Effect of sealer coating and storage methods on the surface roughness of soft liners

Ilknur Usta Kutlu, DDS, a Nuran Dinckal Yankılıç, DDS, PhD, b Esra Kul, DDS, c Zeynep Yesil Duymuş, DDS, PhD, d and Nurdan Polat Sağsöz, DDS e

The use of soft liners for relining removable dentures is usually advantageous1 for patients with an atrophic ridge, bony undercuts, bruxism, dentures opposing natural teeth, thin and nonresilient mucosa,2 xerostomia, sensitivity in the mental foramen region, congenital or acquired defects, or implant placement surgery.3 Lining materials allow the mucosa to heal by distributing functional loads across the denture-bearing tissues1,4,5 and are preferred by patients to conventional hard denture bases.2,3 Although denture trauma can be reduced by soft liners, the porosity of the lining material may increase colonization by microorganisms and cause tissue inflammation.6,7

Lining materials can fail for various reasons, including loss of smoothness, water sorption, discoloration, bacterial growth, or loss of adhesion between the liner and the denture base resin.8,9 Colonization by Candida albicans is one of the most important issues with soft lining materials.6,10,11 Microbes adhere more

ABSTRACT

Statement of problem. A soft lining is applied under a removable prosthesis for various reasons. The porosity of the lining material may increase colonization by microorganisms and cause tissue inflammation.

Purpose. The purpose of this in vitro study was to evaluate the effect of sealer coating on the surface roughness of soft lining materials under 4 different conditions.

Material and methods. A total of 125 specimens were prepared. One high-temperature silicone-based soft lining material and 2 room-temperature-polymerized soft lining materials (1 silicone-based and 1 methacrylate-based) were used. Twenty-five specimens of each room-temperature soft lining material were coated with 2 layers of surface sealer. Additionally, 5 specimens of each material were stored in either distilled water, Coca-Cola, denture cleanser, saliva, or air. The surface roughness was measured at baseline and after 1, 7, 14, and 28 days. Surface roughness values were analyzed with repeated measures analysis of variance, and the Bonferroni multiple comparison test was performed using time-dependent groups and storage methods.

Results. In the time-dependent groups, methacrylate-based sealer-coated soft liners exhibited a significant increase in roughness (1.74-2.09 μm, P<.001), and silicone-based sealer-coated soft liners exhibited a decrease in roughness, but it was not significant (2.16-2.02 μm, P>.05). Therefore, the sealer coating was not effective in reducing surface roughness. Among the time-dependent storage methods, the denture cleanser exhibited an almost significant increase in roughness (1.83-1.99 μm, P=.054). Coca-Cola and artificial saliva did not show a significant difference (P>.05). However, a significant decrease in roughness was found with distilled water (P=.02) and air (P<.001).

Conclusions. Statistically significant differences in surface roughness were found among the different types of soft liners. The sealer coating had no significant effect, and denture cleanser slightly increased the surface roughness. Contrary to expectations, the roughness did not increase in all groups over time. (J Prosthet Dent 2016;115:371-376)
Clinical Implications

Denture cleansers increased the roughness of soft liners, and the application of sealer coating did not seem to reduce the roughness.

easily to soft lining materials than to the acrylic resin denture base because of the surface texture and physical and chemical affinity. Denture stomatitis is caused mainly by microbes and C. albicans, which has frequently been isolated from the fitting surface of dentures. Denture plaque control is important to prevent colonization and infection by these organisms.

Dentures should be cleaned with immersion cleansers and brushing. Chemical soaking is the first choice for elderly patients with poor motor capacity. The use of denture cleansers is efficient in removing stains and deposits. Even though denture cleansers should prevent C. albicans colonization and provide denture plaque control, in daily use, denture plaque bases and soft denture lining materials can be adversely affected by these solutions. Denture cleansers can also cause the loss of soluble components or plasticizers or the absorption of water or saliva by the resilient lining materials.

Factors that affect the adherence of microorganisms to the substrate surface include material type, surface roughness, and diet ingredients. Fungus adheres more often to rough surfaces than to smooth surfaces. Three to four days after soft liners are applied, surface roughness may increase. The rough surface of lining materials can be easily colonized by C. albicans and other oral fungi, which causes deterioration of soft liners and irritates denture-bearing areas. Surface roughness also affects the viscoelastic properties and the dimensional stability of soft lining materials.

Sealers protect soft liners against water sorption and damage by chemical agents by covering surface defects and reducing porosity and fissures. They also increase the durability, resilience, and longevity of tissue conditioners. In addition, the smooth surface obtained with a sealer prevent plaque adhesion and bacterial growth. However, they seem to be affected by time. The use of denture cleansers may cause the properties of sealed soft liners to deteriorate, but cleaners should still be used to reduce denture plaque formation.

The hypotheses of this study were that denture cleansers and carbonated drinks such as Coca-Cola would affect the surface roughness of the soft liners and that the surface roughness of the liners would be reduced by the sealer coating. In addition, although surface roughness values increase over time, methacrylate-based liners would increase more than silicone-based liners.

MATERIAL AND METHODS

Table 1 lists the 3 soft lining materials, 1 denture cleanser, and 2 sealers tested. One hundred and twenty-five specimens were prepared. Fifty specimens were made of an methacrylate-based room-temperature-polymerized soft lining material (GC Tissue Conditioner; GC Corp), 50 specimens were made of a silicone-based room-temperature-polymerized soft lining material (Ufi Gel P; Voco GmbH), and 25 specimens were made of a silicone-based high-temperature-polymerized soft lining material (Molloplast B; Detax Dental).

Each room-temperature soft liner was processed following the manufacturer’s instructions and poured into a stainless steel mold to create 16-mm-diameter and 2-mm-thick disks (Fig. 1). A glass slab (mean roughness 0.009 μm) was placed on top of the mold, another was placed underneath the mold, and both were kept in place for 90 minutes under a 20 N vertical force. After polymerization, the surfaces of 25 of the room-temperature-polymerized soft lining material specimens were coated with 2 layers of sealer according to the manufacturer’s directions and allowed to dry without the use of an air spray.

The heat-polymerized soft lining specimens were prepared with 2-mm-thick and 16-mm-diameter spacers in a denture flask. The spacers were made of hard but flexible silicone rubber (Zetaflow; Zhermack SpA) with the stainless steel mold and glass slabs. After the spacers were removed from the denture flask, the specimens were processed according to the manufacturer’s directions.

Specimens of each material were immersed in distilled water, denture cleanser solution (Corega, 8 hours/day), Coca-Cola (1 hour/day), or artificial saliva (consisting of 0.220 g/L calcium chloride, 1.07 g/L sodium phosphate, 1.68 g/L sodium bicarbonate, and 2 g/L sodium azide [0.2% NaN₃]) at 37°C, or were stored in air. Artificial saliva and distilled water were changed daily. Fresh solutions of denture cleanser were prepared according to the manufacturer’s recommendations, and fresh Coca-Cola was used for every application.
The surface roughness of each material was measured after 0 (time T0), 1 (T1), 7 (T7), 14 (T14), and 28 (T28) days of immersion. Each tissue conditioner specimen was boxed using wax (Fig. 2), and then mixed dental stone (Moldano; Heraeus Kulzer GmbH) was poured over the surface of the tissue conditioner under gentle vibration and removed 60 minutes after mixing for indirect measurement (Fig. 3). Dental stone specimens were stored for 1 day at 23 ±2°C and 70% humidity before measurement.

The surface roughness (Ra) was measured with a profilometer (Surtronic 25; Taylor Hobson Ltd) calibrated at a cut-off length of 0.8 mm, 2.4 mm percussion of measure, and drive speed of 0.5 mm/s. The mean Ra values of each group specimen was obtained from 3 measurements made by 1 observer (I.U.K.). Repeated measures ANOVA was performed to analyze the surface roughness of each time-dependent group and condition. Statistically significant subgroups were compared with the Bonferroni multiple comparison test (α=0.05).

RESULTS

Statistically significant differences (P<0.001) were found among the groups at the baseline (at day zero T0). According to the repeated measure, there were significant differences in surface roughness among different times, groups, conditions, and interactions (Table 2).

In a comparison between mean values from T0 with those from T28 for all groups, the Ufis (coated Ufi gel P) and Ufi (uncoated Ufi gel P) groups were not statistically significantly different (P>.05), and no increase was noted in the roughness of either group (Table 3). Statistically significant differences in roughness were found between the Gcs group (coated GC tissue conditioner) and the Gc group (uncoated GC tissue conditioner) (P=.02): the roughness of the Gcs group increased over time more than that of the Gc group. Thus, the sealer was not effective in reducing the surface roughness of either of the soft liners. Although the surface roughness decreased for the silicone-based soft liners (Ufi, Ufis, Mol) in the period of T28, the decrease in the Ufis group was not statistically significant (Ufis: P>.05, T0=2.16 µm, T28=2.02 µm; Ufi: P=.003, T0=1.58 µm, T28=1.31 µm). The heat-polymerized silicone-based Mol (Molloplast) group had the largest decrease (P<.001, T0=2.18 µm, T28=1.45 µm) (Table 3). The roughness of the methacrylate-based soft liners increased more than that of the silicone-based liners (P=.003). This increase was observed at T14 for both the Gc group (T0=1.58 µm, T14=1.79 µm) and the Gcs group (T0=1.74 µm, T14=2.27 µm) (Fig. 4).

Considering each of the storage methods depending on the change over time, the difference in the denture
cleanser was marginally significant (P=.054), and the surface roughness increased over time (1.83 µm to 1.99 µm). This increase was observed in all the groups except for the Ufi and Mol groups. In artificial saliva, the roughness decreased from T0 to T28 for all the groups (1.875 µm to 1.654 µm). For Coca-Cola, only the methacrylate-based Gc and Gcs groups increased in roughness from T0 to T28 (Gc: T0=1.55 µm, T28=1.79 µm; Gcs: T0=1.68 µm, T28=1.72 µm). However, the artificial saliva and Coca-Cola values were not statistically significant (P>.05). The surface roughness of specimens immersed in distilled water or air decreased significantly (distilled water: P=.02; air: P<.001) (Table 3, Fig. 5).

In a comparison of the time periods, the roughness did not increase over time. Decreases were found in some of the groups. Generally, there was an increase from T7 to T14 (1.70 µm to 1.88 µm) and a decrease from T14 to T28 (1.88 µm to 1.68 µm) in all groups.

**DISCUSSION**

Soft liners increase the adaptation of dentures, reduce stress by distributing it over the supporting tissues, and improve patient comfort. However, the length of time soft liners are in contact with oral tissues is important since the surface roughness causes biofilm formation and bacterial accumulation, resulting in deterioration.27,7 Although soft lining materials have more surface irregularities and are rougher than denture resins and therefore allow more bacterial accumulation,25,20 definitive soft liners can be used for several months or years. In addition, interim lining materials are inexpensive and easily available. To decrease the deterioration caused by food, saliva, denture cleansers, and brushing, a sealer coating can be applied. Silicone lining materials are chemically and physically more stable than acrylic resin lining materials. Methacrylate-based liners require a sealer coating because they tend to absorb water, dissolve, and lose their plastizer.27,26 However, in methacrylate-based lining materials, a sealer coating is not as effective as in silicone-based liners.25 In the present study, although a decrease was observed in the Ufis group (at T7 and T14), an increase was observed in the Gcs group.

Similar to this study, Jin et al18 found that the surface of silicone-based soft liners immersed for 180 days in different denture cleansers was less rough than that of acrylic-based soft liners. Likewise, Dayrell et al27 suggested that methacrylate-based soft liners are rougher than silicone-based soft liners because of the chemical structure of methacrylate-based liners, residual monomer content, polymerization method, volatility of the monomers, air bubbles, and the blending technique used.

### Table 3. Mean value differences of $T_0 - T_{28}$ and standard deviations for all groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Storage</th>
<th>Mean ±SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ufis Coca-Cola</td>
<td>0.10 ±0.653</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Ufis Corega</td>
<td>-0.70 ±0.819</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Ufis Water</td>
<td>0.47 ±0.489</td>
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<td></td>
</tr>
<tr>
<td>Ufis Air</td>
<td>0.69 ±0.557</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Ufis Saliva</td>
<td>0.11 ±0.762</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Ufi Coca-Cola</td>
<td>0.19 ±0.284</td>
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<td></td>
</tr>
<tr>
<td>Ufi Corega</td>
<td>0.17 ±0.333</td>
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<td></td>
</tr>
<tr>
<td>Ufi Water</td>
<td>0.25 ±0.456</td>
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<td></td>
</tr>
<tr>
<td>Ufi Air</td>
<td>0.48 ±0.087</td>
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<td></td>
</tr>
<tr>
<td>Ufi Saliva</td>
<td>0.21 ±0.325</td>
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<td></td>
</tr>
<tr>
<td>Gcs Coca-Cola</td>
<td>-0.85 ±0.792</td>
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<td></td>
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<tr>
<td>Gcs Corega</td>
<td>-0.64 ±0.412</td>
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<tr>
<td>Gcs Water</td>
<td>-0.64 ±0.425</td>
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<tr>
<td>Gcs Air</td>
<td>0.42 ±0.463</td>
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<tr>
<td>Gc Coca-Cola</td>
<td>-0.05 ±0.271</td>
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<tr>
<td>Gc Corega</td>
<td>-0.22 ±0.490</td>
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<td></td>
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<tr>
<td>Gc Water</td>
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<td></td>
</tr>
<tr>
<td>Gc Air</td>
<td>0.11 ±0.206</td>
<td>5</td>
<td></td>
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<tr>
<td>Gc Saliva</td>
<td>0.12 ±0.631</td>
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</tr>
<tr>
<td>Mol Coca-Cola</td>
<td>0.59 ±1.248</td>
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<tr>
<td>Mol Corega</td>
<td>0.57 ±1.053</td>
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<tr>
<td>Mol Water</td>
<td>1.13 ±0.392</td>
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</tr>
<tr>
<td>Mol Air</td>
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<td>Mol Saliva</td>
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<td>Total Coca-Cola</td>
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<td>Total Air</td>
<td>0.48 ±0.400</td>
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</tr>
<tr>
<td>Total Saliva</td>
<td>0.22 ±0.518</td>
<td>25</td>
<td></td>
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</tbody>
</table>

Gc, uncoated GC tissue conditioner; Gcs, sealer coated GC tissue conditioner; Mol, Molloplast; Ufis, coated Ufi Gel P; Ufi, uncoated Ufi Gel P.
Sesma et al.\textsuperscript{23} and Dayrell et al.\textsuperscript{27} which reported crack roughness was rejected; this agrees with the studies of roughness.\textsuperscript{19} Therefore, the specimens were prepared by slab cause changes in the adhesion force and affect volatility and removal speed of the liner from the glass compared by Hong et al.\textsuperscript{24} Different surface roughness values ranged from 1.10 to 2.52 \(\mu m\) to 2.52 \(\mu m\) and were similar according to Nikawa et al.\textsuperscript{30} Murata et al.\textsuperscript{19} indicated that enzyme-type cleansers may be preferable in terms of surface conditions. However, another study showed that peroxide is not the only factor that causes disruption: enzyme denture cleansers can also cause deterioration.\textsuperscript{18}

In this study, Corega increased the surface roughness of soft lining materials (1.83–1.99 \(\mu m\)). This increase may have occurred because of the loss of alcohol and plasticizer and because of water absorption. Thus, because of the minimal loss of alcohol and plasticizer, the roughness values did not increase in air.\textsuperscript{24} Similar to the present study, the study by Kazaki and Watkinson\textsuperscript{16} found that the roughness of soft liners kept in denture cleanser was higher than that of liners kept in water because of the ionic concentration of the cleansers. Pisani et al.\textsuperscript{20} attributed increased roughness to cavities and bubbles that occurred because of the loss of the liner’s soluble components. However, similar to this study, the lack of increased roughness in water was associated with a minimal loss of soluble components and a lack of bubbles.

Hong et al.\textsuperscript{24} measured the roughness of soft liners at 0, 1, 3, 7, and 14 days and observed increases in all groups over time except for liners stored in air, and Dayrell et al.\textsuperscript{27} observed a decrease in roughness in all groups at the first month. In the present study, a decrease was observed in some of the groups over time.

The hypothesis that sealer coating would reduce roughness was rejected; this agrees with the studies of Sesma et al.\textsuperscript{23} and Dayrell et al.\textsuperscript{27} which reported crack formation and detachment of sealer-coated specimens over time. Coca-Cola was one of the storage media tested. The results were not as expected, and no statistical differences were found in any of the storage periods. We also tested artificial saliva, and the results remained stable because of the content of the artificial saliva. When dentures with soft liners are not in the mouth, they should be stored in water. In older patients with poor oral hygiene, chemical cleansers are recommended for plaque control in soft lining materials because ultrasonic cleaners are not effective and brushing can cause damage.\textsuperscript{14,15}

Alkaline peroxides, alkaline hypochlorite, acids, disinfectants, and enzymes are denture cleansers.\textsuperscript{15} In the present study, Corega-containing alkaline peroxide was used. Gedik et al.\textsuperscript{13} stated that Corega-containing alkaline peroxide is the second most effective denture cleaner after NaOCl. However, the distortion caused by denture cleansers of the denture resins and soft liners is as important as the efficiency of a denture cleaner. As observed by Nikawa et al.\textsuperscript{21} when denture cleansers are used every day, they can affect the physical properties of soft liners.

While the specimens are being prepared, monomer volatility and removal speed of the liner from the glass slab cause changes in the adhesion force and affect roughness.\textsuperscript{19} Therefore, the specimens were prepared by one researcher, under the same experimental conditions. In the present study, the mean surface roughness values ranged from 1.10 \(\mu m\) to 2.52 \(\mu m\) and were similar to those of other studies.\textsuperscript{11,13,14,17} Although the specimens in this study were prepared between 2 glass slabs, the surface roughness values at the baseline were different and were more than 0.2 \(\mu m\), which is the threshold value for microorganism retention.\textsuperscript{2,4,22,27} At the baseline, the sealer-coated soft liners had higher surface roughness, which was thought to have been caused by the thickness of the applicator bristles, which is different for each manufacturer’s kit.

Vural et al.\textsuperscript{12} evaluated the surface roughness of autopolymerizing and heat-polymerizing soft lining materials after specimens were submerged in artificial saliva and stated that the polymerization method affected roughness. Similar to the present study, the room-temperature-polymerized soft liner was rougher than the heat-polymerized Molloplast B. This is because heat-polymerization increases the cross-linking of residual monomers, thereby making the liner harder and more wear-resistant.\textsuperscript{13}

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The roughness of methacrylate-based soft liners was compared by Hong et al.\textsuperscript{24} Different surface roughness values were associated with the average particle size of the polymer, the molecular weight of the plasticizer, the powder/liquid ratio of soft liners, and the alcohol content.\textsuperscript{28}

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The studies’ results varied because of the different lining materials, time periods, and solutions used. Murata et al.28,19 used 3 types of tissue conditioner and 2 types of dental stones (Type III and Type IV) in their study and found that the less important factor affecting roughness is the type of dental stone. Thus, a Type III dental stone was used in the present study. Not testing other stones is a limitation of this study. Other limitations include the sole use of the profilometer to evaluate the surface roughness of the materials. Using a scanning electron microscope before and after storage under different conditions might have given more information regarding the nature of the surface change in the specimens.

Factors that can affect the surface conditions of soft liners include masticatory force, thermocycling,19 tissue irregularities, the presence of saliva during polymerization, and microbial factors.2 These factors could be investigated in future studies.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were made:

1. Methacrylate-based soft liners had rougher surfaces than silicone-based liners. Denture cleanser increased the surface roughness, especially with methacrylate-based liners. Surprisingly, sealer coating had no significant effect on surface roughness.

2. All roughness values did not increase over time. In some groups, the surface roughness decreased. The increase was observed especially in the T7-to-T14 period, and there was a decrease in the T14-to-T28 period in every group.

3. Polymerization type affected surface roughness, with heat-polymerized liners having lower surface roughness.

REFERENCES