clinical conditions must be exercised with caution [42]. However, in this *in vitro* study, standardization of experimental conditions was advantage and the results demonstrated a clear correlation between surface roughness of tested materials and application of the cleaning agents and distilled water. Long-term studies are recommended for further evaluation of the adverse effect of these commercial cleansers on the mechanical and physical properties of denture base materials.

CONCLUSIONS

Within the limitations of this study, it can be concluded that: Immersion of acrylic denture base materials in the tested denture cleansers had no significant effect on the roughness of the denture base materials except for self-polymerized resins immersed in Corega. Immersion in distilled water had a significant decrease in surface roughness in self-polymerized compared with heat-polymerized resins. Short-term evaluation of the tested denture cleansers showed changes in surface roughness of acrylic denture bases. For heat-polymerized acrylic resins, the highest mean of surface roughness was noticed in the control group (0.126 μm) while the lowest was detected after immersion in Corega (0.118 μm). For self-polymerized acrylic resin, the highest mean of surface roughness was

recorded for Corega (0.130 μm) while the lowest was recorded for the control group (0.113 μm).

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