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Mainieri VC, Beck J, Oshima HM, Hirakata LM, Shinkai RS. Surface changes in denture soft liners with and without sealer coating after mechanical brushing abrasion. Gerodontology. 2011; 28(2): 146-51.

PMID: 21054504 [PubMed - indexed for MEDLINE]

http://dx.doi.org/10.1111/j.1741-2358.2010.00375.x.

Gerodontology (ISSN: 0734-0664)

Surface changes in denture soft liners with and without sealer coating after mechanical brushing abrasion

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Short title: Toothbrushing abrasion of soft liners with sealer coating

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ABSTRACT

Aim: To evaluate the surface alterations of soft liners with or without sealer coating after mechanical brushing abrasion.

Methods: Thirty specimens were made of a methacrylate- (Coe-Soft) and a siloxane-based material (Ufi-Gel SC), and 15 received two coatings of surface sealer. The specimens were submitted to a mechanical brushing-dentifrice assay under 200 g of force at 250 cycles/min. Mechanical brushing was simulated for a period of 1 (1,250 cycles) and 6 months (5,000 cycles). Surface roughness (Ra parameter) was measured, and SEM images were obtained. Ra data were analyzed by ANOVA for repeated measures and Bonferroni's test (alpha=0.05).

Results: Ra increased from baseline to six months of mechanical brushing abrasion regardless of sealer coating. At baseline, only Coe-Soft without sealer had higher Ra than the other groups. After one month, the Ra of Coe-Soft with sealer was three-fold higher than the Ra at baseline; the other groups showed no significant increase of Ra. SEM images showed degradation of the soft liners over time, except for the Ufi-Gel SC with sealer, which displayed minimum alteration of surface texture.

Conclusion: Sealer coating reduced the surface degradation of the tested soft liners, but the protective effect was more pronounced for the siloxane-based material.

Introduction

The mechanisms of microorganism adhesion and biofilm formation on denture surfaces is similar to that on dental substrates such as enamel or dentin[1-3]. When daily hygiene is poor, denture surfaces allow the retention of food debris and accumulation of microorganisms, which could result in inflammation of the bearing mucosa, unpleasant smell and taste[4]. Biofilm formation depends on a complex interaction of variables including surface characteristics (texture, surface energy, porosity), type of colonizing microorganisms, and saliva properties.

Regarding the materials used for the construction of denture baseplates, denture resins, hard and soft reliners would serve as different substrates for biofilm formation and require specific strategies for adequate cleaning. Resilient liners aim to protect the denture-bearing mucosa from excessive occlusal forces and should maintain optimal softness and smoothness during clinical service[5]. However, the life span of these materials often are shorter than the hard methacrylate-based resin of the denture baseplate because of accelerated degradation and changes in material properties, such as strength, dimensional stability, bonding to acrylic resin, hardness, and surface roughness, as well as increase in porosity and lixiviation of components[6-10].

To extend the clinical service of soft liners, surface sealers may be used to protect the material against the external environment stress caused by mechanical and chemical factors. Sealers are traditionally used on dental surfaces and restorative materials to cover surface imperfections and occlude gaps, fissures, and porosity. Malmström et al. reported an *in situ* study where a tissue conditioner with Monopoly and Permaseal coatings remained intact for up to two weeks[8]. Also, it has been reported that sealed soft liners remain clean and resilient for a longer period than non-sealed materials, and also reduce microorganism growth and biofilm formation[5,8]. The application of a sealer acts as a mechanical barrier to decrease water sorption and solubility of chemical components, which is related to accelerated material degradation with increased surface roughness and porosity. Therefore, the accumulation of food debris and biofilm formation is reduced with a smooth sealed surface, as well as the risk for mucosa inflammation decreases due to a less contaminated and irritating surface[11-15]. However, the properties of sealed soft liners may be affected by routine cleaning methods, such as soaking in chemical agents and mechanical brushing[16-19]. The latter promotes mechanical abrasion and alters surface roughness, which may be modulated by the dentifrice particle size and toothbrush bristle stiffness[16,17]. Nevertheless, little still is known about the long-term effect of mechanical brushing abrasion on soft liners protected by sealer coating.

Therefore, this study aimed to compare the surface roughness (Ra) of two soft liners with and without application of surface sealer after simulation of mechanical brushing abrasion for up six months. A qualitative analysis of surface degradation was performed using scanning electron microscopy (SEM) images to describe changes in surface morphology. The null hypothesis was that surface topography of the tested soft liners does not vary as a function of material, sealer coating, and duration of mechanical brushing abrasion.

Materials and Methods

Table 1 displays the brand name, manufacturer, basic chemical composition, and some other technical information of the denture soft liners and sealer used in this study.

<INSERT TABLE 1>

The materials were prepared according to the manufacturers' instructions to fabricate 30 disk-shaped specimens of each material. The fluid gel was pressed against a plastic base by using a glass slab to obtain specimens with 2-mm thick and approximately 20-mm diameter. The glass slab was manually pressed until reaching a predetermined 2 mm-height stop, kept in place for 30 minutes under a 2 kgf vertical force, and then removed after complete material setting. In 15 specimens of each soft liner the surface was coated with two layers of the sealer provided with the Ufi-Gel SC package according to the manufacturer's directions. All specimens were stored in distilled water at 37°C for four days and then submitted to a simulation of mechanical brushing using a custom-made wear machine specifically designed for abrasion treatment[16,17,19,20], using 200 g of force[21] and 12-mm horizontal back-and-forward movements at 250 cycles/min[22].

Each specimen was brushed with a soft bristle toothbrush (Smile-Kolynos, Colgate-Palmolive Industry and Trade Ltd., São Paulo, Brazil) and a paste made of 6 g of toothpaste with calcium carbonate abrasive (Colgate Triple Action, Colgate-Palmolive Industry and Trade Ltd., São Paulo, Brazil) mixed to 6 mL of distilled water[16,17]. Mechanical brushing was simulated for a period of 1 month (1,250 cycles, T1) and 6 months (5,000 cycles, T6). The toothbrushes and toothpaste were replaced after 5,000 cycles[16,17].

After the abrasion assay for each period of time, the specimens were cleaned with distilled water and ultrasound for 5 minutes to remove any dentifrice debris, dried with a gentle air blast and stored in relative humidity and room temperature until surface roughness measurement. Three points were marked on the specimen treated surface: one central point, one at 0.5 mm to the right, and one at 0.5 mm to the left. These marks were used as reference points for the repeated measurements of the surface roughness at baseline (T0) and after each experimental series of brushing cycles (T1 and T6). Average surface roughness (Ra parameter) was measured using a surface analyzer (Surface Roughness Tester SJ-201, Mitutoyo Corporation, Japan), with accuracy of 0.01µm and 0.8-mm cut-off length. Each specimen was measured in triplicate, and the Ra values were averaged.

Surface roughness data were analyzed by Analysis of Variance for Repeated Measures, using the Greenhouse-Geisser correction for violation of sphericity, followed by multiple post-hoc pairwise comparison of means with adjustment by Bonferroni, with the statistical software SPSS 11.5 (SPSS Inc., Chicago, IL, USA. Independent variables were soft liners (2 levels: Coe-Soft x Ufi-Gel SC), sealer coating (2 levels: yes x no) and time (3 levels: baseline x 1 month x 6 months). All tests were two-tailed, and a *P*-value of 0.05 was used to identify significant differences between group means.

Two specimens of each group were randomly chosen and molded with fluid type vinyl polysiloxane (3M ESPE Express, St. Paul, MN, USA) to duplicate the treated surface in epoxy resin (Embed 812, Electron Microscopy Sciences, Hatfield, PA, USA) after the Ra measurement over time. The epoxy resin specimens were fixed onto stubs and sputter-coated (Balzers Sputer Coater, Germany). Longitudinal changes in surface morphology were observed with scanning electron microscopy (SEM) (Philips XL30, Philips Electronic Instruments Inc., Mahwah, NJ, USA) and photographed at 100X magnification.

Results

Mean surface roughness (Ra) of Coe-Soft and Ufi-Gel SC increased from baseline to six months of simulated mechanical brushing abrasion regardless of sealer coating ($P<0.05$) (Figure 1). The pattern of changes in surface roughness was different between Coe-Soft and Ufi-Gel SC over the experimental period of time.

Table 2 shows the comparison of Ra values among Coe-Soft and Ufi-Gel SC with and without sealer coating at baseline and after mechanical brushing abrasion for one and six months. At baseline, only Coe-Soft without sealer had higher Ra mean than the other experimental groups. After one month of mechanical brushing abrasion, the Ra of Coe-Soft with sealer group was approximately three-fold higher than its Ra at baseline ($P<0.05$), while the other groups showed no significant increase of Ra. After six months of treatment, both Coe-Soft groups with and without sealer showed Ra mean values higher than 5 µm, which was five times higher than the Ra of Ufi-Gel SC groups. Ufi-

Gel SC with sealer showed the smallest Ra mean among the experimental groups at six months of abrasion simulation.

SEM images (Figure 2) showed continuous degradation of the soft liners with mechanical brushing abrasion over time, except for the Ufi-Gel SC with sealer group, which displayed minimum alteration of surface texture even after six months. Independently from sealer coating, Ufi-Gel SC surfaces were smoother than the Coe-Soft counterparts. Surface degradation was characterized by increasing loss of material originating undulations, pits, fissures, and grooves, which were minimized by the application of sealer for both soft liners even after six months of mechanical brushing simulation.

<INSERT TABLE 2, FIGURES 1 & 2>

Discussion

The term “soft liners” refers to a class of resilient materials used to reline denture base surfaces in contact with the occlusal stress-bearing oral mucosa. They have different chemical compositions, which reflect in their physical properties, clinical indications, and duration in service. For example, tissue conditioners are a subcategory of soft liners, which have specific composition and properties to be used in a short term basis mainly after surgery or mechanical trauma. Therefore, at present soft liners are commonly used to help to stabilize denture baseplates in cases of severe bone resorption and protect denture-bearing tissues from excessive occlusal forces after implant surgery [11,14]. Although some materials are used for several months or years as quasipermanent liners, resilient lining materials are not as resistant as denture resins, and their surface have more porosities, irregularities or little defects, which can cause some difficulties for the patients to maintain good hygiene and avoid biofilm accumulation and yeast contamination[15,23]. The use of sealers or varnishes on the surface of soft liners aims to reduce the degradation caused by the contact with saliva, food, disinfection solutions, and mechanical brushing[11,18]. This is clinically important as temporary liners sometimes are used for longer periods than recommended due to costs and material availability.

The present study showed that sealer coating reduced the surface degradation of the tested soft liners submitted to simulation of mechanical brushing abrasion for six months. SEM images confirmed that the surface degradation in sealed specimens was lower than that of the same materials without sealer. Thus, the null hypothesis was rejected as surface topography of the tested soft liners varied as a function of material, sealer coating, and duration of mechanical brushing abrasion.

The application of surface sealer may preserve the material properties to some extent, which was previously reported for hardness measurement of soft liners with two coatings of Permaseal, a resilient lining sealer[12]. However, this surface protection on the methacrylate-based material was not as effective as for the siloxane-based liner. In fact, the surface roughness of the sealed Coe-Soft group increased substantially from baseline to one month of simulated mechanical brushing abrasion, suggesting that some sealer coating was lost and was not covering the entire surface anymore. The chemical composition of the tested soft liners explains the differences of surface texture and degradation observed over time. Coe-soft is a methacrylate-based soft liner used as a temporary resilient reliner material, whereas Ufi-Gel is a permanent silicone-based liner. The tested sealer is also silicone-based and is marketed as part of the Ufi-Gel kit. Therefore, it is expected that the sealer interaction with the methacrylate-based liner was not as effective as for the original silicone material. Nevertheless, the present results showed that two coatings of this sealer significantly improved abrasion resistance of Coe-Soft up to six months of mechanical brushing simulation in comparison with the same material without sealer. Both Ufi-Gel groups with and without sealer coating presented increase in surface roughness after six months of abrasion simulation, but the sealer was effective to protect against surface degradation as shown by Ra values and SEM images.

The literature is controversial on the beneficial effect of surface sealers on soft liners depending on the materials and outcomes assessed. Although a recent paper reported that the use of a varnish had a detrimental effect on a siloxane-based tissue conditioner, allowing higher biofilm adhesion *in vivo*[11], several studies showed that one or two sealer coatings protect the surface of some resilient lining materials from early degradation as measured by increase of surface roughness and changes in hardness[12-14]. The present study supports the use of sealer coating for the tested materials in an attempt to prolong their optimal characteristics. However, during clinical service in the oral cavity the materials may suffer additional stresses, such as thermal changes, pH variations, and deformation by occlusal loading, which may accelerate the degradation of the sealer coating and the material itself. Changes in surface texture of soft liners may be affected by a synergistic interaction among different variables, and suffer influence of diet and saliva. These variables should be addressed in future studies as well as longer abrasion simulation for the siloxane-based soft liners.

One limitation of this study is the restricted generalization of results to other soft liners with different composition. Nevertheless, the results suggest that the sealer coating may provide satisfactory surface integrity for Ufi-Gel SC and slow down the surface degradation for Coe-Soft for up to six months of mechanical brushing abrasion.

Conclusions

In summary, this study found that surface degradation of Coe-Soft and Ufi-Gel SC promoted by mechanical brushing abrasion was reduced by sealer coating, but this protective effect was more pronounced for the siloxane-based material.

Acknowledgement

This study was partially supported by a graduate scholarship of the Brazilian Ministry of Education – CAPES.

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Table 1. Specifications of the soft liners tested in this study: commercial brand, manufacturer, basic chemical composition, and other technical information.[17,18]

Product	**Manufacturer**	**Basic Composition**	**Technical Information**
Ufi-Gel SC	VOCO, Cuxhaven, Germany	Mixture of different polyalkylsiloxanes, fumed silica, catalysts, butanone and additives	Proportion of 1:1 safety cartridge (SC) Silicone-based soft liner Permanent use
Coe-Soft	GC America Inc., Chicago ILL, USA	Powder: Polyethyl methacrylate, zinc undecylenate, and pigments Liquid: Benzyl salicylate, dibutyl phthalate ethyl alcohol, methylsalicylate, oil mint	Proportion of 11g/8mL Methacrylate resin soft liner Temporary use
Ufi-Gel Glaze	VOCO, Cuxhaven, Germany	Two-component A-silicone	Proportion of 1:1 base/catalyst Silicone-based glaze/sealer Sealer was applied in two coats with a 2 minute drying time between coats

Table 2. Surface roughness (Ra) of the tested soft liners with and without sealer coating at baseline and after simulation of one and six months of mechanical brushing abrasion (n=15/group).

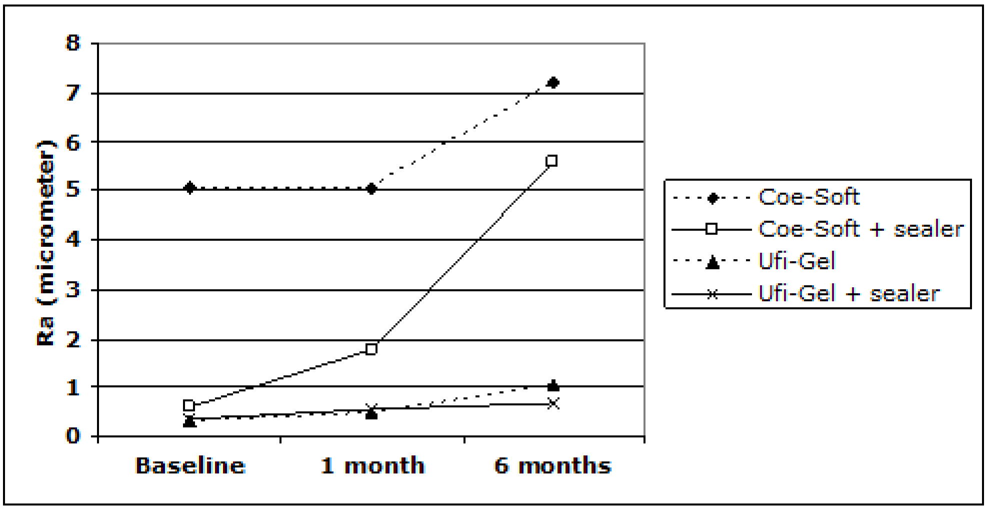
Time	**Soft liners**	**Mean Ra (μm)**	*	**SD (μm)**
Baseline	Coe-Soft without sealer	5.04	A a	0.69
	Coe-Soft with sealer	0.62	B a	0.13
	Ufi-Gel without sealer	0.34	B a	0.13
	Ufi-Gel with sealer	0.37	B a	0.16
After one month	Coe-Soft without sealer	5.06	A a	0.48
	Coe-Soft with sealer	1.78	B b	1.32
	Ufi-Gel without sealer	0.48	C a	0.14
	Ufi-Gel with sealer	0.56	C a	0.15
After six months	Coe-Soft without sealer	7.19	A b	1.33
	Coe-Soft with sealer	5.59	B c	1.50
	Ufi-Gel without sealer	1.05	C b	0.31
	Ufi-Gel with sealer	0.67	D b	0.16

*Means followed by different letters are statistically different (*P* <0.05); comparisons among soft liner groups within each time period are indicated by capital letters; comparisons among time periods within each soft liner are indicated by small caps letters. Data were analyzed by Analysis of Variance for Repeated Measures, using Greenhouse-Geisser correction for violation of sphericity, followed by multiple post-hoc pairwise comparison of means with adjustment by Bonferroni.

FIGURE LEGENDS

Figure 1. Changes in mean surface roughness (Ra) of the soft liners Coe-Soft and Ufi-Gel SC with and without sealer coating when submitted to simulation of mechanical brushing abrasion for up six months. Ra increased over time from baseline to six months of abrasion simulation regardless of sealer coating ($P<0.05$), but was more stable for the siloxane-based material.

Figure 2. SEM images (original 100X) of Coe-Soft® and Ufi-Gel SC® groups show continuous surface degradation over time but in different levels according to the material, sealer coating, and duration of simulated mechanical brushing abrasion.



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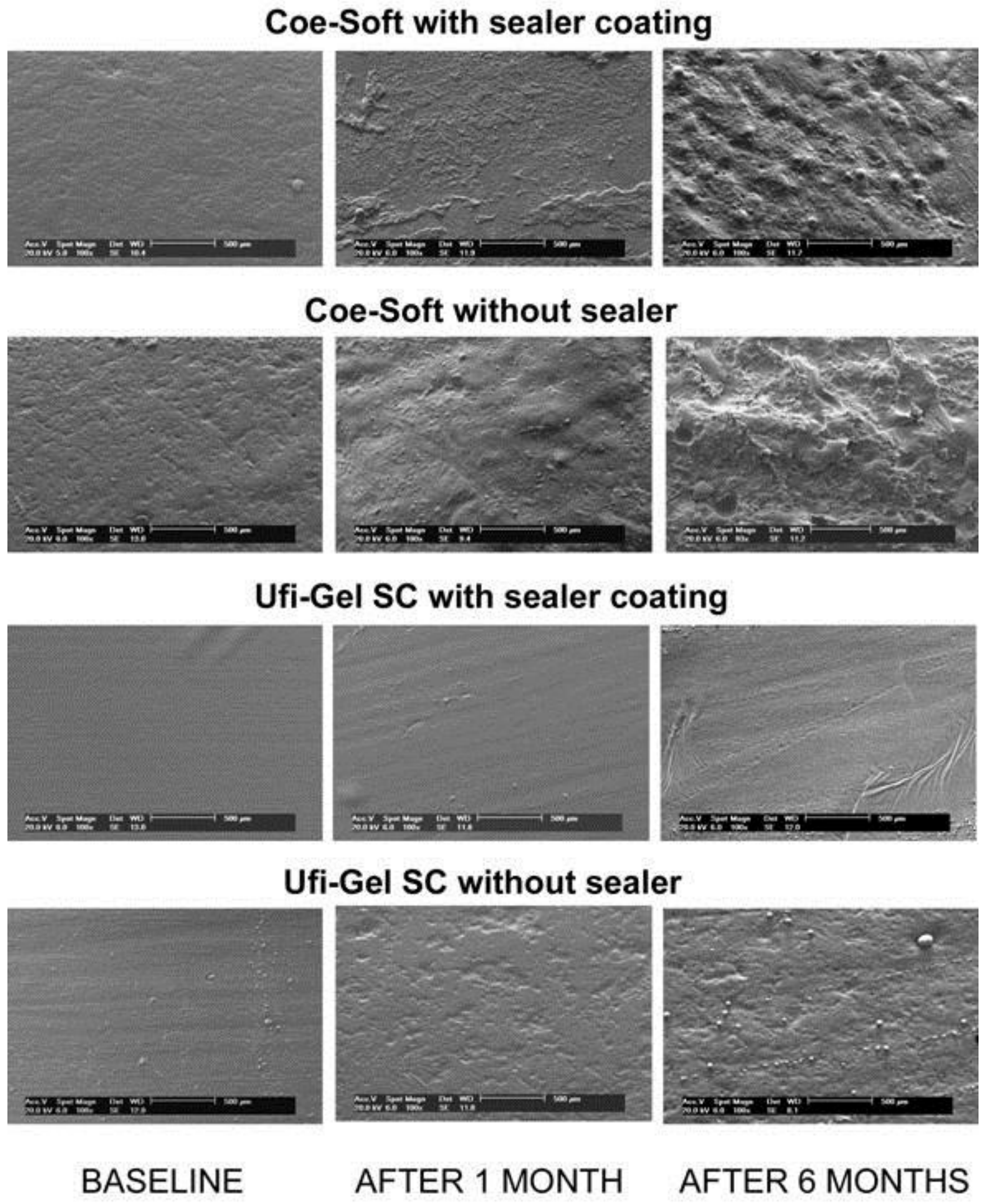

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