Original Article

Effects of Short and Long-Term Immersion in Denture Cleansers on the Dimensional Stability of Acrylic Denture Base Material

*Sanarya A. Younus[1], Neda M. AL-Kaisy[*2]*

Abstract

Objective: This study aimed to compare the effects of three commercially available denture cleansing solutions on the dimensional stability of heat cure acrylic denture bases.

Methods: Twenty four maxillary acrylic denture base samples were constructed and divided into four groups. Group 1. water as control, group 2. 1% Sodium hypochlorite, group 3. 2% Chlorhexidine, and Group 4. Kin tablet solution. Linear dimensional measurements were conducted along with five-time intervals: 0 times: before immersion, three days, ten days, one month, and two months after immersion. After each time interval, the specimens were photographed in a standardized manner, and the images were evaluated by Image J software. The dimensions between six projection points on the intaglio surface of denture bases were recorded and compared. Data were submitted to statistical analysis (Two-way ANOVA, Tukey test, $p < 0.05$).

Results: All specimens in three disinfectant solutions and water exhibited a small amount of linear expansion at all time intervals. The expansion was significant compared to the 0-time immersion. On the tenth day of immersion, the dimensional change becomes stable and constant until the end of the two months. Among the three disinfectants, 1% of Sodium hypochlorite registered the least expansion in some measured lines at two-time intervals followed by 2% Chlorhexidine.

Conclusions: Cleanser solutions induced dimensional changes on acrylic denture bases similar to the effect of water in all examined measurements. The long time cleanser's immersion had the same effect on the dimension as the short time effect.

Keywords: *Denture cleanser, Dimensional stability, Acrylic denture base, Immersion time.*

Submitted: January 30, 2020, Accepted: March 19, 2020, Published: June 1, 2020.

Cite this article as: Younus SA, Al-Kaisy NM. Evaluation of the Effect of Short and Long-Term Immersion in Denture Cleansers on the Dimensional Stability of Acrylic Denture Base Material. Sulaimani Dent J. 2020;7(1):49-57.

DOI: https://doi.org/10.17656/sdj.10106

1. *Prosthodontic Department, M.Sc Student, College of Dentistry, Sulaimani University, Sulaimani, Iraq.*
2. *Prosthodontic Department, College of Dentistry, Sulaimani University, Sulaimani, Iraq.*

** Corresponding author: neda.jaffer@univsul.edu.iq*

Published by College of Dentistry, University of Sulaimani

Introduction

Increasing life expectancy has led to a rising number of older people worldwide, resulting in a high prevalence of edentulism and complete denture wearing[1]. The acrylic resin proved successful as a denture base and remained the most popular choice since it provided the most requirements of denture base materials[2,3]. The success of rehabilitative treatment mainly depends on patients' motivation, correct prosthesis aftercare, and hygiene level[4].

Dental prostheses are exposed to normal oral microbial flora such as viruses, bacteria, and fungi. Home care instructions provided to patients during the denture placement appointment help in the maintenance of a healthy oral mucosa[5]. Thus, the indication of denture cleansing is of vital importance to prevent or treat infections in the edentulous mouth. Dentures can be cleaned by mechanical methods, chemical methods, or a combination of both[6,7].

Denture cleansers that are used for immersion are the most preferred chemical cleaning methods. They are mainly used to improve denture lifetime with the preservation of healthy mucosa[5]. The best cleanser should fulfill most of the requirements of an ideal cleanser while not causing any kind of alteration in the structure of the prosthesis. Therefore, immersion in cleaning solutions has been recommended to complement denture hygiene[8]. In addition, they can be used in some instances where an individual has decreased motor coordination or is disabled[9].

The chemically available denture cleansers can be broadly grouped under alkaline peroxides (percarbonate or perborate), alkaline hypochlorite's, dilute organic or inorganic acids, and enzymes[10,11]. The main immersion regimens of denture cleansers that mainly recommended by the dentists to their patients are 15 min daily soaking and daily overnight dipping[12].

Denture retention is one of the important factors for the preservation and health of underlying tissues. A dimensionally stable and well-fitted denture prevents hyperplasic lesion and provide more chewing efficiency and promote patient comfort[13]. Ideally, a disinfection method should not affect the physical properties of the acrylic denture base.

Many previous studies compare the effect of denture cleansers and disinfectants on different denture properties like tensile strength, color stability, surface roughness, and hardness[14–18]. Nevertheless, little information was found regarding the effect of different chemical cleansers on the dimensional stability of heat-cured acrylic denture base materials. Some studies evaluate the effect of sodium hypochlorite (NaOCL), alkaline glutaraldehyde disinfectant, or experimental essential oils on flat round or rectangular specimens of acrylic denture base materials[19–21]. Others measured the intaglio surface area to determine dimensional stability after short immersion in disinfectant solutions[22].

To the best of author knowledge, little published data is showing the effect of short and long immersion in different denture cleansers on the dimensional properties of heat cure acrylic resin specimens, which are closely simulating clinical conditions.

The purpose of this study is to determine the influence of short and long-term immersion of three types of chemically disinfecting agents on the dimensional stability of heat-cured acrylic denture base materials.

Materials and methods

In this study, a total of 24 standardized maxillary denture bases were fabricated from hot cure acrylic denture base material (Vertex™ Rapid Simplified, Dental B.V. Netherlands) according to manufactural direction, with identical shape, size, and thickness. Six reference point projections were produced on the intaglio surface of the denture base (A, B, C, D, E, and F). The specimens were immersed in three different denture cleansers: 1% sodium hypochlorite (belodez, Russia), 2% chlorhexidine digluconate (microvem, turkey), and Kin denture cleanser tablet solution (Laboratorios KIN S.A. - Germany).

The distances between the reference points (AC, BD, DF, EF, and BE) were measured and recorded to determine the linear dimensional stability (Figure 1).

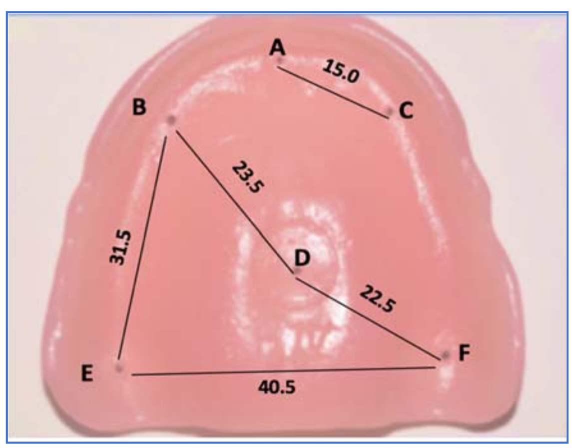

Figure 1: Intaglio surface of acrylic denture base with six projection points and five measured dimensions. The dimensions (mm) at 0 time.

To construct the study denture bases with identical shape, size, and thickness, a maxillary edentulous rubber mold impression model was used to construct two stone cast models by using Type IV dental stone (Snow Rock dental stone, Korea) according to the manufacture's instruction.

The first stone cast was modified by drilling six identical holes using a No.4 carbide round bur with NSK turbine. These holes intended to create projections on the intaglio surface of the processes denture bases to perform linear dimensional measurements (Figure 1).

To achieve a uniform denture base sample thickness among the 24 experiment denture bases, the 2nd stone cast was used to construct a metal spacer of approximately 2.5mm thickness made from chrome cobalt (which will substitute the resin denture base during flasking) (Figure 2).

Figure 2: Cobalt chrome spacer.

The conventional flasking technique was performed by adapting the metal base on the stone cast, then invested in the flask in dental stone according to routine procedures. After 1 hour, the flask parts were separated, the metal spacer was removed, two layers of separating medium was applied. Afterward, the prepared hot acrylic dough was packed and cured according to the manufacturing direction. The flasking procedure was repeated 24 times with the same chrome cobalt-base to get 24 acrylic denture base samples with identical thicknesses.

The resultant acrylic denture bases were randomly divided into four subgroups. Each subgroup composed of six specimens. Each subgroup was submitted to three daily disinfection cycles; each cycle will be an 8h duration (3 cycles/day). The experiment was conducted in springtime at a privet sector with the provision of air conditioner control to keep the room temperature approximately constant (about 27 ºC) and to precise the exchanging cleansers immersion daily times. The group's immersion cycles were as following:

- Control group: Immersion for 8h in a container with 200 ml tap water.
- Experimental group1: Immersion for 8h in a container with 200 ml of 1% NaOCl solution.
- Experimental group2: Immersion for 8h in a container with 200 ml of 2% chlorhexidine digluconate (CHX).
- Experimental group3: Immersion for 8h in a container with 200 ml with one KIN Effervescent tablets.

The solutions were changed every 8h to simulate overnight cleansing. The dimensional measurements were carried out at five-time intervals (Figure 3):

- 0 time: After deflasking and immersion of all samples in water for 24h before the immersion protocol with denture cleansers.
- 3rd day of immersion (3D): Which equal to 9 denture cleansers immersion cycles (3D×3 immersion cycles/day= 9).
- 10th day of immersion (10D): Which equal to 30 denture cleansers immersion cycles (10D×3 immersion cycles/day=30).
- One month of immersion (1M): Which equal to 90 denture cleansers immersion cycles (30D×3 immersion cycles/day=90).
- Two months of immersion (2M): Which equal to 180 denture cleansers immersion cycles (60D×3 immersion cycles/day=180).

The specimens were immersed for 60 continuous days (2M) to simulate 180 days of cleansers immersion[23,24].

All solutions were changed three times a day. After each immersion, the resin specimens were removed from the chemical solutions, thoroughly washed in running water, and dried with absorbent paper then conduct dimensional measurements.

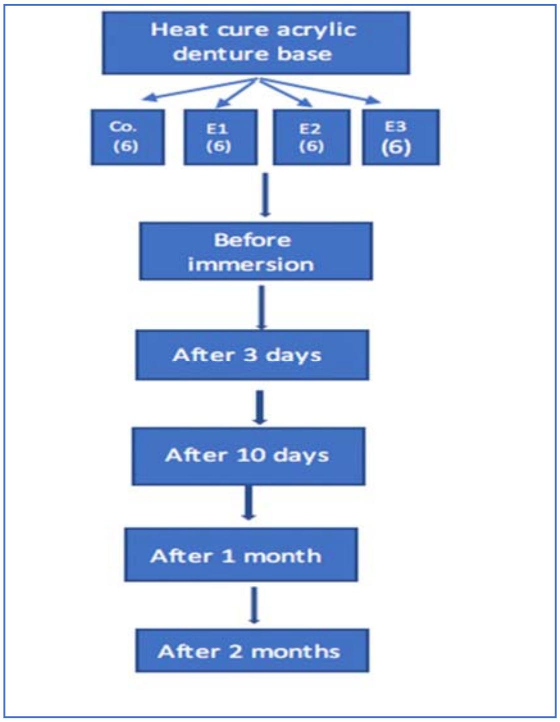

Figure 3: Diagram illustrate time intervals for dimensional measurement.

Dimensional stability measurements:

Standardized photographs of each intaglio surface of maxillary denture bases were recorded in a standardized manner (after removal from chemical solutions at the end of each tested time intervals) with a digital camera (Nikon 5300, with macro lens: sigma 105mm 1:2.8 DG MACRO HSM), The distance between the inner surface of the denture base and the camera lens was fixed at 50 cm to ensure distortion-free images. The captured images were analyzed using Image J software[25] that made distance measurements (mm) between the points projections (AC, BE, EF, BD, and DF). Each dimension was measured and recorded three times by one operator, and the average value was calculated (Figure 4).

Statistical analysis

Data were analyzed with statistical software SPSS (version 22.0). One-way ANOVA testing was applied for determining the difference between the means of the groups, where the significance alpha level was set at P<0.05, followed by a post-hoc Tuckey's test whenever the results were significant.

Results

The mean linear dimension (AC, BE, EF, BD, and DF) of acrylic denture base samples (in mm) at zero time before immersion is illustrated in Figure 1. EF (which connect the two maxillary tuberosities) was the greatest

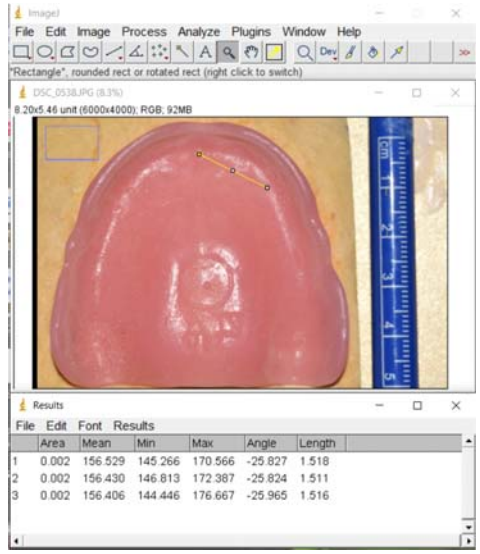

Figure 4: Image J measurements.

Linear distance (40.5mm), followed by BE (edentulous ridge area from canine to tuberosity area) (31.5mm). While AC (anterior ridge area from the incisive papilla to the canine area) represents the smallest distance, which equals to 15 mm, the diagonal/slopes measurement of the intaglio surface of the denture base BD and DF were approximately equal to each other (23.5mm, 22.5mm respectively).

BD and DF represent a diagonal (sloping) measurements. Points B and F situated in the deepest part of the denture base while pointing D in the highest middle area of the inner surface of the palate. Other lines (AC, BE, and EF) were considered transverse lines as they connect two points at the same level (deepest part of the denture base) (Figure 1).

Figure 5 shows the dimensional changes of acrylic denture bases at different time intervals of cleansers immersion (3D= 3 days, 10D= ten days, 1M= one month and 2M= two months) compared to zero time (the time before cleansers immersion). Mainly all dimensions (AC, BD, BE, and EF) get significant dimensional change (P<0.05) in control and all experiment groups of denture cleansers. The exception detected at AC line with NaOCL showed insignificant expansion at all time intervals compared to 0 times. DF line was the only dimension that reflects shrinkage rather than expansion in control and all denture cleansers groups. DF shrinkage was significant in all cleansers except in NaOCL, where it was insignificant.

At 3D time interval (equivalent to 9 immersion cycles), the majority of denture cleansers showed mainly insignificant expansion, except in Kin samples, which showed insignificant shrinkage in three of dimensions (AC, BD, and BE) (Figure 5).

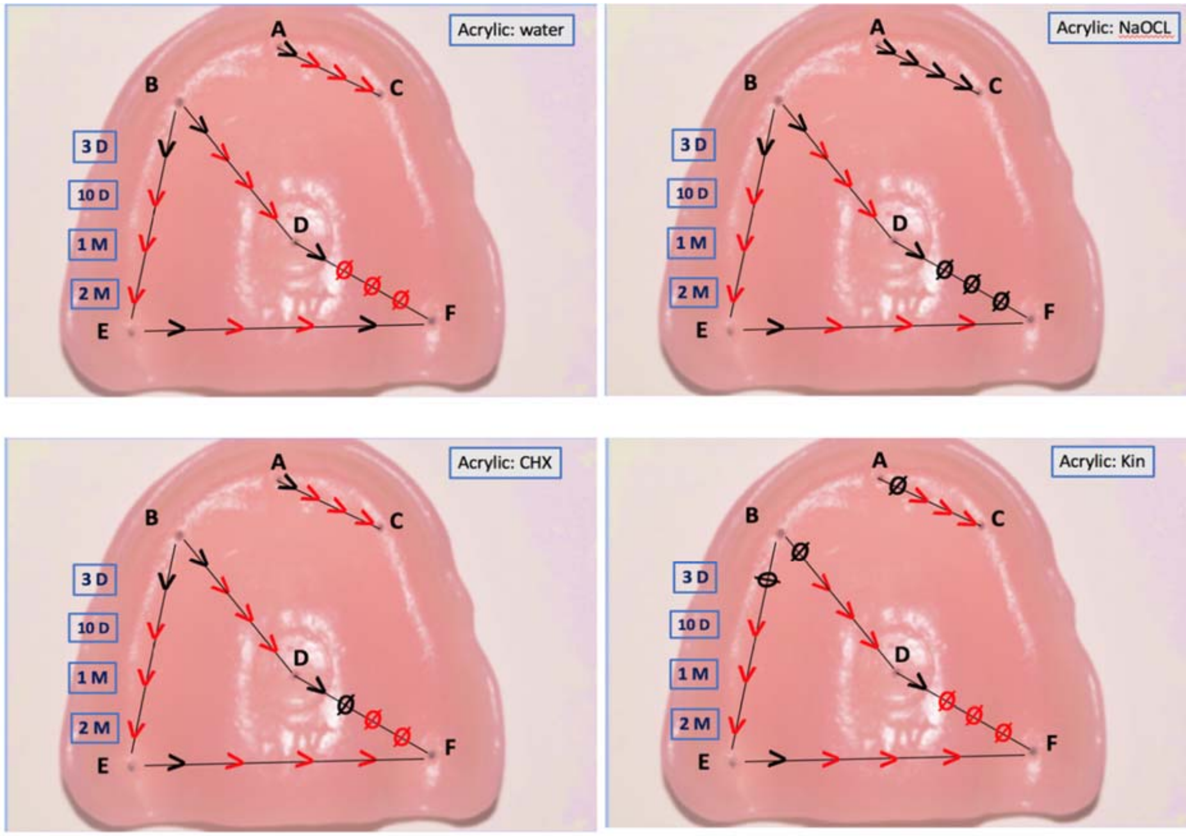

Figure 5: Comparison of linear Dimensional changes of acrylic denture base samples (AC, BD, DF, EF, and BE) during 4 successive time intervals (3 D= 3 days, 10 D = 10 days, 1 M = 1 month, 2 M = 2 months) compared to zero time (time before immersion) immersed in control (water) and 3 types of denture cleansers. > : significant expansion in dimension; > : insignificant expansion in dimension; θ : significant shrinkage in dimension; θ : insignificant shrinkage in dimension.

The transverse dimensions AC, BE, EF showed significant expansion ranging from the smallest percentage value (0.5%) of NaOCL (in AC line) to the greatest value (1.8% - 1.9%) of water (also in AC line) and NaOCL (in BE line) at both time intervals (10D and 2M which equivalent to 30 and 180 immersion cycles respectively), and for KIN at 10D. The NaOCL effect was the smallest and the only insignificant expansion (Table 1).

Although EF was the longest dimension (40.5 mm) (Figure 1), the percentage change was ranging from 0.7% -1.5%, which could be considered less valuable than changes in other transverse shorter lines (AC and BE). In contrast line AC (shortest line = 15mm), the percentage expansion was greater than EF line (0.5% - 1.9%) (Figure 6).

Table 1: Percentage linear changes and their comparison among different denture cleansers at two-time intervals: 10D and 2M compared to 0 times (P<0.05 indicate significant dimensional change).

Acrylic				Difference		p value		Difference		p value
		0 time ±SD	10 D ±SD	10 D- 0 time	%		2 M ±SD	2 M- 0 time	%	
AC	Water	14.96 ± 0.14	15.25 ± 0.09	0.29	1.9%	0.001	15.24 ± 0.08	0.28	1.8%	0.001
	NaOCL	15.04 ± 0.07	15.11 ± 0.16	0.08	0.5%	0.26	15.11 ± 0.15	0.08	0.5%	0.219
	CHX	15.05 ± 0.17	15.24 ± 0.08	0.2	1.3%	0.006	15.23 ± 0.09	0.19	1.2%	0.004
	Kin	14.97 ± 0.11	15.15 ± 0.13	0.18	1.2%	0.049	15.16 ± 0.11	0.19	1.3%	0.022
BD	Water	23.34 ± 0.29	24.49 ± 0.45	1.15	4.7%	0.006	24.45 ± 0.34	1.11	4.5%	0.003
	NaOCL	23.38 ± 0.38	24.21 ± 0.28	0.84	3.5%	0.01	24.14 ± 0.33	0.77	3.2%	0.017
	CHX	23.43 ± 0.13	24.23 ± 0.19	0.8	3.3%	< 0.001	24.29 ± 0.3	0.86	3.5%	< 0.001
	Kin	23.34 ± 0.32	24.37 ± 0.24	1.04	4.3%	0.001	24.33 ± 0.24	1	4.1%	0.002
DF	Water	22.49 ± 0.23	21.68 ± 0.29	-0.8	-3.7%	0.006	21.67 ± 0.3	-0.82	-3.8%	0.006
	NaOCL	22.48 ± 0.36	22.13 ± 0.49	-0.34	-1.6%	0.3	22.12 ± 0.5	-0.35	-1.6%	0.3
	CHX	22.46 ± 0.14	22.01 ± 0.44	-0.45	-2.1%	0.052	22.01 ± 0.44	-0.45	-2.0%	0.044
	Kin	22.41 ± 0.34	21.76 ± 0.38	-0.65	-3.0%	0.007	21.78 ± 0.37	-0.63	-2.9%	0.007
EF	Water	40.51 ± 0.26	40.97 ± 0.24	0.46	1.1%	0.001	40.8 ± 0.42	0.29	0.7%	0.091
	NaOCL	40.56 ± 0.12	40.96 ± 0.18	0.41	1.0%	0.001	41.01 ± 0.13	0.46	1.1%	0.001
	CHX	40.46 ± 0.09	40.85 ± 0.18	0.4	1.0%	0.013	40.87 ± 0.23	0.42	1.0%	0.016
	Kin	40.41 ± 0.15	41.02 ± 0.37	0.62	1.5%	0.009	40.86 ± 0.23	0.46	1.1%	0.009
BE	Water	31.63 ± 0.1	32.18 ± 0.2	0.56	1.7%	0.001	32.17 ± 0.22	0.55	1.7%	0.044
	NaOCL	31.71 ± 0.12	32.33 ± 0.18	0.62	1.9%	< 0.001	32.3 ± 0.21	0.59	1.8%	< 0.001
	CHX	31.7 ± 0.09	32.09 ± 0.17	0.4	1.3%	0.006	32.02 ± 0.23	0.33	1.0%	0.025
	Kin	31.57 ± 0.14	32.19 ± 0.1	0.62	1.9%	< 0.001	32.16 ± 0.09	0.59	1.8%	0.001

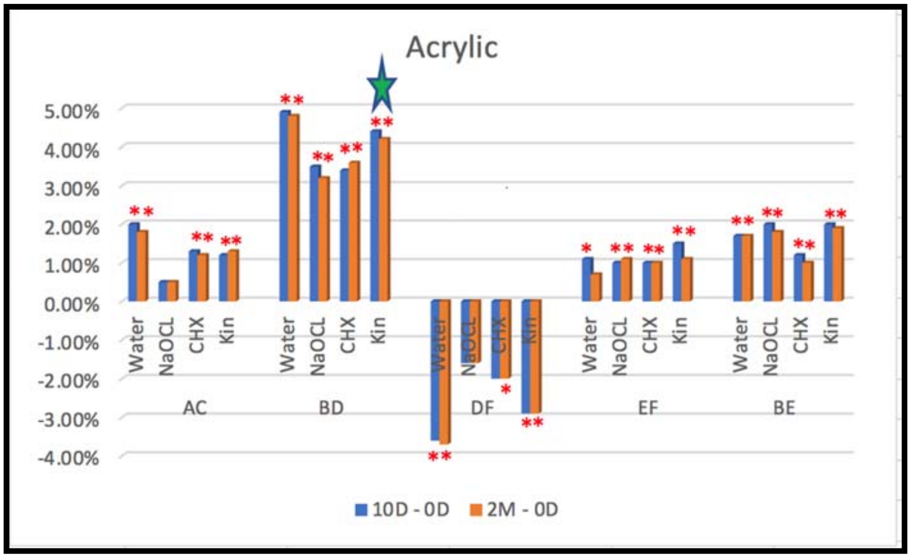

Figure 6: Percentage linear changes of acrylic samples immersed in water and three types of denture cleansers at two-time intervals: (time1= dimension at ten days – dimension at 0 times) and (time 2= dimension at two months – dimension at 0 times). *: significant dimensional changes within the same time interval compared to 0 times; ★ significant dimensional change between the two-time intervals

Discussion

The results of this study showed that the three tested solutions (1% NaOCL, 2% CHX, and solution of Kin tablets) reflected similar dimensional effect at all tested time intervals as water (control). This is mainly because the tested cleansers are the basic solution, which subsequently behaves like water. The most important consequence of water sorption is forced the resin macromolecules apart, which lead to the dimensional changes[26-29].

Till three days of immersion (9 immersion cycles), there was no effect from solutions absorption on linear dimensions, as insignificant saturation was mainly recorded with water, NaOCL, and CHX. Whereas in Kin solution, an insignificant shrinkage was recorded in some measured lines compared to 0-time dimensions.

Long EF line (40.5mm) records a lesser % expansion than a short AC line (15mm). This finding denoted either to the fact that the shrinkage due to polymerization reaction, being more accentuated in the posterior region of the palate[30], or could relate to the fact that high palate denture bases (which current study bases were) demonstrate a smaller dimensional change in posterior palatal seal area[31].

Another interesting finding recorded was the shrinkage of the posterior diagonal DF line. Such a finding is confusing and difficult to explain. Normally when denture bases immersed in solutions and absorbed water, an expansion rather than shrinkage should occur [27-29]. Whereas, shrinkage normally happened when samples faced dry condition[32,33]. The DF reduction in dimension mainly attributed to the shape of the tested area, which exhibited a U-shaped area. The expansion of this area push the U-shape bottom vertically, and the open end inward horizontally, thus reducing the distance between point D and F. Other causes might be related to the palate shape[31], thickness, approximation to the posterior palatal seal area.

Of the three measured dimensions, NaOCL reflected the lowest value of dimensional changes. It was an insignificant effect in the anterior transverse line (AC), and in the posterior diagonal line (DF). This counteracts the result of Basavanna[20], who stated that disinfection with 1% NaOCL induced the highest linear expansion after 12h of immersion. On the other hand, Kin registered the highest value in the majority of lines. CHX could be considered having a moderate effect (equal more or less to other cleansers among the measured lines).

Cleansers had a better effect on dimension than water in AC, BD, and DF (with NaOCL reflect the best insignificant effect). Nevertheless, they showed an approximately similar effect to water in EF and BE. The alterations in cleansers' effect could due to their chemical composition, pH changes, and viscosity of liquids[34].

In a previous study[35], the saturation for de-flasking shrinkage continued till 30 days of immersion, afterward the specimen begun to expand. However, in current study samples, a saturation state was achieved at 10D of immersion (30 cleansers immersion cycles), and the dimensions become stable and constant till the end of 2M of immersion (180 cleansers immersion cycles). All values between these two-time intervals were insignificant. The dimensional effect of Kin in an anterior diagonal line (BD) was the only one that required more time to get stability as a significant value registered at the end of 2M than at 10D.

Our results indicate that researchers need to establish other testing methods to define ideal cleansers that would be acceptable for long term clinical use.

Conclusions

Based on the findings of this observational in-vitro study, the following conclusions were drawn:

- At all time intervals, denture cleanser solutions induced dimensional linear changes similar to the effect of water in all examined measurements.
- No ideal cleanser could be detected—all denture cleanser solutions, including water, induced linear expansion of the specimens. However, disinfectants 1% NaOCL induced least dimensional change followed by CHX and Kin in restricted areas and specific immersion time of denture base. Nonetheless, water-induced the highest effect.
- The long time cleansers' immersion had the same effect on the dimension as the short time effect.
- Linear dimensional measurement alone will be unable to identify different dimensional changes, especially in complex denture base shape. The percentages of diagonal dimensional changes were higher than the transverse measurement changes.

References

1. Moreira R da S, Nico LS, Tomita NE, Ruiz T. Oral health of Brazilian elderly: a systematic review of epidemiologic status and dental care access. Cad Saude Publica. 2005;21(6):1665-75.
2. Ajay R, Suma K, Ali S. Monomer modifications of denture base acrylic resin: A systematic review and meta-analysis. J Pharm Bioallied Sci. 2019;11(suppl 2):S112-25.
3. Powers, JM, Sakaguchi, RL Craig RG. Fundemental of material science. In Ronald L. Sakaguchi, John M. Powers, Philadelphia P, editors. Craig's restorative dental materials. 13 ed. Elsevier/Mosby;2012. 34-70.
4. Al-Kaisy N, Saddq TH, Raouf LL. Assessment of denture hygiene habits among complete denture wearers attending Sulaimani Dental School. Sulaimani Dent J. 2016;3(2):69-76.
5. Peracini A, Davi LR, de Queiroz Ribeiro N, de Souza RF, da Silva CHL, de Freitas Oliveira Paranhos H. Effect of denture cleansers on physical properties of heat-polymerized acrylic resin. J Prosthodont Res. 2010;54(2):78-83.
6. Budtz-Jørgensen E. Materials and methods for cleaning dentures. J Prosthet Dent. 1979;42(6):619-23.
7. Nicholson RJ, Stark MM, Scott HE. Calculus and stain removal from acrylic resin dentures. J Prosthet Dent. 1968;20(4):326-9.
8. Paranhos H de FO, da Silva CHL, Venezian GC, Macedo LD, de Souza RF. Distribution of biofilm on internal and external surfaces of upper complete dentures: the effect of hygiene instruction. Gerodontology. 2007;24(3):162-8.
9. Buergers R, Rosentritt M, Schneider-Brachert W, Behr M, Handel G, Hahnel S. Efficacy of denture disinfection methods in controlling Candida albicans colonization in vitro. Acta Odontol Scand. 2008; 66(3):174-80.
10. Abelson DC. Denture plaque and denture cleansers. J Prosthet Dent. 1981;45(4):376–9.
11. Felipucci DNB, Davi LR, Paranhos HFO, Bezzon OL, Silva RF, Pagnano VO. Effect of different cleansers on the surface of removable partial denture. Braz Dent J. 2011;22(5):392-7.
12. Pisani MX, Da Silva CHL, De Freitas Oliveira Paranhos H, Souza RF, Macedo AP. The effect of experimental denture cleanser solution ricinus communis on acrylic resin properties. Mater Res. 2010;13(3):369-73.
13. Ganzarolli SM, Rached RN, Garcia RCMR, Del Bel Cury AA. Effect of cooling procedure on final denture base adaptation. J Oral Rehabil. 2002;29(8):787-90
14. Cakan U, Kara O, Kara HB. Effects of various denture cleansers on surface roughness of hard permanent reline resins. Dent Mater J. 2015;34(2):246-51.
15. Paranhos H de FO, Peracini A, Pisani MX, Oliveira V de C, souza RF de, Silva-Lovato CH. Color stability, surface roughness and flexural strength of an acrylic resin submitted to simulated overnight immersion in denture cleansers. Braz Dent J. 2013;24(2):152-6.
16. Sato S, Cavalcante MRS, Orsi IA, Paranhos HDFO, Zaniquelli O. Assessment of flexural strength and color alteration of heat-polymerized acrylic resins after simulated use of denture cleansers. Braz Dent J. 2005;16(2):124-8.

17. Pavarina AC, Machado AL, Giampaolo ET, Vergani CE. Effects of chemical disinfectants on the transverse strength of denture base acrylic resins. J Oral Rehabil. 2003;30(11):1085-9.
18. Hong G, Murata H, Li YA, Sadamori S, Hamada T. Influence of denture cleansers on the color stability of three types of denture base acrylic resin. J Prosthet Dent. 2009;101(3):205-13.
19. Aziz HK. Effect of myrtus communis solution as denture cleaning on the some properties of heat cured acrylic denture base material. J Univ Kerbala. 2017;15(2):250–8.
20. Basavanna JM. Effects of laboratory disinfecting agents on dimensional stability of three commercially available heat-cured denture acrylic resins in india: An in-vitro study. J Clin Diag Res. 2016;10(3):ZC27-31.
21. Polyzois GL, Zissis AJ, Yannihakis SA. The effect of glutaraldehyde and microwave disinfection on some properties of acrylic denture resin. Int J Prosthodont. 1995;8(2):150-4.
22. Nirale RM, Thombre R, Kubasad G. Comparative evaluation of sodium hypochlorite and microwave disinfection on dimensional stability of denture bases. J Adv Prosthodont. 2012;4(1):24-9.
23. Davi LR, Peracini A, De Queiroz Ribeiro N, Soares RB, Da Silva CHL, De Freitas Oliveira Paranhos H, et al. Effect of the physical properties of acrylic resin of overnight immersion in sodium hypochlorite solution. Gerodontology. 2010;27(4)297-302.
24. Paranhos H de FO, Peracini A, Pisani MX, Oliveira V de C, souza RF de, Silva-Lovato CH. Color stability, surface roughness and flexural strength of an acrylic resin submitted to simulated overnight immersion in denture cleansers. Braz Dent J. 2013;24(2):152-6.
25. Schneider CA, Rasband WS, Eliceiri KW. NIH Image to ImageJ: 25 years of image analysis. Vol. 9, Nature Methods. 2012. p. 671–5.
26. Keenan PLJ, Radford DR, Clark RKF. Dimensional change in complete dentures fabricated by injection molding and microwave processing. J Prosthet Dent. 2003;89(1):37-44.
27. Cheng YY, Chow TW, Ladizesky NH. Denture base resin reinforced with high-performance polyethylene fiber: water sorption and dimensional changes during immersion. J Macromol Sci Part B. 1993;32(4):433-81.
28. Tsuboi A, Ozawa K, Watanabe M. Water absorption characteristics of two types of acrylic resin obturators. J Prosthet Dent. 2005;94(4):382-8.
29. Ristic B, Carr L. Water sorption by denture acrylic resin and consequent changes in vertical dimension. J Prosthet Dent. 1987;58(6):689-93.
30. Compagnoni MA, Barbosa DB, De Souza RF, Pero AC. The effect of polymerization cycles on porosity of microwave-processed denture base resin. J Prosthet Dent. 2004;91(3):281-5.
31. Sykora O, Sutow EJ. Posterior palatal seal adaptation: influence of processing technique, palate shape and immersion. J Oral Rehabil. 1993;20(1):19-31.
32. Lim SR, Lee JS. Three dimensional deformation of dry-stored complete denture base at room temperature. J Adv Prosthodont. 2016;8(4):296-303.
33. Peyton FA, Mann WR. Acrylic and acrylic-styrene resins: their properties in relation to their uses as restorative materials. J Am Dent Assoc. 1942;29(15):1852-64.
34. Wilson J. The aetiology, diagnosis and management of denture stomatitis. Br Dent J. 1998;185(8):380-4.
35. Anderson GC, Schulte JK, Arnold TG. Dimensional stability of injection and conventional processing of denture base acrylic resin. J Prosthet Dent. 1988;60(3):394-8.