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Original research

Effect of beverages, denture cleanser and chlorhexidine gluconate on surface roughness of flexible denture base material: an in vitro study

Sneha Saraf[1], Sunil Kumar Mishra[2], Benaiffer Agrawal[3]

Purpose

The purpose of the study was to evaluate and compare the effect of beverages, denture cleanser and chlorhexidine gluconate solution on surface roughness of flexible denture base material.

Materials and Methods

Fifty flexible denture base resin specimens measuring 50±1mm in diameter and 0.5±0.05 mm in thickness were fabricated. The specimens were divided into five groups each containing ten specimens. The specimens were immersed in distilled water (Control group A); hot coffee (Group B); cold beverage (Group C); sodium perborate containing denture cleanser (Group D) and 2% chlorhexidine gluconate solution (Group E). The specimens were immersed for 10 min daily in mentioned solutions for up to 60 days. Surface roughness (Ra) was evaluated on the 1st, 20th and 60th day with the help of atomic force microscope. The statistical analysis was done using two-way ANOVA and Tukey's Post hoc test.

Results

The two- way ANOVA revealed that the average Ra values varied significantly depending on the type of solution used for immersion ($p<0.001$) and the duration of immersion ($p<0.001$). Variation in surface roughness with cold beverage was highest ($p=0.001$). On the 60th day the surface roughness of flexible denture base resin material was higher with cold beverage (0.184 µm) and denture cleanser (0.203 µm) than that of distilled water (0.052 µm) hot coffee (0.030 µm) and 2% chlorhexidine gluconate (0.068 µm).

Conclusion

Exposure to cold beverage, which was acidic in nature and peroxide containing denture cleanser, produces much rougher surface in the thermoplastic polyamide flexible denture base resin specimens.

Keywords: *Biofilm, flexible denture, polyamide, polymethylmethacrylate, surface roughness*

Introduction

Until now, up to 95% dental prostheses were made with polymethyl meythacrylate (PMMA), because of its optical properties, biocompatibility, and aesthetics (1). To overcome the widely known limitations of PMMA like shrinkage during polymerization, less flexural strength, inferior resistance to wear and allergy to monomer, polyamide resin have been used as an alternative material. Polyamide is the polymers having thermoplastic nature, manufactured with condensation reaction among dibasic acid and diamine (2,3).

Removable partial dentures (RPDs) fabricated only with thermoplastic resin or in combination with metal is attaining greater acceptance among

ORCID IDs of the authors: S.S. 0000-0002-2582-3623; S.K.M. 0000-0003-4844-1844; B.A. 0000-0002-2117-8890

[1]Senior Lecturer, Department of Prosthodontics, Pacific Dental College, Udaipur, Rajasthan, India

[2]Department of Dentistry, Autonomous State Medical College, Kushinagar, Uttar Pradesh, India

[3]Consultant Prosthodontist and Implantologist, Agrawal Dental Clinic and Research Centre, Bhopal, Madhya Pradesh, India

Corresponding Author: Sunil Kumar Mishra

E-mail: sunilmsr200@yahoo.co.in

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general dentists. It has good esthetics and improved comfort, so regarded as a better treatment modality compared to regular metallic clasp retained RPDs (4). Researches on denture base materials have showed a straight connection between the roughness of the surface and increase in collection of plaque and adhesion of *Candida albicans* over it. Surface roughness is a matter of concern to any denture base material and must be evaluated. Literatures have considered 0.2μm roughness of surface as a threshold level for dental restorations. (5-7).

Previously, studies were done on erosive outcome of soft drinks, coffee, red wine, freshly prepared fruit juices and denture-cleansing agents, to found the roughness occurred on the surface of regularly used dental restorations. It has been found that restorative materials showed statistically significant micro-leakage and surface roughness as the immersion regime increased (8-14). Surface topography is done to find the appropriateness of surface for a particular use. (15). For measuring surface roughness, scanning electron microscopy and profilometery were the methods being commonly used (16). Atomic force microscopy (AFM) is a primary form of scanning probe microscopy (17). Data regarding use of AFM in field of prosthodontics for studying surface topography of denture base resins in all 3 dimensions i.e. x, y and z directions with nanoscale resolution is scarce.

The basis for doing this research was to evaluate the surface roughness caused by using beverages, denture cleanser and 2% chlorhexidine gluconate solution on flexible denture base material using AFM. The null hypothesis assumed that there would be no variance in surface roughness of flexible denture base material with beverages, denture cleanser and 2% chlorhexidine gluconate solution.

Materials and Methods

Ethical approval

This study was performed in the Department of Prosthodontics. The ethical clearance was acquired from the institutional ethical committee number PDA/Dean/14/90A..

Specimen Fabrication

Fifty flexible denture base resin (Lucitone FRS, Dentsply, Mumbai, India) specimens of dimensions 50±1mm in diameter and 0.5±0.05 mm in thickness were fabricated according to ADA specification No.12 by the injection molding method (18). A master model of hard plastic material with precise dimensions was used for the specimen fabrication (Figure 1A). Molten wax (DPI, Mumbai, India) was poured, allowed to solidify, and then retrieved from the mold. The obtained patterns in wax were further invested in a flask with dental stone (Kalrock, Kalabhai, Mumbai, India).

The flask was put for 5min in boiling water and dewaxing was done. A layer of separating media was coated and allowed for complete drying. Single cartridge (24gm) was used for making individual specimen. The silicone was sprayed on the cartridge, and then cartridge was kept in the carrier, and put in the electric furnace for softening. The material was allowed to plasticize at 575°F for about 15 minutes. The cartridge was remove from the furnace and position over the inlet of the flask, and compressed for 1 minute at an injection pressure of 75psi with narrow piston head. Bench cooling was done for 5min before deflasking (19). The flask was opened to recover the specimens. The sprue formers were cut with the disk and finishing was done. Initially the specimens were kept at 37^{0}C for 24 hours in distilled water for rehydration. The specimens were divided in to 5 groups, consisting of 10 specimens each. The groups were as follows:

Group A: Flexible denture base resin specimens immersed in distilled water (control group).

Group B: Flexible denture base resin specimen immersed in hot coffee (Nescafe, Nestle, Mumbai, India) at temperature 50±1 ^{0}C.

Group C: Flexible denture base resin specimen immersed in lime juice (Nimbooz, PepsiCo, New Delhi, India) at room temperature.

Group D: Flexible denture base resin specimen immersed in denture cleansing solution (Fitty Dent, Group Pharmaceuticals, Mumbai, India)

Group E: Flexible denture base resin specimen immersed in 2% chlorhexidine gluconate solution (Safe Plus, Neelkanth enterprises, New Delhi, India)

All the finished specimens were stored in artificial saliva (MP Sai enterprises, Mumbai, India) in an incubator at 37 ^{0}C for 14 hours daily. The stored specimens were taken out from the artificial saliva and cleaned in running water for 10 seconds, and bloated dry with tissue paper. All the specimens in each group were immersed in their respective solution for 10 minutes every day. The specimens were removed and washed in running water for 10 seconds and then stored in distilled water for the rest of the day at room temperature. The same regime was followed for 60 days.

Surface roughness

Surface roughness was checked on the 1st, 20th and 60th day. Prior to testing, the specimens were cleaned in an ultrasonic cleaner for 60 seconds, blotted dry using tissue paper and air dried with an air pressure pump. As per the requirement of the testing machine, the specimens were cut in to squares of 1cm x 1cm with the help of a diamond disc (Figure 1B). The baseline readings were obtained for the surface roughness (arithmetic mean surface roughness, Ra). The surface roughness was assessed using AFM (Solver Next NT-MDT, Moscow, Russia) (Figure 2).

The AFM provides a 3D profile on a nanoscale and 3 linear scans taken across individual specimens over 30 x 30 um fields with a scan rate of 10.03 mm/s and 300 pixel resolution.

Statistical analysis

Surface roughness data obtained was subjected to two-way analysis of variance (ANOVA) for repeated measures (before and after immersion and artificial aging) and Tukey's Post Hoc test ($p<0.05$). The factors analyzed were resin, surface treatment, artificial aging, surface roughness and their interactions. The results were analyzed using software package IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp, USA.

Results

The two-way ANOVA suggested that the average Ra values differs significantly based on the type of solution used for immersion ($p<0.001$) and duration of immersion ($p<0.001$) (Table 1). The null hypothesis was rejected. A gradual increase in the surface roughness was noted when comparison was done between 1st day, 20th day and 60th day of testing for the individual test group and the control group (Figure 3).

When the mean surface roughness values were compared on 1st day, 20th day and 60th day of 4 test groups and the control group, significant variations in surface roughness of Group B (hot coffee, P=0.022), Group C (cold beverage, P=0.001) and Group D (denture cleanser, P=0.013) was observed. On the 1st day, the flexible denture base resin material had more surface roughness with 2% chlorhexidine gluconate (0.057 µm) followed by distilled water (0.034 µm), hot coffee (0.023 µm) cold beverage (0.021 µm) and denture cleanser (0.019 µm). On the 20th day the surface roughness was more with 2% chlorhexidine gluconate (0.052 µm) followed by distilled water (0.045 µm), cold beverage (0.040

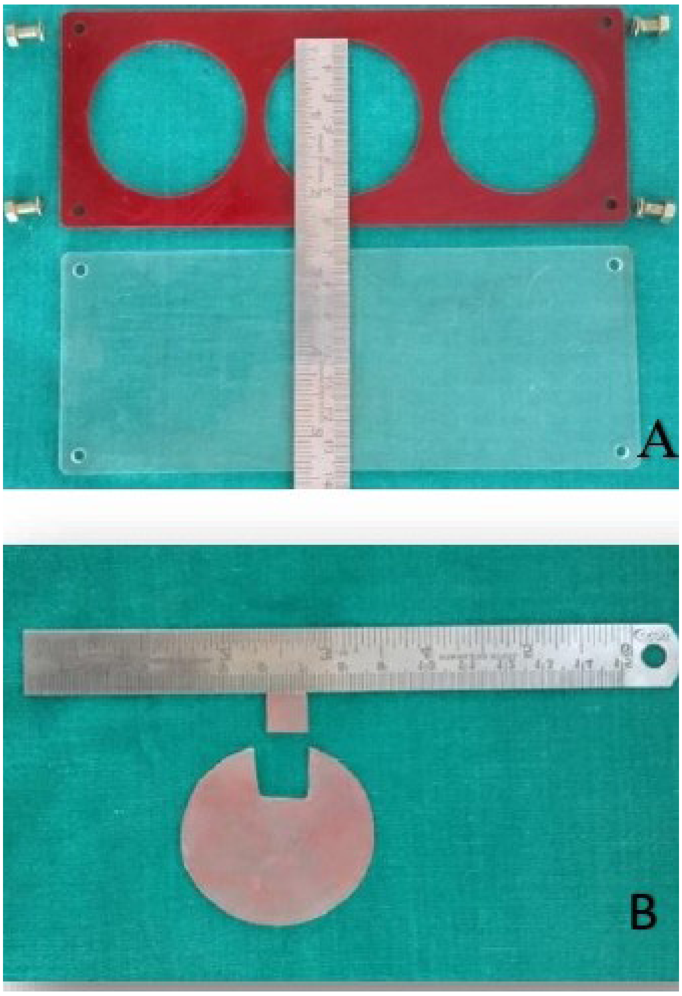

Figure 1. *A, Standardized mold for specimen fabrication. B, Specimens of size 1cm x 1cm x 0.5mm was used for testing.*

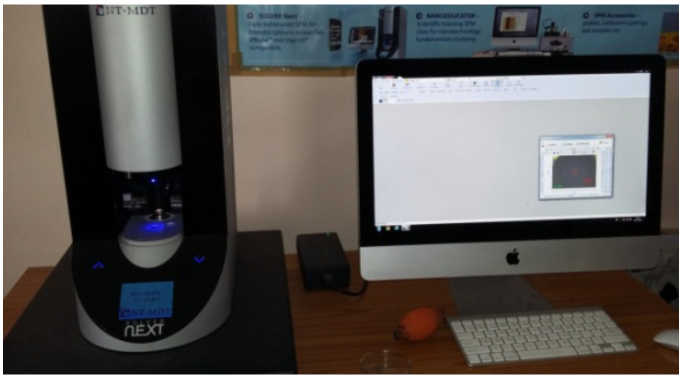

Figure 2. *Evaluation of surface roughness under atomic force microscope.*

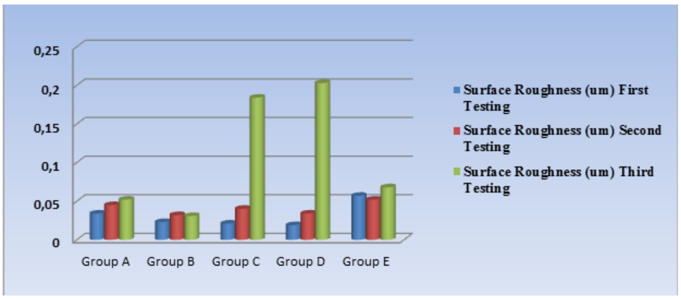

Figure 3. *Mean surface roughness on 1st day (first testing), 20th day (second testing) and 60th day (third testing)*

Table 1: *Mean surface roughness and two-way ANOVA for repeated measures on 1st day, 20th day and 60th day of immersion, *p value<0.05 was considered statistically significant. ANOVA=Analysis of variance*

Groups	Number of of specimens	Surface Roughness (µm)						Repeated measure ANOVA (F-value)	p-value
		1st day		20th day		60th day			
		Mean	S.D	Mean	S.D	Mean	S.D		
Distilled water (Group A)	10	0.034	0.005	0.045	0.021	0.052	0.036	2.444	0.152
Hot coffee (Group B)	10	0.023	0.006	0.032	0.007	0.030	0.004	7.565	0.022*
Cold beverage (Group C)	10	0.021	0.022	0.040	0.019	0.184	0.088	27.921	0.001*
Denture cleanser (Group D)	10	0.057	0.077	0.052	0.016	0.203	0.193	9.580	0.013*
2% chlorhexidine gluconate (Group E)	10	0.019	0.009	0.034	0.024	0.068	0.058	0.090	0.771
Total	50	0.031	0.037	0.041	0.019	0.108	0.120	16.958	0.001*

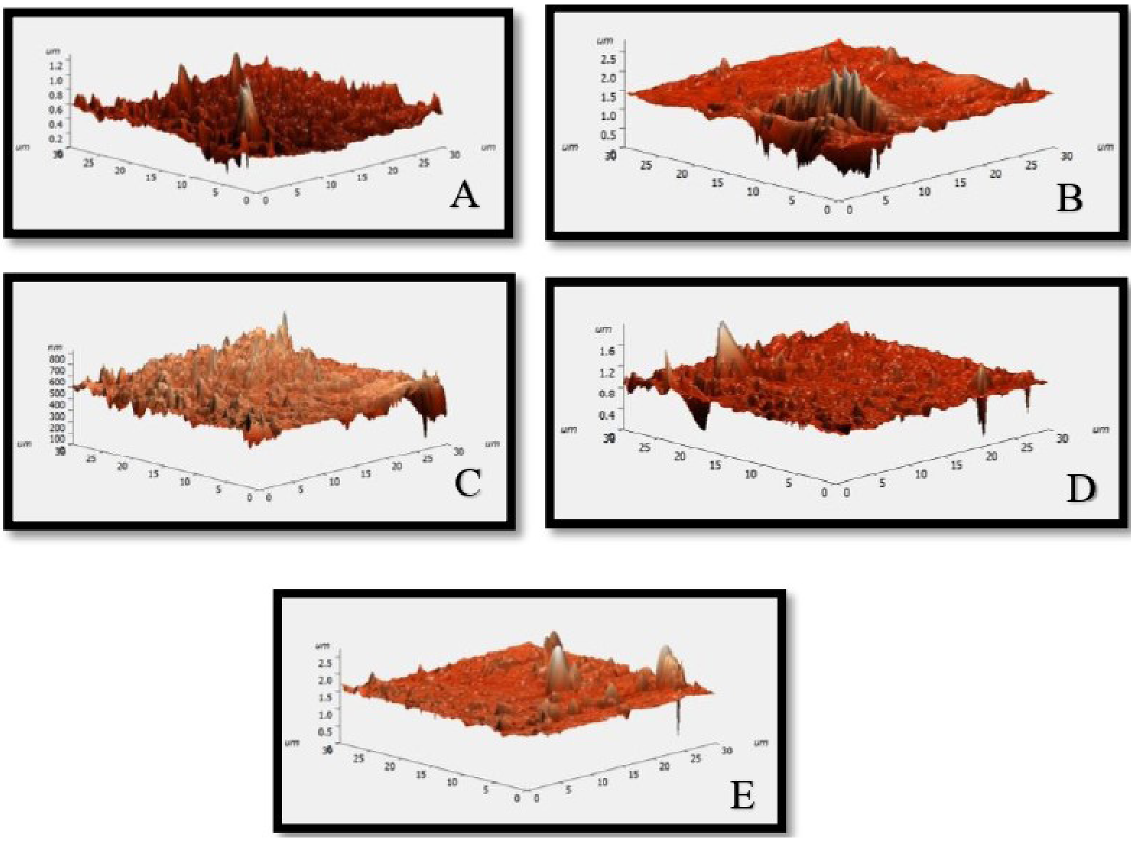

Figure 4. *Surface roughness on 60th day. A, with cold beverage. B, with denture cleanser. C, with distilled water. D, with hot coffee. E,*

Table 2: *Tukey's Post-hoc Analysis for pairwise comparisons on 1st day, 20th day and 60th day. *p value<0.05 was considered statistically significant; Ra= Surface roughness*

Groups	**1st day**		**20th day**		**60th day**	
	Mean Difference in Ra (µm)	**P value**	**Mean Difference in Ra (µm)**	**P value**	**Mean Difference in Ra (µm)**	**P value**
Distilled water (Group A) vs Hot coffee (Group B)	0.010	0.969	0.013	0.504	0.021	0.988
Distilled water (Group A) vs Cold beverage (Group C)	0.013	0.928	0.005	0.964	0.131	0.039*
Distilled water(Group A) vs Denture cleanser (Group D)	0.014	0.898	0.011	0.665	0.151	0.012*
Distilled water(Group A) vs 2% Chlorhexidine gluconate (Group E)	0.023	0.614	0.007	0.915	0.015	0.996
Hot coffee (Group B) vs Cold beverage (Group C)	0.002	1.000	0.007	0.879	0.153	0.011*
Hot coffee (Group B) vs Denture cleanser (Group D)	0.004	0.999	0.002	0.999	0.173	0.003*
Hot coffee (Group B) vs 2% Chlorhexidine gluconate (Group E)	0.033	0.255	0.020	0.122	0.037	0.917
Cold beverage (Group C) vs Denture cleanser (Group D)	0.001	1.000	0.005	0.959	0.019	0.992
Cold beverage (Group C) vs 2% Chlorhexidine gluconate (Group E)	0.036	0.187	0.012	0.565	0.116	0.089
Denture cleanser (Group D) vs 2% Chlorhexidine gluconate (Group E)	0.037	0.158	0.018	0.222	0.135	0.032*

µm), denture cleanser (0.034 µm) and hot coffee (0.032 µm). On the 60th day the surface roughness was more with cold beverage (0.184 µm; Figure 4A) and denture cleanser (0.203 µm; Figure 4B) than that of distilled water (0.052 µm; Figure 4C) hot coffee (0.030 µm; Figure 4D) and 2% chlorhexidine gluconate (0.068 µm; Figure 4E).

Pairwise comparison among groups on 1st day and 20th day did not showed any significant difference among the groups. Pairwise comparison among groups on 60th day showed significant difference (P<0.05) between distilled water (Group A) vs cold beverage (Group C) (P=0.039), between distilled water (Group A) vs denture cleanser (Group D) (P=0.012), hot coffee (Group B) vs cold beverage (Group C) (P=0.011), hot coffee (Group B) vs denture cleanser (Group D) (P=0.003) and denture cleanser (Group D) vs 2% chlorhexidine gluconate (Group E) (P=0.032) (Table 2).

Discussion

Polyamide material possesses good aesthetics, favorable gingival color, and toxicological safety in patients who are allergic to conventional resins and metals. It is flexible and has high strength, as well as resistance to chemicals and heat. Additionally, it has low porosity, low water absorption, and solubility. These properties have made polyamide increasingly popular as a denture base biomaterial (20,21).

Before applying dental prostheses orally, the surface roughness of the materials should be evaluated. A rough surface can lead to microbial colonization, biofilm formation, and discoloration of the prosthesis (22,23). In the present study, the specimens underwent artificial aging. The effect of artificial aging on the surface roughness of specimens immersed in distilled water (Control Group A) was found to be insignificant after 60 days of testing, when comparing Ra values of the 1st and 20th days. This result was similar to studies conducted by Pusz et al. (24) and Fueki *et al.* (4). Polyamide resins are injection-molded and supplied in a cartridge, which minimizes mixing errors. This provides long-term shape stability, less contraction, and improved resistance to aging (4,24).

In the present study, the surface roughness of the flexible denture base material was not significantly affected by the coffee solution (pH-5.3). This finding is consistent with the study by Navarro *et al.* (14). However, conflicting results were obtained in a study conducted by Sagsoz *et al.* (25), where an increase in surface roughness of resin specimens was observed due to extrinsic stain deposition. The discrepancy in results with coffee samples might be attributed to differences in the processing and polishing methods of the specimens. It has been proven that specimens fabricated using the injection-molded method have better physical and chemical stability compared to conventional heat and chemical processing methods (3,4).

The specimens immersed in the cold beverage Nimbooz (Group C) showed a significant alteration in surface roughness. According to a study by Constantinescu *et al.* (26), the acidity of saliva influences the surface properties of acrylic resins and increases roughness. Lemon juice, with a pH of about 2.3, is highly acidic, while the normal salivary pH ranges between 6.2 and 7.4. The type of food consumed can change the pH of saliva and cause erosion of the denture base materials' surface (27).

Considering the cleaning methods followed by patients, the resin specimens in this study were immersed in a commercially available denture cleanser and 2% chlorhexidine gluconate. The surface roughness of the specimens immersed in the denture cleansing solution increased with the duration of immersion. This result is consistent with previous studies conducted by Durkan *et al.* (28), where they also found that denture cleansers containing sodium perborate increased surface roughness. Nikawa *et al.* (29) found that denture cleansers with higher peroxide content and oxygenation levels in strongly alkaline solutions could damage denture base materials. This may be due to the chemical nature and mode of action of these cleansers. They reduce surface tension, release oxygen, and mechanically loosen debris. The oxygen bubbles aid in mechanical cleaning. Therefore, these cleansers may cause hydrolysis and decomposition of the polymerized acrylic resin itself (30).

The surface roughness of resin specimens immersed in a 2% chlorhexidine gluconate solution showed no significant variation after following a 60-day immersion regime. The result of the present study was similar to previous studies conducted by Da Silva *et al.* (31), Azevedo *et al.* (32), and Machado *et al.* (33). However, Davi *et al.* (30) obtained contradictory results in a study where they found a significant increase in surface roughness after disinfecting denture base resins with a 0.12% chlorhexidine gluconate solution. The composition of the flexible denture base resin material is chemically stable, as they are injection-molded and supplied in a cartridge, which excludes mixture errors. This provides long-term stability and resistance to aging and surface roughening (4).

One limitation of the present experiment is that it is an in-vitro study and does not completely simulate oral conditions. Further research is required with flexible dentures in patients using different beverages and denture cleansers.

Conclusion

Exposure to a cold beverage, which is more acidic in nature, and the use of peroxide-containing denture cleanser result in a much rougher surface in thermoplastic polyamide flexible denture base resin specimens. On the other hand, exposure to hot coffee does not cause a significant change in the surface roughness of the flexible denture base resin material. Therefore, 2% chlorhexidine gluconate can be considered a better option for maintaining the hygiene of flexible denture base resin material.

Türkçe özet: *İçeceklerin, protez temizleyicinin ve klorheksidin glukonatın esnek protez kaide malzemesinin yüzey pürüzlülüğüne etkisi: in vitro çalışma. Amaç: Bu çalışmanın amacı, esnek protez kaide malzemesinin yüzey pürüzlülüğüne içecek, protez temizleyici ve klorheksidin glukonat solüsyonunun etkisini değerlendirmek ve karşılaştırmaktı. Gereç ve yöntem: Çapı 50±1 mm ve kalınlığı 0.5±0.05 mm olan elli esnek protez kaide reçinesi örneği üretildi. Örnekler, her biri on örnek içeren beş gruba ayrıldı. Numuneler damıtılmış suya daldırıldı (Kontrol grubu A); sıcak kahve (Grup B); soğuk içecek (Grup C); protez temizleyici (Grup D) ve %2 klorheksidin glukonat solüsyonu (Grup E) içeren sodyum perborat. Numuneler, 60 güne kadar belirtilen çözeltilerde günde 10 dakika süreyle daldırıldı. Yüzey pürüzlülüğü (Ra) atomik kuvvet mikroskobu yardımıyla 1, 20. ve 60. günlerde değerlendirildi. İstatistiksel analiz, iki yönlü ANOVA ve Tukey's Post hoc testi kullanılarak yapıldı. Bulgular: İki yönlü ANOVA, ortalama Ra değerlerinin daldırma için kullanılan solüsyon tipine (p<0.001) ve daldırma süresine (p<0.001) bağlı olarak önemli ölçüde değiştiğini ortaya koydu. Soğuk içecek ile yüzey pürüzlülüğündeki değişim en yüksekti (p=0.001). 60. günde, esnek protez kaide reçine malzemesinin yüzey pürüzlülüğü, soğuk içecek (0.184 µm) ve protez temizleyici (0.203 µm) ile, damıtılmış su (0.052 µm), sıcak kahve (0.030 µm) ve %2 klorheksidin glukonat (0,068 mikron). Sonuç:*

Doğası gereği asidik olan soğuk içeceğe ve peroksit içeren protez temizleyiciye maruz kalmak, termoplastik poliamid esnek protez kaidesi rezin numunelerinde çok daha pürüzlü bir yüzey oluşturur. Anahtar Kelimeler: biyofilm, esnek protez, poliamid, polimetilmetakrilat, yüzey pürüzlülüğü

Ethics Committee Approval: The ethical approval was obtained from the institutional ethics committee number PDA/Dean/14/90A.

Informed Consent: Participants provided informed consent.

Peer-review: Externally peer-reviewed.

Author contributions: SS, SKM, BA participated in designing the study. SS, SKM, BA participated in generating the data for the study. SS, SKM participated in gathering the data for the study. SS, SKM, BA participated in the analysis of the data. SS, SKM, BA wrote the majority of the original draft of the paper. SS, SKM, BA participated in writing the paper. SS has had access to all of the raw data of the study. SS, SKM, BA has reviewed the pertinent raw data on which the results and conclusions of this study are based. SS, SKM, BA have approved the final version of this paper. SKM guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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References

1. Tanoglu M, Ergun Y. Porous nanocomposites prepared from layered clay and PMMA [poly (methyl methacrylate)].Composites Part A: Appl Sci Manufact 2007;38:318-22. [CrossRef]
2. Vojdani M, Giti R. Polyamide as a denture base material: a literature review. J Dent(Shiraz) 2015; 16:1-9.
3. Singh JP, Dhiman RK, Bedi RP, Girish SH. Flexible denture base material: a viable alternative to conventional acrylic denture base material. Contemp Clin Dent 2011;2:313-17. [CrossRef]
4. Fueki K, Ohkubo C, Yatabe M, Arakawa I, Arita M, Ino S, et al. Clinical application of removable partial dentures using thermoplastic resin-Part I: Definition and indication of non-metal clasp dentures. J Prosthodont Res 2014;58:3-10. [CrossRef]
5. Abuzar MA, Bellur S, Duong N, Kim BB, Lu P, Palfreyman N,et al. Evaluating surface roughness of a polyamide denture base material in comparison with poly (methyl methacrylate). J Oral Sci 2010;52:577-81. [CrossRef]
6. Paranhos HFO, Silva-Lovato CH, Souza RF, Cruz PC, Freitas KM, Peracini A. Effects of mechanical and chemical methods on denture biofilm accumulation. J Oral Rehab 2007;34:606-12. [CrossRef]
7. Schwindling FS, Rammelsberg P, Stober T. Effect of chemical disinfection on the surface roughness of hard denture base materials: a systematic literature review. Int J Prosthodont 2014;27-215-25. [CrossRef]
8. Bansal K, Acharya SR, Saraswathi V. Effect of alcoholic and non-alcoholic beverages on color stability and surface roughness of resin composites: An in vitro study. J Conserv Dentistry 2012; 15:283-8. [CrossRef]
9. Senna PM, Vieira AP, Sotto-Maior BS, Silva WJ, Del Bel Cury AA. Influence of immersion time of denture cleansers on the surface roughness of resilient denture liners. Revista Odonto Ciência. 2011;26(1):35-9. [CrossRef]
10. Bajwa NK, Pathak A. Change in surface roughness of esthetic restorative materials after exposure to different immersion regimes in a cola drink. ISRN dentistry 2014;2014:353926. [CrossRef]
11. Poggio C, Dagna A, Chiesa M, Colombo M, Scribante A. Surface roughness of flowable resin composites eroded by acidic and alcoholic drinks. J Conservative Dent 2012;15:137-40. [CrossRef]
12. Maganur PC, Prabhakar AR, Satish V, Namineni S, Kurthukoti A. Erosive effect of soft drink and fresh fruit juice on restorative materials. World J Dent 2013;4:32-40. [CrossRef]
13. de Gouvea CV, Bedran LM, de Faria MA, Cunha-Ferreira N. Surface roughness and translucency of resin composites after immersion in coffee and soft drink. Acta Odontol Latinoam. 2011; 24:3-7.
14. Sepúlveda-Navarro WF, Arana-Correa BE, Ferreira Borges CP, Habib Jorge J, Urban VM, Campanha NH. Color stability of resins and nylon as denture base material in beverages. J Prosthodont 2011;20:632-8. [CrossRef]
15. Pradhan S, Mathuriya S, Sonkesriya S, Maheshwari A, Gaur G, Choubey A. Evaluation of surface topography of heat cure acrylic denture-base resin before and after reinforcement with different fibers using stylus-based profilometer. J Contemp Dent Pract 2022;23:415-8. [CrossRef]
16. Alfouzan AF, Alotiabi HM, Labban N, Al-Otaibi HN, Al Taweel SM, AlShehri HA. Effect of aging and mechanical brushing on surface roughness of 3D printed denture resins: A profilometer and scanning electron microscopy analysis. Technol Health Care 2022;30:161-73. [CrossRef]
17. Ilieva T, Karova E. Application of Atomic Force Microscopy in Dental Investigations. Int J Sci Res 2020;9:1319-26.
18. Revised American Dental Association specification no.12 for denture base polymers. J Am Dent Assoc 1975;90:451-8. [CrossRef]
19. Singh K, Gupta N. Injection molding technique for fabrication of flexible prosthesis from flexible thermoplastic denture base materials. World J Dent 2012;3:303-7 [CrossRef]
20. Ucar Y, Akova T, Aysan I. Mechanical properties of polyamide versus different PMMA denture base materials. J Prosthodont 2012;21:173-6. [CrossRef]
21. Hamanaka I, Takahashi Y, Shimizu H. Mechanical properties of injection-molded thermoplastic denture base resins. Acta Odontol Scand 2011;69:75-9. [CrossRef]
22. Bollenl CM, Lambrechts P, Quirynen M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. Dent Mater 1997;13:258-69. [CrossRef]
23. Tari FB, Nalbant D, Dogruman Al F, Kustimur S. Surface roughness and adherence of candida albicans on soft lining materials as influenced by accelerated ageing. J Contemp Dent Pract 2007;8:18-25. [CrossRef]
24. Pusz A, Szymiczek M, Michalik K. Ageing process influence on mechanical properties of polyamide-glass composites applied in dentistry. J Achiev Mater Manufact Eng 2010;38:49-55.
25. Sagsoz NP, Yanıkoglu N, Ulu H, Bayındır F. Color changes of polyamid and polymetyhl methacrylate denture base materials. Open J Stomatol 2014;4:489-96. [CrossRef]
26. Constantinescu IR, Ursache M, Mardarez D. Effect of pH on the surface roughness of heat cured denture base acrylic resins. Rev Med Chir Soc Med Nat Iasi 2007;111:477-81.
27. Abdul-Razaq RW. The effect of thermocycling and different pH of artificial saliva on the impact and transverse strength of heat cure resin reinforced with silanated ZrO2 nano-fillers. J Bagh Coll Dent 2013;25(Special Is):12-7. [CrossRef]
28. Durkan R, Ayaz EA, Bagis B, Gurbuz A, Ozturk N, Korkmaz FM. Comparative effects of denture cleansers on physical properties of polyamide and polymethyl methacrylate base polymers. Dent Mater J 2013;32:367-75. [CrossRef]
29. Nikawa H, Hamada T, Yamashiro H, Kumagai H. A review of in vitro and in vivo methods to evaluate the efficacy of denture cleansers. Int J Prosthodont 1998;12:153-9.
30. Davi LR, Felipucci DNB, de Souza RF, Bezzon OL, Lovato-Silva CH, Pagnano VO, et al. Effect of denture cleansers on metal ion release and surface roughness of denture base materials. Braz Dent J 2012;23:387-93. [CrossRef]

31. da Silva FC, Kimpara ET, Mancini MNG, Balducci I, Jorge AOC, Koga-Ito CY. Effectiveness of six different disinfectants on removing five microbial species and effects on the topographic characteristics of acrylic resin. J Prosthodont 2008;17:627-33. [CrossRef]
32. Azevedo A, Machado AL, Vergani CE, Giampaolo ET, Pavarina AC, Magnani R. Effect of disinfectants on the hardness and roughness of reline acrylic resins. J Prosthodont 2006;15:235-42. [CrossRef]
33. Machado AL, Giampaolo ET, Pavarina AC, Jorge JH, Vergani CE. Surface roughness of denture base and reline materials after disinfection by immersion in chlorhexidine or microwave irradiation. Gerodontology 2012;29:e375-82. [CrossRef]