Original Article

A Denture Cleansing Solution and Household Agents Differentially Affect the Surface Roughness of Acrylic Resin

Sita Thaworanunta[1], Naluemol Sriprasert[1], Chutimon Nanarong[2], Pichsinee Dittaratchaphong[2], Thananya Momin[2] , Thanpitcha Krisanawong[2]

[1]Prosthodontics Dept, College of Dental Medicine, Rangsit University, Pathumthani, Thailand

[2]College of Dental Medicine, Rangsit University, Pathumthani, Thailand

Abstract

This article evaluated the surface roughness of heat-cured acrylic resin before and after immersion in 4 different household agent solutions and a commercial denture cleansing solution after simulated 6-month and 12- month durations. Seventy-two specimens were fabricated from heat-cured acrylic resin and were divided into 6 groups (n=12); namely 4 household agents (100% clear vinegar, 5% acetic acid 0.1%, and 0.5% Sodium hypochlorite), a commercial denture cleansing solution, Polident® (Block Drug Company Inc, Memphis, TN38113, USA.) and tap water. The acrylic resin specimens were immersed for 10 min/cycle, 5 times/day for 36 days representing 6-month of clinical service, and continued for another 36 days representing 12-month of clinical service. The surface roughness (Ra, nm) was measured before and after simulated immersion. The data were compared using repeated ANOVA and Tukey's test. The mean difference in the Ra after the 6-month and 12-month immersions in the control group and the Polident®, 100% clear vinegar, and 5% acetic acid groups was not significantly different ($P > 0.05$). In contrast, the mean Ra in the 0.1% and 0.5% sodium hypochlorite groups was significantly higher ($P < 0.05$) after the 6-month immersion. However, the Ra increased with a diminishing value after the 12-month immersion. The Ra of the specimens immersed in 0.1% and 0.5% sodium hypochlorite was significantly increased after 6-month, which decreased by 12-month immersion. The Ra in the 100% clear vinegar and 5% acetic acid groups were not significantly different from that of the Polident® group. Therefore, 100% clear vinegar and 5% acetic acid, which are household agents, can be an alternative option for routine use. Further study should be performed to evaluate whether 0.1% and 0.5% sodium hypochlorite might be an alternative option for denture cleansing.

Keywords: Commercial denture cleansing solutions, Household agents, Heat-cured acrylic resin, Surface roughness

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Correspondence to:
Naluemol Sriprasert , College of Dental Medicine, Rangsit University, 52/347 Muang-Ake, Phaholyothin Road, Lak-Hok, Muang, Pathumthani 12000 Thailand. E-mail: Naluemol.s@rsu.ac.th

Introduction

Thailand is becoming an aging society. The National Statistical Office of Thailand reported that in 2019, the aging population comprised 16.73 % of the total 66-millionThai population.[1] The Thai National Oral Health Survey by the Department of Health, Ministry of Public Health also revealed that 1 million elderly people wore complete dentures, and 4.9 million people wore removable partial dentures[2] Axe *et al.* found that denture wearers often suffered from the anxiety of further oral care problems and concerned about the esthetic problems of denture, malodor, and staining which may reveal denture wearing to others.[3] Therefore, appropriate denture cleaning is essential in plaque elimination, and maintaining good oral hygiene to eradicate all problems that denture wearers concern.

Acrylic resin was introduced as a denture base material in 1937. The reason for acrylic resins continued popularity in dentistry is the simple processing equipment required and the relatively low cost of the fabrication process.[4] The properties of a denture base which should be taken into account are biological properties, microbiological properties, and physical properties; which include surface roughness.[5] The surface roughness of a denture base is clinically meaningful and influences the amount of plaque and bacteria that accumulate on the denture.[6] *Candida albicans* is the most common opportunistic pathogen found in the oral cavity and can cause oral diseases, such as denture stomatitis. Increased porosity has been proven to increase microorganism colonization. The adhesion of *Candida albicans* to the surfaces is significantly affected by the interactions with other microorganisms in the oral cavity.[7] The acceptablesurface roughness to prevent plaque accumulation should be lower than the critical threshold of 0.2 μm.[6,8]

There are two major approaches for cleaning the denture base. The first approach is the mechanical method, such as brushing and an ultrasonic cleanser. These methods are effective in reducing and removing the biofilm.[9,10] However, brushing effectiveness can be reduced by poor manual skills of the denture wearer.

The second cleansing approach is the chemical cleaning method in which the denture base is immersed in different chemical agents, such as alkaline peroxides, alkaline hypochlorite, acids, and disinfectants.[9-11] These agents can be excellent tools because they reduce the amount of microorganisms adhering to the denture, compensate for possible limitations in brushing ability, have good acceptance by wearers, and are easy to acquire?.[12,13]

One of the chemical methods is immersion in a commercial denture cleansing solution. A good denture cleansing solution should not alter the denture properties, such as its color, dimensional stability, strength, and surface roughness.[14] In geriatric or disabled patients who are denture wearers, chemical denture cleansers can be a choice.[15]

Despite the effectiveness of commercial denture cleansing solutions, there are difficulties in finding them in the rural areas. If household agents, such as sodium hypochlorite and clear vinegar could be used to clean the denture and do not affect the surface roughness to the point of potentially increased bacteria/plaque accumulation, denture wearers would have an appropriate alternative to clean their dentures.

To evaluate the surface roughness of heat-cured acrylic resin before and after immersion in 4 different household agent solutions and a commercial denture cleansing solution for simulated 6-month and 12-month durations. The null hypothesis was that there were no significant differences in surface roughness between the immersion groups or immersion intervals.

Materials and Methods

1. Specimen preparation

The sample size calculation was performed using the G*Power 3.1.9.4® program. The calculation was performed using data from a prior study.[16]

Seventy-two 10x10x2 mm^3 disc-shaped specimens were fabricated from heat-cured acrylic resin using a stainless steel mold. The mold was designed with three layers, the upper and the lower parts were used as covers;

the center part had a 10x10x2 mm^3 disc-shaped space that was used to fabricate the specimens. These three parts were locked into one piece by screws. Therefore, all of the specimens were the same size. The mold used for preparing the test specimens was applied with separating medium. The heat-cured acrylic resin used was in the powder-liquid form. The powder and liquid was mixed at the ratio recommended by the manufacturer. When the mixture reached the dough stage, it was packed into the mold space and processed per the manufacturer's instructions. A short cure polymerization cycle (73°C for 90 min followed by 94°C for 30 min) was used. The specimens were removed from the molds and finished with 1000 and 2000 grit sandpaper, followed by a buffing polishing wheel. The other surfaces were marked with a number and left unpolished to be distinguished from the experimental surface that was measured by the surface roughness tester. Finally, the specimens were steamed in an ultrasonic cleaner.

2. Immersion procedure

A commercially available denture cleansing solution: Polident® (Block Drug Company Inc, Memphis, TN38113, USA) and 4 household agents, 0.1% and 0.5% sodium hypochlorite (Suksapan®, Thailand), 100% clear vinegar (อสร®, PFO FOOD co., ltd, Thailand), and 5% acetic acid (Suksapan®, Thailand) were used in this study. The immersion groups consisted of 4 household agents: 100% clear vinegar (pH 3.5), 5% acetic acid (pH 3.5), 0.1% and 0.5% Sodium hypochlorite (pH 7.5 and pH 8.0, respectively), the commercial denture cleansing solutions (pH 7.0) and tap water (pH 7) which served as a negative control. The pH in each group was determined using PL Precision LABORATORY® Litmas paper. The Polident® immersion solution was prepared using 1 Polident® tablet dissolved in 50 ml of tap water. The solutions were prepared in glass beakers at room temperature and the specimens were immersed horizontally.

After immersion in the respective solutions for 10 minutes/cycle, each test specimen was rinsed in running tap water for 2 min and immersed in a new respective solution, repeated for 5 cycles per day for 36 days, which is equivalent to 6-month of clinical service and continued for another 36 days representing 12-month of clinical service. When not immersed in the cleansing solutions, the specimens were stored in tap water.

3. Surface Roughness Measurement

The surface roughness (Ra) was measured at the central area of each specimen using a non-contact surface roughness tester (InfiniteFocus SL, Alicona®, Austria) at a speed of 0.5 mm/s. The speed of 0.5 mm/s was set for precisely detecting the surface roughness and the magnification of the objective lens was 50x. Each specimen was measured as an area. The Ra of each specimen was determined in three areas, and the mean Ra was calculated. The change in surface roughness was obtained by the difference in surface roughness between pre-immersion and post-immersion for 6-month and 12-month.

The specimens were divided into 6 groups (n=12). The surface roughness of the specimens in each group was measured using the non-contact surface roughness tester immediately after polishing and cleaning. The results demonstrated that the Ras of all groups were not significantly different at T0, confirming that the specimens had a similar surface roughness.

Table1 *Solutions used in the study*

Solutions	pH	Conc.	Brand	Immersion Time at room temp. (min/cycle)
Tap water (negative control)	7			10
Polident® (positive control)	7		Polident®, Inc, USA.	10
Clear vinegar	3.5	100%	อสร®,PFO FOOD., ltd, Thailand	10
Sodium hypochlorite (NaOCl)	7.5	0.1%	Suksapan®,PFO FOOD., ltd, Thailand	10
Sodium hypochlorite (NaOCl)	8.0	0.5%	Suksapan®,PFO FOOD., ltd, Thailand	10
Acetic acid	3.5	5%	Suksapan®,PFO FOOD., ltd, Thailand	10

3. Data analysis

The data analysis was performed using repeated measures analysis of variance (repeated measures ANOVA) and Post-hoc Tukey test to compare and evaluate the differences in surface roughness values between the groups. All statistical analyses were set at a significance level of < 0.05. The statistical tests were calculated using the SPSS 20.0 program (SPSS Inc., Chicago, IL, USA)

This experimental study was performed under ISO/TC212: Clinical laboratory testing and *in vitro* diagnostic test systems.

Results

The data was analyzed and confirmed to have homogeneity of variance and normality. Descriptive statistics was used to present the mean and standard deviation (S.D.) of the Ra by time (T0, T6, and T12) and by cleansing solution groups (Polident®, 100% clear vinegar, 5% Acetic acid, 0.1% sodium hypochlorite, 0.5% sodium hypochlorite, and Tap water) (Table 2). These results demonstrated no significant difference between the mean in the Ra in the control group and the Polident®, 100% clear vinegar, and 5% acetic acid groups ($P > 0.05$) after simulated the 6-month and 12-month immersions. However, the mean Ra in the 0.1% and 0.5% sodium hypochlorite groups was significantly higher ($P < 0.05$) after the 6-month immersion compared with the control group. Furthermore, the values of Ra increased with a diminishing value after the 12-month immersion in these groups. Based on these results, the null hypothesis was rejected.

Table 2 *Descriptive statistics of Ra in nm for the cleansing solution groups*

Solutions	Mean Ra (nm) ± S.D.		
	T0	T6	T12
Polident®	195.13 ± 8.92	197.84 ± 10.60^{A,1}	200.11 ± 11.12^{a,1}
100% clear vinegar	196.04 ± 8.92	195.13 ± 8.50^{A,1}	197.77 ± 8.70^{a,1}
5% Acetic acid	195.64 ± 8.94	198.25 ± 7.44^{A,1}	200.17 ± 7.44^{a,1}
0.1% NaOCl	193.72 ± 10.55	214.32 ± 13.81^{B,2}	229.07 ± 13.88^{b,2}
0.5% NaOCl	194.76 ± 7.42	218.84 ± 9.53^{B,2}	235.70 ± 11.16^{b,2}
Tap water	195.58 ± 8.69	195.80 ± 10.90^{A,1}	196.15 ± 11.00^{a,1}

** Similar superscript capital letters indicate no significant differences between groups at 6-month (left columns), similar superscript lowercase letters indicate no significant differences between groups at 12-month (right columns), and similar superscript numbers indicate no significant differences between 6-month and 12-month within each group (rows) according to Tukey's (HSD) test (p>0.05)*

The analysis of the mean in surface roughness of the heat-cured acrylic resin in 6 cleansing solutions using repeated measures ANOVA (Table 3).

Table 3 *Repeated measure ANOVA results*

Tests	Source	Type III Sum of Squares	df	Mean Square	F	*p*-value
Within-Subjects	TIME	7762.051	1	7762.051	600.311	0.000*
Contrasts	TIME * GROUP	10083.295	5	2016.659	155.967	0.000*
	Error (TIME)	853.383	66	12.930	853.383	
Between-Subjects	Intercept	8881715.333	1	8881715.333	31081.172	0.000*
Effects	GROUP	15004.404	5	3000.881	10.501	0.000*
	Error	18860.074	66	285.759		

Note: Asterisks indicate significance at the 99% confidence level

The first test was the test of within-subjects contrasts, which determined if the time used for testing (T0, T6, and T12) affected the surface roughness of the heat-cured acrylic resin. The results demonstrated that Time significantly affected the surface roughness of the heat-cured acrylic resin both directly (TIME) and indirectly (TIME * GROUP) at the 99% confidence level (Table 3).

The second test was the Between-Subjects Effects, which evaluated whether the different cleansing solutions (GROUP) (commercial denture cleansing solution, 100% clear vinegar, 5% Acetic acid, 0.1% sodium hypochlorite, 0.5% sodium hypochlorite, and Tap water) affected the surface roughness of the heat-cured acrylic resin. The results indicated that the GROUP significantly affected the surface roughness of the heat-cured acrylic resin at the 99% confidence level (Table 3).

The surface roughness of heat-cure acrylic resin immersed in groups of tap water (a negative control), commercial denture cleansing solution (a positive control), 100% clear vinegar, and 5% acetic acid had no significant difference in term of group and time. On the other hand, time and group had significant effect in groups of 0.1% and 0.5% Sodium hypochlorite

The next analysis classified the differences in the surface roughness of the heat-cured acrylic resin from the cleansing solutions (GROUP) using Tukey's test for Post-Hoc analysis.

Table 4 *The results of the Tukey's test for Post-Hoc analysis*

Solutions	N	Rate of Ra	
		Subset 1	Subset 2
Tap water	12	195.8422	-
100% clear vinegar	12	196.3142	-
Polident®	12	197.6931	-
5% Acetic acid	12	198.0206	-
0.1% NaOCl	12	-	212.3664
0.5% NaOCl	12	-	216.4336
***p*-value**		0.994	0.909

The Tukey's test for Post-Hoc analysis (Table 4) classified the treatments into 2 groups. The mean Ras in the tap water, 100% clear vinegar, 5% acetic acid, and Polident® groups were 195.8422, 196.3142, 197.6931, and 198.0206 nm, respectively, and they were not significantly different. In addition, the Ras in the 0.1% sodium hypochlorite (212.3664 nm) and the 0.5% sodium hypochlorite (216.4336 nm) were not significantly different.

Discussion

Denture cleansing is a necessary procedure that reduces the risk of oral infection and improves denture longevity. There are two methods to clean acrylic dentures: mechanical method, such as brushing, and chemical method, such as using a denture cleansing solution. Kurniawan *et al.* demonstrated that mechanical method by brushing dentures with toothpaste and chemical method by immersing in denture cleanser greatly increased the surface roughness, which causes more plaque retention.[17] Thus, this study focused on the chemical method, which is still the alternative to clean dentures to reduce biofilm formation due to their limited effect on surface roughness.

For daily use, patients soak their dentures in the cleansing solution for 10 min, then wash and store in tap water overnight. The present study simulated that situation using running tap water to clean the specimens for 2 min before immersing in a new solution in each cycle to eliminate the remaining cleansing solution. After the immersion cycles,

the specimens were stored in tap water representing soaking the denture overnight. Felipucci[18] revealed that ideally, denture cleansers should reduce or remove the biofilm without altering the physical and mechanical properties of the denture base material. However, many studies found that the daily use of denture cleansing solutions can affect the denture's mechanical and chemical properties, including the denture base material's color, surface roughness, and hardness.[9,15,17-23]

Most of the studies found that commercial denture cleansing solutions did not show any significant increase in term of surface roughness.[24,25] In our experimental study, immersing in a commercial denture cleansing solution (Polident®) was found to increase the surface roughness. Jørgensen found that Alkaline peroxides were the most commonly used cleansing solution in denture cleansers including Polident®.[26] Sodium percarbonate becomes a hydrogen peroxide when dissolved in water and releases an oxygen. The oxygen bubbles are supposed to exert a mechanical cleansing effect which is suspected to cause an increase in the surface roughness. However, the surface roughness between Polident® and tap water (a negative control) was not significantly different.

Acetic acid is one of the most important components of vinegar; which contains other by-products from the manufacturing method. Therefore, we diluted pure acetic acid to 5% which is the amount of acetic acid in clear vinegar, and used this as a comparative experimental group. The results indicated that the surface roughness in the clear vinegar and 5% acetic acid groups was not significantly different. We can also assume that these by-products do not affect the surface roughness of acrylic denture specimens.

Therefore, ester group in heat-cured acrylic resin are easily hydrolyzed with acids and formed numerous cracks on acrylic resin specimen. The number of cracks on the surface of heat cured acrylic resin causes surface irregularity and increases the roughness of the surface of the acrylic resin.[27] The results of the present study demonstrated that the surface roughness in the clear vinegar and 5% acetic acid groups was not statistically different from that of the positive control group.

Chau *et al.*[28] found that 10-minute immersion in 0.5% sodium hypochlorite eliminated microorganisms from the superficial and the inner surface of acrylic resin. de Sousa Porta *et al.*[20] stated that 0.5% sodium hypochlorite effectively reduced microorganisms without significantly changing the denture resin color or roughness. However, sodium hypochlorite significantly increased surface roughness.[23] In the present study, 0.1% and 0.5% sodium hypochlorite significantly increased the surface roughness, similar to the study by Porwal *et al.*[22] These researchers evaluated the effect of different denture cleansers on the color stability, surface hardness, and surface roughness of three denture base resin materials. The results demonstrated the most remarkable change in the surface roughness of conventional heat-cured acrylic resin when immersed in 0.5% sodium hypochlorite for 180 days. Sodium hypochlorite causes structural changes in the polymer matrix of acrylic resins. This effect could result in softening of the surface and, as a consequence, roughness could be expected to increase.[21]

Arruda *et al.* found that 0.1% sodium hypochlorite effectively removed the biofilm when used by participants with denture stomatitis.[19] Therefore, 0.1% sodium hypochlorite would be a better choice for denture cleansing compared to 0.5% sodium hypochlorite because it is less toxic and adequately removes biofilm. Göpferich and AlAmeer demonstrated that the degradation of heat cured acrylic material significantly increased when soaking in neutral or basic pH solutions.[29,30] The pH affects the degradation rates of the polymer because the breaking strength of the polymer depends markedly on the pH and is highest at neutral pH. In basic pH solutions, there is a high number of Hydroxyl ions, which is responsible for accelerating polymer degradation, thus increasing the surface roughness.[31]

The present study had limitations; the shape of the specimens did not resemble the denture shapes that reflect the patients' oral tissue anatomy. The present study focused on surface roughness only; thus, the effect of immersion on the other properties of denture base material requires further investigations.

Conclusion

The present study found that immersion in 0.1% and 0.5% sodium hypochlorite significantly increased the denture bases' surface roughness after 6- and 12-month immersions. The surface roughness in the other household groups was not significantly different from that of the commercial dentures cleansing solution and tap water groups. However, this study only evaluated 6- and 12-month immersion periods, and there may be other household agents that could be investigated in the future studies.

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