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Investigation of the Effect of Denture Cleaning Solutions on Surface Hardness and Surface Roughness of Soft Lining Materials

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ABSTRACT

Aim: The purpose of this study is to investigate the effects of commercial and non-commercial agents used to clean dentures on the surface roughness and hardness of two soft lining materials.

Material and Methods: A total of 50 samples were used in this study. Samples were prepared from acrylic resin (Visco Gel) and silicone-based (Molloplast B) soft lining materials. The samples' roughness and hardness values were measured. After the samples were kept in distilled water, white vinegar, denture cleanser tablet, 2% chlorhexidine gluconate, and 5% sodium hypochlorite for 15 minutes, 30 minutes, 45 minutes, 60 minutes, 2 hours, 8 hours, 24 hours, and 48 hours, roughness and hardness values were measured again. Statistical analysis was performed using the computer program SPSS Statistics 20.0 (SPSS Inc. Chicago, IL, USA) at a 95% confidence interval and p=0.05 significance level. Three-way ANOVA and Tukey's multiple comparison tests were used for the statistical analysis of data.

Results: The analysis of variance determined that the material type and time had a very significant effect ($p<.001$) on surface roughness and hardness values, while the solutions in which samples were kept had an insignificant effect ($p>.05$).

Conclusion: The surface roughness and hardness of acrylic resin and silicone-based soft lining materials were affected by denture cleaning solutions to different extents.

Protez Temizleyici Solüsyonlarının Yumuşak Astar Maddelerinin Yüzey Sertliği ve Yüzey Pürüzlülüğüne Etkisinin İncelenmesi

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ÖZET

Amaç: Bu çalışmanın amacı, protezlerin temizlenmesi amacıyla kullanılan ticari ve ticari olmayan ajanların iki farklı yumuşak astar materyalinin yüzey pürüzlülüğü ve sertliğine etkisinin incelenmesidir.

Gereç ve Yöntemler: Bu çalışmada akrilik rezin (Visco Gel) ve silikon esaslı (Molloplast B) yumuşak astar materyallerinden toplam 50 adet örnek hazırlandı. Örneklerin pürüzlülük ve sertlik değerleri ölçüldü. Örnekler distile su, beyaz sirke, protez temizleyici tablet, %2 klorheksidin glukonat ve %5 sodyum hipoklorit te 15 dakika, 30 dakika, 45 dakika, 60 dakika, 2 saat, 8 saat, 24 saat ve 48 saat bekletildikten sonra pürüzlülük ve sertlik değerleri tekrar ölçüldü. İstatiksel analiz %95 güven aralığında ve p=0,05 anlamlılık düzeyinde SPSS Statistics 20.0 (SPSS Inc. Chicago, IL, ABD) bilgisayar programı kullanılarak yapıldı. Verilerin istatiksel analizinde üç yönlü ANOVA ve Tukey çoklu karşılaştırma testleri kullanıldı.

Bulgular: Yapılan varyans analizleri sonucunda; yüzey pürüzlülük ve sertlik değerleri üzerinde materyal türünün ve zamanın çok anlamlı ($p<,001$), bekletilen solüsyonların anlamsız ($p>,05$) olduğu belirlendi.

Sonuç: Akrilik rezin ve silikon esaslı yumuşak astar materyallerinin yüzey pürüzlülüğü ve sertliği protez temizleme solüsyonlarından farklı miktarlarda etkilenmiştir.

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INTRODUCTION

Among the primary issues with removable dentures is the disrupted compatibility between the mucosa and the denture base plate. The disruption of this compatibility adversely affects the denture's stability and retention, causing a reduction in a patient's chewing function.[1] Pain may occur due to the compression of the mucosa between the alveolar bone and the denture base plate due to impacts during chewing. In such cases, the denture is completely renewed or made compatible by performing lining between tissues and the base plate.[2] Soft lining materials are defined as polymers applied to dentures' tissue surfaces to balance forces and reduce the force in atrophied areas in complete and removable partial dentures.[3] These days, commonly used soft lining materials are categorized into two types based on their content: silicone-based and acrylic resin-based.[4,5] Depending on polymerization methods, soft lining materials are divided into four groups: autopolymerized, heat-polymerized, light-polymerized, and microwave-polymerized. Autopolymerized soft liners can be used temporarily for two to six weeks, whereas heat-polymerized types can be used permanently for six months to five years.[6] The architecture of soft lining materials, characterized by their textured surfaces, promotes the adhesion and proliferation of oral microorganisms.[7,8] Denture hygiene is extremely important since patients use dentures during the day and dentures are in constant contact with the oral environment containing diverse microorganisms.[9] The elevated microbial burden present on dentures contributes significantly to the heightened occurrence of oral complications, such as denture stomatitis and inflammatory papillary hyperplasia.[10] Since plaque formation is the main factor in the etiology of denture stomatitis, it is essential to ensure effective plaque control on the surface of soft lining materials.[11] Toothbrush or denture cleaning solutions are preferred for plaque control. It is recommended to use denture cleansers because mechanical cleaning with a toothbrush may damage a soft lining material.[12] According to their content, denture cleaning solutions can be classified into alkaline hypochlorites, disinfectants, alkaline peroxides, acids, and enzymes.[13] Denture cleansers that patients use prevent the formation of fungal and bacterial infections that typically cause denture-related stomatitis.[14] Various effervescent denture cleansers are available on the market in tablet or powder form.[15] Denture cleanser tablet, with the trade name Corega, is a commonly used denture cleanser.[16] Corega denture cleanser can remove light stains from denture bases and loosen residues.[17] Although denture cleansers are used routinely, they can impact the color stability, surface hardness, and surface roughness of denture base materials.[15,18] Sodium hypochlorite (NaOCl) is an effective disinfecting agent usually utilized as a denture cleanser. It has been demonstrated that, due to its bactericidal and fungicidal properties, sodium hypochlorite can decrease the organic matrix in biofilms and help remove stains when utilized as an overnight immersion solution.[18,19] Effective results were achieved for plaque formation on denture surfaces with a 0.2% concentration of chlorhexidine gluconate.[20] Vinegar is an easily available household cleaning product with an affordable price and low toxicity in comparison with other solutions. Vinegar is essentially a 6-13% weak acetic acid that only partially dissociates in aqueous solutions.[10] White vinegar is often utilized at concentrations of 50% and 100% to disinfect toothbrushes and denture bases.[10] Da Silva et al.[21] and Yildirim-Bicer et al.[22] It is recommended to employ a 100% vinegar solution for a duration of 10 minutes as a denture disinfection method, particularly effective against Candida albicans.

The increased hardness of soft lining materials is at the forefront among the various physical properties that may be impacted by using denture cleaning materials because the increased hardness of soft lining materials is an important factor that leads to clinical failure.

The desired shock absorption property disappears with the increased hardness. The influence of cleansers on the surface roughness of soft lining materials represents a critical determinant that may influence the adherence of microorganisms, consequently exacerbating oral complications.[23]

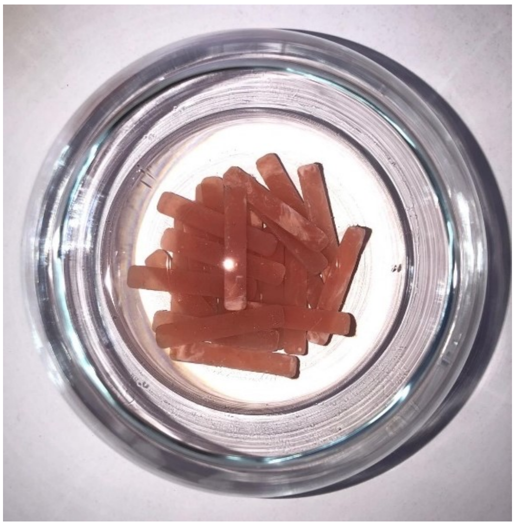
The present study was conducted to investigate the effects of commercial and non-commercial agents used to clean dentures on the surface microhardness and roughness of two soft lining materials.

The study's null hypothesis is that denture cleaning solutions will increase the surface roughness and hardness of two different soft lining materials over time. The alternative hypothesis was created as follows: for both soft lining groups, surface roughness and hardness will increase with the increased storage duration in solutions.

MATERIAL AND METHODS

The present study used Visco Gel (Dentsply Ltd., De Trey Division, Weybridge, UK) as an acrylic resin-based soft lining material and Molloplast B (Detax Karl Huber GmbH, Ettlingen, Germany) as a silicone-based soft lining material and used white vinegar (Bizim Vatan, Türkiye), denture cleanser tablet (Corega, GlaxoSmithKline, London, UK), 2% chlorhexidine gluconate (Microvem, Türkiye), 5% sodium hypochlorite (Microvem, Türkiye), and distilled water as denture cleansers. A total of 50 samples (25 from the acrylic resin-based and 25 from the silicone-based soft lining material) were prepared with the dimensions 65 mm x 10 mm x 3 mm using a metal mold in line with the standard ISO 1567[24]. The dimensions can be seen in the image showing a part of the silicone-based samples in Figure 1. Acrylic resin-based materials were formed by cold curing in specially prepared metal molds without applying any heat treatment. Silicone-based materials were obtained by placing them in a specially prepared metal mold and boiling them**.** Silicone-based soft lining materials were placed in cold water in a specially prepared metal mold, slowly heated to 100°C, and boiled for 2 hours. The samples were allowed to reach room temperature and then were removed from the metal mold. After smoothing the samples' surface with 600 grit sandpaper, they were polished with a pumice brush for 15 seconds. To ensure that residual monomers were removed, all specimens were immersed in distilled water maintained at a temperature of 37°C for a duration of 48 hours. Surface microhardness and roughness values were determined after the samples were allocated randomly into five groups (n=5), each comprising five specimens, and subsequently labeled with numerical identifiers. Following the immersion of the samples in distilled water**,** NaOCl at a ratio of 1:5, denture cleanser tablet, chlorhexidine gluconate water, and white vinegar, their surface microhardness and roughness values were measured. Measurements were made at the 15th, 30th, 45th, and 60th minutes and at the 2nd, 8th, 24th, and 48th hours.

Figure 1. A part of silicone-based samples kept in distilled water



The materials' surface hardness (Shore A values) was determined with an Equotip (Proceq) test testing device. Figure 2 shows the Equotip testing device. The samples' surface hardness values were measured from three different points on the lower and upper surfaces and averaged. A contact profilometer (Taylor Hobson, Surtronic 25) was used to measure surface roughness. Figure 3 shows the profilometer. The testing conditions were determined at a diameter of 5 µm and a tip speed of 0.25 mm/sec. The mean Ra value was calculated in µm by aligning the tip of the profilometer from one end to the other on the samples' surfaces. Surface roughness was measured three times on both surfaces, and surface roughness values were determined by averaging them.

Figure 2: The Equotip device measuring samples' hardness

Figure 3: A sample whose surface roughness is measured with a profilometer

Statistical analysis

Analysis using statistical methods was carried out using the computer program SPSS Statistics 20.0 (SPSS Inc. Chicago, IL, USA) at a 95% confidence interval and p=0.05 significance level. The statistical analysis of data was carried out by Tukey's multiple comparison test and three-way analysis of variance (ANOVA). The t-test was used to analyze the statistical significance of data between two samples. The sample size was determined as a minimum of 50 samples using the package G*Power (G*Power Ver. 3,0,10, Franz Faul, Üniversität Kiel, Germany) with a 25% effect size, 80% power, and α=0.05 type I error rate.

RESULTS

The analysis of variance conducted to evaluate the samples' surface microhardness values determined that the material type and time had a very significant effect ($p<.001$), the solutions in which samples were kept had an insignificant effect ($p>.05$), the time-material and time-solution interaction had a significant effect ($p<.05$), and the other interactions had an insignificant effect ($p>.05$). Table 1 contains the mean and standard deviation results for surface microhardness values.

As seen in Table 1, the highest surface microhardness value was identified in acrylic resin-based (40.20 Shore A) samples kept in bleach for two days. Surface microhardness values usually increased in samples kept in all solutions, the highest increase was detected in samples kept in bleach, and the lowest increase was in samples kept in distilled water.

Table 2 presents the outcomes derived from Tukey's multiple comparison test, specifically examining surface microhardness values relative to the duration of storage.

According to Table 2, the difference between the durations after preparation and 30 minutes; 15 minutes and 30, 45, and 60 minutes, 2 hours and 8 hours; 30 minutes and 45 minutes; 2 hours and 8 hours was statistically insignificant ($p>.05$), while differences between all other durations were statistically significant ($p<.001$).

Table 1. Mean and standard deviation results for surface hardness (Shore A) values of samples

MATERIAL	DURATION	Solution in Which Samples are Kept									
		Distilled Water		Corega		White Vinegar		Chlorhexidine Gluconate		Bleach	
		X	Std. Deviation	X	Std. Deviation	X	Std. Deviation	X	Std. Deviation	X	Std. Deviation
ACRYLIC RESIN	0 min	30.80	3.42	32.60	0.89	31.80	1.79	32.60	2.30	32.00	1.22
	15 min	34.40	4.04	35.40	1.52	36.20	3.03	36.80	4.21	36.60	2.61
	30 min	34.60	4.34	34.40	0.89	32.80	3.27	35.40	4.39	35.00	1.00
	45 min	35.00	3.61	35.60	1.14	33.60	3.05	36.20	4.32	35.80	0.84
	60 min	35.40	3.21	36.00	1.22	34.40	2.70	37.00	4.30	36.40	0.55
	2 h	36.00	2.92	36.60	1.14	35.60	2.30	37.80	3.42	37.40	0.55
	8 h	36.40	2.97	37.00	1.00	36.60	2.07	38.80	2.77	38.40	0.55
	1 day	36.60	2.70	37.80	0.84	37.20	1.92	39.40	2.30	39.40	0.55
	2 days	37.00	2.55	38.40	1.14	37.80	2.28	40.00	1.87	40.20	0.45
SILICON EBASED	0 min	27.80	1.64	27.40	2.41	28.40	2.51	29.00	1.87	25.20	1.48
	15 min	29.00	1.22	28.60	2.61	30.00	2.83	31.80	2.59	27.40	2.30
	30 min	28.20	2.17	27.60	1.67	27.80	3.42	29.60	3.21	27.40	2.30
	45 min	28.60	1.82	28.40	2.07	28.80	2.68	30.00	3.24	28.00	1.58
	60 min	29.00	1.58	29.00	1.87	29.20	2.59	30.60	3.13	28.80	1.64
	2 h	29.40	1.52	29.80	1.92	29.80	2.17	31.20	3.11	29.80	1.64
	8 h	29.80	1.30	30.40	1.52	30.60	1.95	31.80	2.95	32.00	4.12
	1 day	30.40	0.89	31.00	1.22	31.20	1.64	32.40	2.88	33.00	4.24
	2 days	31.40	1.34	32.40	1.52	32.60	1.14	33.80	2.59	34.60	3.78

Table 2. Results of Tukey's multiple comparison test for surface microhardness values according to storage duration

Time	Time	Mean of Squares	SE	df	t	PTukey
After preparation	15 min	-2.86	0.21	40.00	-13.67	<.001
	30 min	-1.52	0.40	40.00	-3.83	0.012
	45 min	-2.24	0.37	40.00	-6.07	<.001
	60 min	-2.82	0.36	40.00	-7.80	<.001
	2 h	-3.58	0.33	40.00	-10.86	<.001
	8 h	-4.42	0.35	40.00	-12.56	<.001
	1 day	-5.08	0.34	40.00	-15.05	<.001
	2 days	-6.06	0.32	40.00	-18.81	<.001
15 min	30 min	1.34	0.46	40.00	2.94	0.109
	45 min	0.62	0.43	40.00	1.46	0.868
	60 min	0.04	0.43	40.00	0.09	1.000
	2 h	-0.72	0.40	40.00	-1.80	0.684
	8 h	-1.56	0.43	40.00	-3.64	0.020
	1 day	-2.22	0.42	40.00	-5.24	<.001
	2 days	-3.20	0.41	40.00	-7.76	<.001
30 min	45 min	-0.72	0.19	40.00	-3.72	0.016
	60 min	-1.30	0.21	40.00	-6.13	<.001
	2 h	-2.06	0.24	40.00	-8.58	<.001
	8 h	-2.90	0.33	40.00	-8.67	<.001
	1 day	-3.56	0.35	40.00	-10.13	<.001
	2 days	-4.54	0.36	40.00	-12.71	<.001
45 min	60 min	-0.58	0.08	40.00	-7.25	<.001
	2 h	-1.34	0.12	40.00	-11.33	<.001
	8 h	-2.18	0.25	40.00	-8.78	<.001
	1 day	-2.84	0.27	40.00	-10.38	<.001
	2 days	-3.82	0.29	40.00	-13.29	<.001
60 min	2 h	-0.76	0.08	40.00	-8.96	<.001
	8 h	-1.60	0.23	40.00	-7.00	<.001
	1 day	-2.26	0.25	40.00	-8.92	<.001
	2 days	-3.24	0.27	40.00	-12.09	<.001
2 h	8 h	-0.84	0.21	40.00	-3.93	0.009
	1 day	-1.50	0.23	40.00	-6.45	<.001
	2 days	-2.48	0.24	40.00	-10.16	<.001
8 h	1 day	-0.66	0.09	40.00	-7.67	<.001
	2 days	-1.64	0.13	40.00	-12.36	<.001
1 day	2 days	-0.98	0.08	40.00	-12.45	<.001

Table 3. Results of the t-test for surface microhardness values of materials

Material	Material	Mean of Squares	SE	df	t	PTukey
Acrylic resin	Silicone	6.18	0.56	40.00	10.98	< .001

Table 3 contains the t-test results for hardness values of both materials.

The findings from the t-test presented in Table 3 indicate significant variations in surface microhardness among the materials tested.

The analysis of variance performed to evaluate surface roughness values determined that the material type and time had a very significant effect (p<.001), the solutions in which samples were kept had an insignificant effect (p>.05), the time-material and time-solution interaction had a significant effect (p<.05), and the other interactions had an insignificant effect (p>.05).

Table 4 contains the mean and standard deviation results for the surface roughness values of the materials.

Table 4. Mean and standard deviation results for surface roughness values (Ra) of samples

MATERIAL	DURATION	Solution in Which Samples are Kept									
		Distilled Water		Corega		White Vinegar		Chlorhexidine Gluconate		Bleach	
		X	Std. Deviation	X	Std. Deviation	X	Std. Deviation	X	Std. Deviation	X	Std. Deviation
ACRYLIC RESIN	0 min	0.80	0.26	0.89	0.37	1.12	0.38	1.02	0.19	0.93	0.31
	15 min	0.91	0.32	1.28	1.07	1.43	0.75	1.68	0.47	0.96	0.31
	30 min	1.25	0.69	1.44	0.60	1.54	0.44	1.64	0.17	1.32	0.55
	45 min	1.34	0.70	1.50	0.65	1.69	0.39	1.68	0.16	1.47	0.60
	60 min	1.45	0.74	1.68	0.62	1.94	0.37	1.77	0.23	1.90	0.63
	2 h	1.60	0.73	1.87	0.57	2.26	0.35	1.87	0.37	2.17	0.54
	8 h	1.67	0.74	2.13	0.57	2.51	0.38	2.05	0.45	2.49	0.50
	1 day	1.78	0.68	2.33	0.48	2.64	0.46	2.24	0.44	2.75	0.42
	2 days	1.92	0.62	2.57	0.48	2.61	0.69	2.37	0.49	3.02	0.34
SILICON EBASED	0 min	0.52	0.16	0.58	0.21	0.42	0.17	0.44	0.07	0.44	0.11
	15 min	0.79	0.41	1.20	1.24	0.49	0.34	0.78	0.56	0.68	0.30
	30 min	1.07	0.47	0.53	0.22	0.69	0.48	0.76	0.42	0.67	0.24
	45 min	1.16	0.49	0.67	0.22	0.83	0.45	0.94	0.41	0.85	0.24
	60 min	1.26	0.50	0.89	0.26	0,94	0.45	1.11	0.39	1.04	0.22
	2 h	1.35	0.48	1.08	0.28	1.12	0.41	1.32	0.42	1.15	0.11
	8 h	1.44	0.48	1.29	0.27	1.23	0.40	1.50	0.40	1.36	0.11
	1 day	1.50	0.46	1.43	0.27	1.36	0.37	1.66	0.42	1.59	0.11
	2 days	1.56	0.45	1.56	0.26	1.47	0.37	1.79	0.40	1.75	0.09

According to Table 4, the highest surface roughness value was identified in acrylic resin-based (3.02 Ra) samples kept in bleach for two days. Surface roughness values generally increased in samples kept in all solutions, the highest increase occurred in samples kept in bleach, and the lowest increase was in samples kept in distilled water.

The results of Tukey's multiple comparison test for surface roughness values according to the storage duration is displayed in Table 5.

No significant difference was observed between the 15-minute and 30-, 45-, and 60-minute intervals, and differences between all other durations were statistically significant (p<.001), and the data corresponding to this analysis is provided in Table 5.

According to the t-test results in Table 6, there were significant differences in surface roughness values among the materials.

The findings from the three-way ANOVA are tabulated in Tables 7 and 8.

Table 5. Results of Tukey's multiple comparison test for surface roughness values according to storage duration

Time	Time	Mean of Squares	SE	df	t	PTukey
After preparation	15 min	-0.30	0.08	40.00	-3.78	0.013
	30 min	-0.37	0.06	40.00	-5.78	<.001
	45 min	-0.50	0.07	40.00	-6.87	<.001
	60 min	-0.68	0.07	40.00	-9.53	<.001
	2 h	-0.86	0.07	40.00	-12.63	<.001
	8 h	-1.05	0.07	40.00	-15.28	<.001
	1 day	-1.21	0.07	40.00	-18.14	<.001
	2 days	-1.34	0.07	40.00	-18.95	<.001
	30 min	-0.07	0.11	40.00	-0.65	0.999
	45 min	-0.19	0.11	40.00	-1.67	0.760
15 min	60 min	-0.38	0.11	40.00	-3.28	0.049
	2 h	-0.56	0.11	40.00	-4.92	<.001
	8 h	-0.75	0.11	40.00	-6.50	<.001
	1 day	-0.91	0.11	40.00	-8.01	<.001
	2 days	-1.04	0.12	40.00	-8.92	<.001
	45 min	-0.12	0.03	40.00	-3.87	0.010
	60 min	-0.31	0.03	40.00	-9.08	<.001
	2 h	-0.49	0.04	40.00	-12.85	<.001
30 min	8 h	-0.68	0.04	40.00	-15.89	<.001
	1 day	-0.84	0.05	40.00	-17.90	<.001
	2 days	-0.97	0.06	40.00	-17.03	<.001
	60 min	-0.19	0.02	40.00	-10.61	<.001
	2 h	-0.37	0.03	40.00	-13.49	<.001
45 min	8 h	-0.55	0.03	40.00	-17.50	<.001
	1 day	-0.72	0.04	40.00	-19.87	<.001
	2 days	-0.85	0.04	40.00	-19.65	<.001
	2 h	-0.18	0.02	40.00	-10.07	<.001
60 min	8 h	-0.37	0.02	40.00	-15.24	<.001
	1 day	-0.53	0.03	40.00	-16.80	<.001
	2 days	-0.66	0.04	40.00	-16.43	<.001
2 h	8 h	-0.19	0.01	40.00	-16.00	<.001
	1 day	-0.35	0.02	40.00	-17.05	<.001
	2 days	-0.48	0.03	40.00	-15.82	<.001
8 h	1 day	-0.16	0.02	40.00	-10.69	<.001
	2 days	-0.29	0.03	40.00	-11.43	<.001
1 day	2 days	-0.13	0.01	40.00	-8.95	<.001

Table 6. Results of the t-test for roughness values of materials

Material	Material	Mean of Squares	SE	df	t	PTukey
Acrylic resin	Silicone	0.69	0.10	40.00	7.01	< .001

Table 7: Results of the three-way analysis of variance (ANOVA) according to hardness values of materials

Source	Sum of Squares	df	Mean of Squares	F	P
Time	1379.27	8	172.41	74.95	< .001
Time*Material	52.20	8	6.53	2.84	0.005
Time*Solution	121.75	32	3.80	1.65	0.017
Time*Material*Solution	42.24	32	1.32	0.57	0.971
Total	736.09	320	2.30		

Table 8. Results of the three-way analysis of variance (ANOVA) according to surface roughness values of materials

Source	Sum of Squares	df	Mean of Squares	F	P
Time	81.03	8	10.13	95.44	< .001
Time*Material	2.16	8	0.27	2.54	0.011
Time*Solution	5.29	32	0.17	1.56	0.031
Time*Material*Solution	3.35	32	0.10	0.99	0.493
Total	33.96	320	0.11		

DISCUSSION

As demonstrated in the current study, the surface roughness and hardness values increased in samples kept in all solutions, the study's null hypothesis was accepted. Over time, an increase was detected in surface roughness and hardness due to the increased storage duration in solutions for both soft lining groups, and accordingly, these findings strongly indicate support for the alternative hypothesis.

Studies have used sodium hypochlorite as a solution at different concentrations that turns into hydrogen peroxide solutions when mixed with water.[19] Disinfectant solutions such as chlorhexidine gluconate, which are not commercially available for denture cleaning, have been tested in laboratory settings and significantly decreased the amount of plaque on the denture when dentures were immersed.[19] Hence our study preferred cleaning solutions used and not used for commercial purposes in the market.

The current work found the highest surface microhardness value in acrylic resin-based (40.20 Shore A) samples kept in bleach for two days. Mese and Güzel[5] assessed the impacts of storage duration in denture cleaning solutions on the tensile bond strength and hardness of acrylic resin-based heat-polymerized (Vertex Soft), acrylic resin-based autopolymerized (Coe-Soft), silicone-based heat-polymerized (MolloplastB), and silicone-based autopolymerized (Mollosil Plus) soft lining materials. The samples were immersed in water maintained at a temperature of 37°C for durations spanning 1 day, 1 week, 1 month, 3 months, and 6 months. Consequently, it was found that the silicone-based heat-polymerized (Molloplast B) soft lining material had significantly higher tensile bond strength and lower hardness values in comparison with the other materials. Our research also found that the silicone-based heat-polymerized soft lining material (Molloplast B) had lower surface hardness values at the end of the storage duration in solutions compared to the acrylic-based autopolymerized soft lining material (Visco Gel).

The present research detected the highest surface roughness value in acrylic resin-based (3.02 Ra) samples kept in bleach for two days. It was determined that the surface roughness values of samples kept in all solutions usually increased, the highest increase occurred in samples kept in bleach, and the lowest increase was in samples kept in distilled water. In line with the results of this study, Paranhos et al.[25] determined an increase in surface roughness values depending on the concentration of sodium hypochlorite and the immersion time. Our study revealed that the surface microhardness and roughness values of soft lining materials increased over time. In their study, Mohammed HS et al.[26] prepared samples from acrylic resin and silicone-based soft lining materials to keep them for 1, 7, 30, and 90 days. Measurements were performed at these time intervals. No significant increase was identified in terms of hardness in both the test and control acrylic lining groups on day 1. However, our study observed a significant increase in the hardness values of acrylic resin-based soft lining materials at the end of day 1.

Whereas the solutions utilized to clean dentures usually adversely impact the characteristics of soft lining materials and reduce their elastic properties, acrylic resin-based ones are more affected than silicone-based ones. The above-mentioned changes occur due to the loss of diverse chemical substances, involving plasticizers and monomers, from soft lining materials.[27] The study determined that surface microhardness and roughness values increased more in samples prepared from acrylic resin-based soft lining materials compared to silicone-based ones.

Tan et al.[28] found in their research that perborate-containing denture cleansers increased surface roughness, as in the current study. Garcia et al.[29] determined that surface roughness was not impacted when they immersed the samples prepared from the soft lining material into the denture cleanser tablet solution. This study revealed that surface roughness values increased in both acrylic resin- and silicone-based soft lining materials when treated with denture cleaning solutions.

The increased surface roughness of acrylic resin-based soft lining materials may be associated with the possible loss of soluble components, e.g. plasticizers, that cause voids in the material.[26] Over time, these voids become probably responsible for the increased size, leading to surface roughness and protrusions. A rough surface also facilitates the colonization of microorganisms due to plaque accumulation.[30]

In the research done by Gonçalves et al.[31] in 2023 on the hardness values of soft lining materials after keeping them in cleaning solutions, three of the products used were from acrylic-based groups, and one was from a silicone-based group. The researchers immersed all materials in distilled water for varying durations. Unlike our study, samples were kept only in distilled water as a denture cleaning solution, while our study used more than one cleaning solution. Consequently, the least change in hardness occurred in the group with the silicone-based soft lining material (Ufi Gel p). Accordingly, the researchers suggested that it might be preferred for longer-term use. Among the other three acrylic-based groups, the most change in hardness took place in the group with the brand Soft Confort. In our study, the least change in terms of hardness values also occurred in the groups with the silicone-based soft lining material, even in different solutions.

Ueda et al.[32] researched the effects of mechanical and chemical cleaning on the surface morphology of silicone-based soft and hard lining materials. For each group, samples were prepared in a plate shape with a thickness of 1.5 mm (1-control group-only base material, 2-hard lining, and 3-soft lining groups). After the control group samples were kept in water, the hard and soft lining group samples were cleaned using denture brushes with hard and soft bristles, respectively. An abrasion test with a toothbrush and an immersion test using an enzyme-containing peroxide denture cleanser was conducted by simulating a period of about four months. The study found that using an enzyme + neutral peroxide denture cleanser for chemical cleaning did not cause surface roughening of the silicone-based soft lining material. Our study revealed that peroxide-containing denture cleanser tablets (Corega) showed efficacy in altering the surface roughness of both soft lining material types (silicone- and acrylic-based).

Mutluay and Tezvergil[33] assessed alterations in the softness and surface properties of soft lining materials after repeated loading in water. Three polysiloxanes (Silagum AM Comfort, Molloplast B, and Mollosil Plus) and two acrylic-based (Vertex Soft and Astron LC Soft) registered soft lining materials and one vinyl polysiloxane (Imprint 2 Garant) as the reference impression material were assessed. A control group of every material was immersed only in distilled water. Non-destructive cyclic loading was conducted for 200,000 cycles in distilled water at a temperature of 37°C, applying a strain of 16.6% and a frequency of 1.6 Hz. Afterward, the samples were replicated and compared to controls with roughness measurements, detail reproduction, and scanning electron microscopy. Moreover, Shore A hardness values were assessed both before and after immersion in water.

Polysiloxane-based materials better sustain their surface texture, softness, and surface smoothness under cyclic loading than acrylic resin-based materials. In our study, silicone-based soft lining materials preserved their surface properties better both in distilled water and other solutions in comparison with acrylic-based soft lining materials.

Niarchou et al.[34] evaluated the color stability and hardness of visible light-polymerized and autopolymerized soft lining materials after exposing them to various denture cleaning treatments. Six soft denture lining materials were subjected to four cleaning procedures. A Shore A durometer measured hardness, while a tristimulus colorimeter assessed color changes. The smallest change in hardness occurred in Sofreliner, and the most change was observed in the soft lining material Light Liner. While Versasoft and Sofreliner appeared to have the smallest color change after storage in all cleaning solutions, Light Liner and Eversoft yielded the highest values. Silicone-based materials displayed the smallest changes in both color and hardness when utilizing distilled water or any of the other cleaning treatments. Our study generally measured lower hardness values in silicone-based soft lining materials.

Rao et al.[35] investigated the impacts of denture cleansers on the flexibility of soft lining materials. The researchers used two soft liners (Molloplast B and Refit) and two denture cleansers (Clinsodent and Fittydent). Samples were tested with a Hounsfield tensometer. The researchers concluded that clinical performance would be more effective with the increased softness and elastic recovery of the denture soft lining. They found that silicone-based materials, e.g. Molloplast B, quickly restored surface properties and were preferable to an acrylic-based material. Our study made similar inferences.

This study detected the lowest roughness values in samples kept in distilled water among samples prepared from both soft lining materials. Among the samples prepared from the acrylic resin-based soft lining material, the highest surface roughness values were determined in the samples kept in bleach. Among the samples prepared from the silicone-based soft lining material, the highest roughness values were detected in the samples kept in chlorhexidine gluconate solution. The highest increase in surface hardness values occurred in the samples kept in bleach for both soft lining materials, while the lowest values were found in the groups kept in distilled water. The observed reduction in surface microhardness and roughness values in samples immersed in distilled water is attributed to the lesser structural impact exerted by water, contrasting with the more pronounced effect of bleach on the samples' structure, leading to heightened roughness and hardness. It is thought that silicone-based soft lining materials increase surface roughness due to their being adversely affected by chlorhexidine gluconate. Hence using chlorhexidine gluconate cleaning solutions may not be recommended, particularly in cases where silicone-based soft lining materials are used.

We consider it inappropriate to compare due to differences in the tests and research protocols utilized in studies. It is very challenging to associate the results of the current work with other research due to differences in sample size, type of soft lining materials, experimental duration, surface preparation, and cleaning solutions utilized. One limitation of this study is that only two of the numerous soft lining materials available were assessed and the research was carried out within a laboratory setup. Testing conditions utilized in in vitro studies may not fully reflect the oral environment. The characteristics of soft lining materials in the clinical state differ considerably from laboratory tests. Among the limitations of this study is that it was carried out as an in vitro study, a limited number of solutions were used, and measurements were performed at short time intervals. Hence, future research should be planned in a manner that they would include soft lining materials applied to dentures in the patient’s mouth and different solutions and involve long-term follow-ups.

CONCLUSION

Within its current limitations, this in vitro study provides strong evidence that the soft lining materials we will choose in the clinic should be silicone-based materials maintaining their structure for a long time. Concerning the denture cleaning solution we can recommend to patients, evidence showed that distilled water or white vinegar, which disrupt surface structure properties the least, should be preferred. The data derived from this study offer a valuable point of reference for understanding which denture cleaning solution is more compatible with which lining material.

Ethical Approval

Since sources obtained from humans or animals were not used in this study, ethics committee approval was not obtained.

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Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

Design: ZY, Data collection or data processing: ZY, CÇG, Analysis and comment: ZY, CÇG, Literature search: ZY, CÇG, Writing: CÇG.

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