Effect of a denture cleanser on hardness, roughness and tensile bond strength of denture liners

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Abstract

Aim: This study aim to investigate the effect of a denture cleanser on hardness, roughness and tensile bond strength of a rigid (Kooliner) and a soft denture liner (Elite Soft) after 7, 60 and 120 days of immersion. **Methods**: Thirty circular and twenty rectangular specimens of each material were randomly distributed in two groups: control - immersion in artificial saliva at 37˚C; and experimental - immersion in artificial saliva at 37ºC combined with immersion in the cleanser for 5 min. Hardness was measured using either a Vickers or Shore A hardness tester, and a surface roughness tester was used to measure the surface roughness. Tensile bond strength was carried out on a universal testing machine. Data were analyzed statistically by ANOVA or Kruskal-Wallis test ($\alpha = 0.05$). **Results**: No significant difference was found between the groups for the tested properties ($p > 0.05$). There was an increase in the hardness of both materials after 60 days ($p > 0.05$). No difference between the immersion periods was found for the roughness of Kooliner ($p > 0.05$), although the roughness of Elite Soft decreased after 120 days in both groups ($p > 0.05$). Kooliner presented higher tensile bond strength than Elite Soft ($p > 0.05$). **Conclusions**: Both materials showed alterations on the tested properties during the experimental period, but these changes were not promoted by the denture cleanser.

Key Words:
Acrylic resins, denture liners, denture cleanser, properties.

Introduction

The search for increased quality for patients who use removable dentures means improving adaptation of the bases after residual ridge resorption. Because of their resilience, soft denture liners provide a better distribution of functional loads on the denture foundation area, having a key role in modern removable prosthodontics because of their capacity to restore health to inflamed and injured mucosa[1-2].

Dentures made from two different materials can only be successful if there is an adequate bond between the materials[1]. However, the most common reason for failure of soft-lined dentures is the basic structural differences between the materials. Hardness is one of the most important properties of liners, with a direct impact on ductibility, malleability and resistance to abrasion. Surface roughness is also an important clinical property. A rough denture surface can lead to biofilm accumulation and colonization by *Candida albicans,* which the major etiologic factor for denture-induced stomatitis[2]. Nevertheless, these properties can be affected when the material is submitted to daily immersions in denture cleansers[3].

When immersed in soaking solutions or placed in the oral cavity, soft denture liners undergo two processes: leaching out of plasticizers and other soluble materials, and sorption of water or salivary components. The fluctuation between these two processes affects the properties of the denture liner material[4].

The use of denture liners has become popular in the fabrication of complete dentures. Therefore, in clinical practice, the choice for an appropriate denture liner, especially long-term materials as well efficient chemical cleanser that does not interfere with the liner's properties is of paramount importance. The purpose of this study was to evaluate hardness, roughness and tensile bond strength between a heat-processed acrylic resin and two

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different types of denture liners (a soft and a rigid one), following daily immersion in a sodium perborate effervescent cleansing solution.

Material and Methods

A self-curing reline acrylic resin (Kooliner; GC America, Inc., Alsip, IL, USA), and a elastomeric liner, (Elite Soft; Zhermack S.p.A., Badia Polesine, Italy) were selected for this study. The main components of Kooliner are poly(ethyl) methacrylate (powder) and isobutyl methacrylate (monomer), whereas Elite Soft is a two-component paste system composed by polyvinyl siloxane.

Hardness and Roughness

Thirty specimens of each material were obtained for analysis of each property, using a rectangular aluminum matrix containing circular moulds (20x4mm) fixed to a glass plate. The liners were processed according to the manufacturer's instructions, inserted in the moulds and manually compressed by another glass plate. After setting, the specimens were removed, and excess was trimmed with burs (Kooliner) or a sharp penknife (Elite Soft). Next, the specimens were randomly divided into two groups: G1 (control; n = 15) - immersion in artificial saliva at 37°C; and G2 (experimental; n = 15) - immersion in artificial saliva at 37°C combined with daily immersion for 5 min in a sodium perborate effervescent cleansing solution (Corega Tabs; Block Drug Company, Inc. Jersey City, NJ, USA). The artificial saliva was prepared at the School of Pharmaceutical Sciences of Ribeirão Preto, University of São Paulo, SP, Brazil, and had the following composition: potassium diacid phosphate, potassium dibasic phosphate, KCl, NaCl, $MgCl_2$ (6 H_2O), $CaCl_2$ (2 H_2O), NaF, 70% sorbitol, aromatizer and pigment, preservative (10 mL; nipagin/nipasol), inspissator, water q.s.p (1.0 L).

The hardness of Elite Soft was evaluated using a Shore A Durometer (Instrument and Manufacturing Co. Inc, Freeport, NY, USA) and the hardness of Kooliner was evaluated using a Vickers hardness tester (HMV-2, Shimadzu, Kyoto, Japan) immediately after finishing the specimens (T0) and after 60 days (T60) of immersion in the cleansing solution. Three indentations were made in each sample. Data were analyzed statistically by two-way ANOVA for each material. The significance level for all comparisons was set at $\alpha = 0.05$. Roughness (*Ra*) was evaluated in three areas of each specimen using a surface roughness tester (SJ 201-P, Mitutoyo, Kanagawa, Japan) with a 0.8 mm cutoff for an evaluated length of 4.0 mm. Roughness readings were made at T0 and after 120 days of immersion (T120) in the cleansing solution. Data were analyzed statistically by Kruskal-Wallis test at 5% significance level.

Tensile Bond Strength

Eighty blocks measuring 40 mm in length, 10 mm in height, and 10 mm thickness were fabricated from an PMMA specimens (Vipi, Dental Vipi Ltd. Ind., Pirassununga, SP, Brazil). Pairs of blocks with a 3-mm-thick layer of liner were then bonded in a sandwich configuration, providing 40 specimens measuring 83 mm in total length and with a cross-sectional area of 10 x 10 mm (Figure 1). Twenty specimens were prepared for each material (2 materials x 2 times x 2 groups x 5 repetitions = 40) (Figure 1).

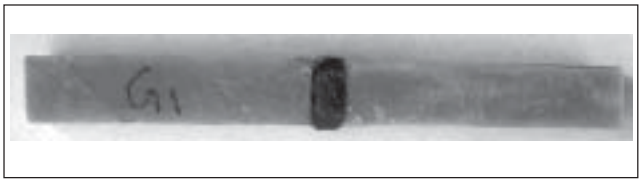

Fig. 1. *Specimen of acrylic resin and Elite Soft*

The PMMA specimens were prepared by investing polyurethane patterns measuring 40 mm x 10 mm and 3-mm-thick brass spacer in a denture flask. The patterns and the spacer were invested in a hard but flexible silicone rubber (Zetalabor; Zhermack S.p.A., Zhermack S.p.A., Badia Polesine, Italy) to allow easy removal of the processed specimens from the flask. After removal of the polyurethane dies, the PMMA specimens was mixed, packed into a mold with a brass spacer, and processed as recommended by the manufacturer in an automatic polymerization machine (Termocycler T-100, Ribeirão Preto, São Paulo, SP, Brazil). After heat polymerization, the brass spacer and the PMMA specimens were removed from the mold, trimmed, and the surfaces to be bonded with liners were prepared and treated according to the manufacturer's instructions for each denture liner. For Elite Soft, one coat of bonding agent was applied to the PMMA specimens. The interface of the acrylic resin specimens that was joined to Kooliner was prepared with burs (Tungsten point) for acrylic resin finishing.

The PMMA specimens were then returned to the molds, the denture liners were packed into the space created by the brass spacer and auto-cured, according to the manufacturers' directions. After curing, the specimens were removed from the flask and the denture liner was finished. The 20 specimens of each material were randomly divided into two groups according to the immersion protocol (n = 10; G1- control and G2 - experimental). For the tensile bond strength test, 5 specimens of each group were loaded until failure in a Universal Testing Machine (MEM 2000, EMIC, São José dos Pinhais, PR, Brazil) at a crosshead speed of 5 mm/min after 7 days (T7) and other 5 specimens after 60 (T60) days of immersion. Bond strength (MPa) was calculated as stress at failure divided by the cross-sectional area of the specimen. The results were tested by ANOVA test (material, time and groups). All data were analyzed at a 0.05 level of significance.

Results

Hardness and Roughness

Table 1 - Two-way ANOVA for hardness of the Kooliner and Elite Soft specimens.

Kooliner	Df	Sum of squares	Mean square	F	P. value
Groups (G)	1	9.2095	9.20	1.52	0.22
Error I	28	169.0958	6.03		
Immersion period (IP)	2	147.9866	73.99	84.50	0.00
G x IP	2	0.8889	0.44	0.51	0.39
Error II	56	49.0389	0.87		
Elite Soft	**Df**	**Sum of squares**	**Mean square**	**F**	**P. value**
Groups (G)	1	0.63	0.63	1.22	0.278
Error I	28	14.65	0.52		
Immersion Period (IP)	1	272.95	272.95	261.16	0.00
G x IP	1	0.46	0.46	0.88	0.357
Error II	28	29.26	1.04		

The analysis of variance of the data relative to the material's hardness indicated a statistically significant difference between the immersion periods (Table 1). There was no statistically significant difference between the groups. Hardness means and standard deviations of the tested materials in both evaluation periods are present in Figure 2.

The Kruskal-Wallis test did not show significant difference ($p > 0.05$) between immediate and 120-day immersion periods or with the use of the sodium perborate on Kooliner roughness. The roughness of Elite Soft reliner decreased significantly during the 120 days in both groups ($p < 0.05$). The use of the sodium perborate had no influence on the roughness of this material. Comparing both materials, Elite Soft presented a significantly lower roughness means ($p < 0.05$) than Kooliner. Roughness (mm) means and standard deviations of the tested materials in both evaluation periods are present in Table 2.

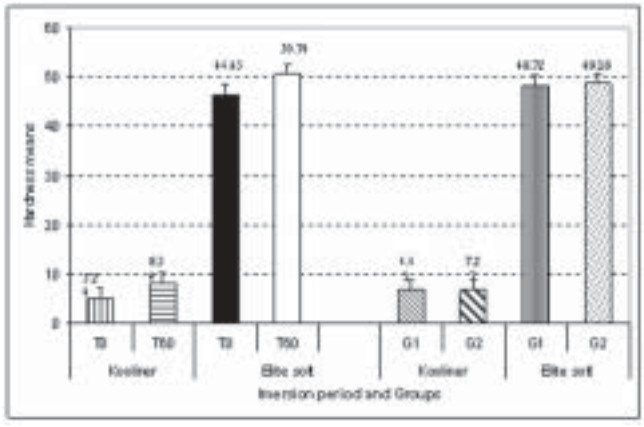

Fig. 2 - *Hardness means and standard deviations of the tested materials.*

Tensile Bond Strength

The results of ANOVA indicate significant differences between the tensile bond strength ($p < 0.05$) of the materials. Kooliner presented significantly higher bond strength means than Elite Soft in both groups. Regarding the immersion period, the mean bond strength of Kooliner ranged from 2.97 ± 0.47 (T7) to 2.62 ± 1.51 (T60) MPa in

Table 2 - Roughness means and standard deviations (SD) of the tested materials.

	Control group		Experimental group	
	T0	T120	T0	T120
Kooliner	2.15 (1.78) ^{aA}	1.42 (1.01) ^{aA}	1.52 (1.51) ^{aA}	1.07 (0.88) ^{aA}
Elite Soft	0.36 (0.16) ^{aB}	0.24 (0.06) ^{bB}	0.30 (0.05) ^{aB}	0.22 (0.03) ^{bB}

Different small letters mean statistical difference between times in each evaluation period
Different capital letters mean statistical difference between materials

GI, and from 2.67 ± 0.42 (T7) to 3.45 ± 1.10 (T60) MPa in GII. Elite Soft presented an increase in the mean bond strength throughout the 60 days in GI (T7 = 0.32 ± 0.20, T60 = 1.19 ± 0.29) and in GII (T7 = 0.43 ± 0.32, T60 = 1.16 ± 0.30). However, no statistical significance was any of the materials. There was no significant difference ($p > 0.05$) between the groups, which indicates that the denture cleanser solution did not affect the materials' bond strength.

Discussion

One of the most serious problems found in the use of denture liners is the adhesion failure between the liner and the denture base[4]. Some factors are expected to affect the bond between lining materials and denture bases, including aging in water, use of a primer with the lining material and the nature of the material base[4].

Hardness is one of the most challenging factors in the use of complete denture liners, since the most of them are not stable in a moist environment such as the mouth. The literature does not establish an ideal hardness value for resilient liners. Craig and Gibbons (1961)[5] suggested that the greater the softness, the greater the extension in absorbing the impact effect. Thus, less hardness is a desirable characteristic for soft liners.

According to the literature, the denture cleansing method is one of the factors that can modify the superficial characteristics of the liners[6]. The prosthesis should be immersed cleansing solutions in order to remove the biofilm from the liner's surface, which might increase the possibility of increasing the instability of the resilient materials.

Two structurally different materials were selected for comparison of the tensile bond strength: Kooliner (hard acrylic or polymethyl methacrylate resin) and Elite Soft relining (a silicone-based material). There are different methods for obtaining adhesion with acrylic resins. Kooliner has chemical affinity and Elite Soft relining requires the use of an adhesive to obtain this union. As acrylic resin-based materials present similar components when compared to the conventional acrylic resin, they form a molecular network that simultaneously penetrates in both union surfaces of similar compositions[7]. These findings can explain the results found in this work.

Kooliner presented the highest tensile bond strength means. This material does not have an adhesive in its kit, but a surface sealant is supplied. Sealant's application produces a pack that makes water absorption difficult and reduces the deterioration of the base, thus extending the material's useful life. Elite Soft relining is supplied with the adhesive and the sealant. The role of the adhesive is to increase the bond strength between the silicone-based soft liner and the acrylic resin. These results are similar to those of Aydin et al.[8].

In the present study, the significant difference found between the materials was apparently due to their individual characteristics, such as the capacity to humidify the surface of the thermopolymerized acrylic resin, properties and chemical composition[7]. The literature recommends that the tensile bond strength should not be less than 0.45 MPa in order to these materials be clinically used[9]. Considering this criterion, Kooliner seems to be the most indicated material. Although Elite Soft relining presented a lower mean initial bond strength than this value in both groups, at the end of 60 days the mean bond strength was higher than 0.45 MPa.

Regarding the immersion solutions, artificial saliva at 37ºC and artificial saliva with daily 5-min immersions in a denture cleanser, neither of the materials presented statistically significant difference when compared to immersion in the artificial saliva. Similar results were found by Rodrigues Garcia et al.[10], who stated that the bond strength increased throughout the 60 days in both evaluated groups. Such increase in the bond strength over time was also found by Craig and Gibbons[5] and Aydin et al.[8], and was attributed to the leaching out of the plasticizer, resulting in an increase of stiffness.

The favorable results found in this study about the use of the denture cleanser solution can be attributed to the fact that the solution does not contain any chemical component that affects the dissolution of the tested materials. Moreover, the thermopolymerized acrylic resin used contains "cross-linking" agents, whose function is to increase the resistance of solvents and surface stresses. However, other authors[2,4] have observed a weakness of the adhesion at the acrylic resin/liner interface in the presence of water. On the other hand, the authors found that diffusion of the water in the area of union between the acrylic resin and the liner did not have a deleterious effect in the adhesion capacity between the materials.

Since different materials were evaluated, an acrylic resin-based (Kooliner - hard) and a silicon-based (Elite Soft) material, we could not compare their hardness, but it was possible to compare their behavior regarding the use of the denture cleansing product (control and experimental) and the period of immersion (60 days). For both materials, it was observed that immersion in sodium perborate did not influence hardness significantly. These results are in agreement with those of Davenport et al.[11] and Haywood et al.[12]. Materials that present cross-linking agents in their composition demonstrate a greater hardness stability when stored in water. Unlike Elite Soft, Kooliner does not present this component. However, both materials presented the same behavior with the cleansing solution. Contradictory results were found by Pavan et al.[13]. These authors observed an increase in the hardness of resilient materials immersed in cleaning products. Tan et al.[14] and Botega et al.[15], on the other hand, demonstrated a decrease in the hardness of the tested silicon based liners after the treatment with different denture hygiene solutions. According to Davenport et al.[11], silicon-based materials do not possess plasticizers, but rather contain load in their composition,

and the water absorption caused by the presence of this component reduces the hardness.

Regarding the immersion time, a significant increase in the hardness could be noticed throughout the 60-day period in both groups for both materials. Polyzois and Frangou[16] verified an increase in hardness in all tested materials during the first month of immersion; after that period, the materials presented a stabilization of hardness values.

Hardness is a important property for resilient material and should remain constant for a long period so that the materials can efficiently fulfill their function. However, the findings in literature and the results of the present study show that time is a limiting factor. Studies must be conducted with the intention to increase hardness stability of resilient materials in such a way that its clinical indication is carried through with certainty. Although Kooliner is a hard liner, its hardness is well below that of acrylic resin, therefore offering a greater capacity to absorb impact. The ideal hardness or softness for providing a greater comfort to the patient can be obtained with the use of soft materials, but they still have many properties along with unstable use.

Surface roughness was determined based on the value of *Ra*, which represents the average of peaks and depressions on the surface, enabling us to evaluate the possibility of bacteria colonizing the area. This parameter was selected for being the most used in literature, allowing comparisons with the results of this study.

Previous studies have already mentioned alterations on the surface of liners when immersed in effervescent alkaline solutions. However, Nikawa et al.[17] and Jin et al.[18] affirmed that not only the active component, but also other components of the cleansing chemical agent as well as the pH can cause damage to the material. According to Jagger and Harrison[19], the effervescent hygiene agents have a chemical and a mechanical cleaning action, resulting in the production of bubbles created by oxygen release during the reaction, which could increase the material's surface roughness.

The materials evaluated in this study did not undergo a significant alteration in the surface roughness caused by immersion in sodium perborate throughout the 120 days of evaluation when compared to the immersion in artificial saliva for the same time. These results are in agreement with those found by Tan et al.[14]. The immersion time did not modify the surface roughness of Kooliner, but promoted a significant reduction in the surface roughness means of Elite Soft over the 120 days.

Regarding the roughness of soft liners, Rodrigues Garcia et al.[10] stated that apparently when these materials were immersed in cleansing products, a loss of soluble components occurred leaving empty voids or bubbles, which are responsible for surface roughness. These voids or bubbles underwent an increase in size that resulted in craters. The limits of the craters are probably smaller when compared to the bubbles, leaving the specimens smoother. Comparing the materials, Kooliner presented significantly higher means than Elite Soft. Pavan et al.[13] evaluated silicon- and acrylic resin-based liners and observed that the silicon presented surfaces that were smoother than the acrylic resin ones. These results were contrary to those of Zissis et al.[20]. The smoothness of the specimens produced by the glass plate used in the methodology of this study does not correspond to the clinical reality, as the glass provides a more polished surface compared to the denture processed using plaster models and the finishing that is provided by bur, sandpapers or polishing products.

The roughness difference of the silicon compared to the acrylic resin-based materials is probably related to their consistencies. Kooliner presents a more fluid consistency than Elite Soft and, although its application is easier, until the moment of flasking with the glass plate, the material is already more consistent, raising the hypothesis that Kooliner is less capable of reproducing the details of the extremely smooth glass surface on which the specimens were processed, thus providing higher roughness values.

Clinical factors as the oral environment and the conformation of the denture base were not considered. The results of in vitro investigations should be applied to the clinical conditions with caution. The final evaluation of the material's performance should be determined by means of clinical tests in vivo, in addition to performing the physical tests.

In conclusion, the use of sodium perborate did not modify the hardness, roughness and the tensile bond strength of the evaluated materials. Kooliner showed a greater increase in the tensile bond strength throughout the 60 days of immersion when compared to Elite Soft. Kooliner and Elite Soft presented a significant increase in the hardness values at the end of the 60 days in both groups. Only Elite Soft presented a reduction in the roughness values after 120 days of immersion. Both materials showed alterations on the properties tested during the experiment, but these changes were not promoted by the denture cleanser.

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