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Bond Strength and Degree of Infiltration between Acrylic Resin Denture Liner after Immersion in Effervescent Denture Cleanser

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Abstract

Purpose: The purpose of this study was to investigate the effect of sodium perborate on the bond strength and degree of infiltration between acrylic resin/resilient denture liners.
Materials and Methods: Three denture liners (Elite Soft, Mucopren Soft, Kooliner) were investigated. Twenty specimens ($83 \times 10 \times 10$ mm^3) of each material were made by processing the denture liners against two polymerized PMMA blocks. Ten specimens for each material were stored in artificial saliva at 37°C (control group: TBS1), and the other ten specimens were stored in artificial saliva at 37°C combined with sodium perborate (experimental group: TBS2). All specimens were placed under tension until failure in a Universal Testing Machine at a crosshead speed of 5 mm/min after 7 (T7) and 60 (T60) days ($n = 5$). Failure strength (MPa) was recorded, and mode of failure was characterized as cohesive, adhesive, or cohesive/adhesive. For the infiltration tests, ten circular specimens (14-mm diameter × 2-mm thick) of each material were stored in artificial saliva and 0.5% methylene blue at 37°C (control group: I1), and ten specimens were stored in artificial saliva and 0.5% methylene blue at 37°C combined with daily immersions for 5 minutes in an effervescent solution of sodium perborate (experimental group: I2). The degree of infiltration was obtained through photographs and using Software Image Tool after 120 days.
Results: For Kooliner, the statistical test did not show a significant difference in the bond strength due to the influence of the immersion period or to the use of sodium perborate. Elite Soft presented a significant increase in the average tension in T7 and in T60 in both TBS1 and TBS2. Inversely, the Mucopren suffered a significant decrease in the tension value in the same period as the TBS1 group as well as in the TBS2. The infiltration percentage was analyzed with the Kruskal–Wallis test (26.18; $p < 0.05$), which indicated significant differences between the compared averages for the groups. Comparing the averages of materials, the statistical test did not show significant differences between the control (I1) and experimental (I2) groups after 120 days.
Conclusions: The use of sodium perborate did not promote significant alterations in the evaluated properties. Kooliner presented the best results.

Resilient denture liners may be advantageous for patients who are capable of delivering a relatively heavy occlusal load to unfavorable denture-bearing tissues.[1] Resilient denture liners have several problems associated with their use, including loss of softness, change of permanent deformation characteristics, water absorption, colonization by *Candida albicans*, and bond failure between the liner and denture base,[2,3] which can promote the leakage of fluids between the liner and denture base,[4] creating potential surfaces for bacterial growth, biofilm, and calculus formation.[5] Therefore, frequent clinical evaluations and periodic replacement of resilient denture liners are required.

Effective denture biofilm control is indispensable for clinical use of these materials, because bacteria and yeasts from the biofilm are a major factor in the etiology of denture stomatitis.[6] Although chemical cleansing has been considered an effective method to prevent *C. albicans* invasion and denture biofilm formation, some types of denture cleansers have been reported to cause significant deterioration of tissue conditioners in a relatively short time.[7-9]

The use of liners has become consistent in the fabrication of complete dentures; however, many questions about the ideal resilient liner that improves patients' quality of life and that does not present alterations in its physical and mechanical properties when exposed to chemical cleansers have still not been clarified.

Based on these questions, the purpose of this study was to evaluate the bond strength and the degree of infiltration between resilient denture liners and acrylic resin to the base of dentures, after immersion in effervescent solution for cleaning. The hypothesis to be tested was that sodium perborate (denture cleanser) could cause adverse effects to the bond strength and infiltration between the denture lining and denture base acrylic resin.

Materials and methods

Three commercially available lining materials were used, all being chemically and structurally different. Their types, batch numbers, and manufacturers are presented in Table 1, as are other materials used in this study. Kooliner is a powder-liquid system and Elite Soft and Mucopren Soft are two component paste systems.

One hundred and twenty blocks of the acrylic resin (PMMA) measuring 40 mm in length, 10 mm in height, and 10-mm thick were prepared. The blocks were then bonded, 2 by 2, in a sandwich configuration with a 3-mm thick layer of the resilient lining material.[1] Consequently, 60 specimens measuring 83 mm in total length with a cross-sectional area of 10×10 mm^2 were created—20 specimens for each material (3 materials $\times$ 2 times $\times$ 2 groups $\times$ 5 repetitions = 60).

The PMMA specimens were prepared by investing polyurethane dies with $40 \times 10 \times 3$ mm^3 brass spacers in a denture flask. Dies and spacers were invested in hard but flexible silicone rubber (Zetalabor, Zhermack, Rovigo, Italy) to allow ease removal of the processed specimens from the flask (Fig 1A). After the removal of the polyurethane dies, the acrylic resin (Vipi, Table 1) was mixed, packed into a mold with a brass spacer, and processed in a water bath at 100°C for 20 minutes. After heat polymerization, the brass spacer and the PMMA resin specimens were removed from the mold; the PMMA resins were trimmed, and the surfaces to be bonded were treated according to the manufacturer's instructions for each resilient denture liner. For the Elite Soft and Mucopren materials, one coat of bonding agent was applied to the PMMA blocks, while for the Kooliner, the PMMA blocks were trimmed. The PMMA denture base resin specimens were returned to the molds, and the liners were packed into the space made by the brass spacer and autopolymerized according to the manufacturers' directions (Fig 1B). After polymerization, specimens were removed from the flask and trimmed[12] (Fig 1C).

The 20 specimens of each material were divided into two groups: control (TBS1 = immersion in artificial saliva at 37°C) and experimental (TBS2 = immersion in artificial saliva at 37°C combined with daily immersions for 5 minutes in sodium perborate effervescent solution). For the tensile test, specimens were loaded until failure in a Universal Testing Machine (MEM 2000, EMIC, São José dos Pinhais, Brazil) at a crosshead speed of 5 mm/min after 7 (T7) and 60 (T60) days of immersion (Fig 1D). Bond strength (MPa) was calculated as stress at failure divided by the cross-sectional area of the specimen. After visual observation, failure was recorded as either cohesive, adhesive, or both. Results were tested by multiple analysis of Kruskal–Wallis test at a 0.05 level of significance.

For the infiltration test, a mold was prepared from a disk-shaped metal master die (14 mm diameter $\times$ 2 mm thick), and with the help of this mold, specimens were produced. The heat-cured acrylic resin associated with liner specimens was prepared in the silicon for inclusion (Zetalabor) and stone molds (Herodent Soli-rock, Vigodent, Rio de Janeiro, Brazil) in denture flasks, 2 by 2, overlapped with each other. After the polymerization of the inclusion materials, the flask was opened, and the master die directed toward the base of the flask was removed for polymerization of the acrylic resin (Vipi) in accordance with the manufacturer's instructions. After cooling, the flask was opened, and the remaining master die and the specimens in acrylic resin were removed. The acrylic resin specimens were finished, the surface that would be in contact with the lining material was treated, and the specimen was repositioned in the flask's mold. The lining materials were prepared and conditioned in the molds on the acrylic resin specimens and were polymerized according to the manufacturer's instructions. In the end, 20 specimens were obtained for each material (14 mm diameter, 4 mm thick: 2 mm of acrylic resin and 2 mm of resilient liner). The specimens were randomly distributed into two groups: control (I1 = immersion in artificial saliva at 37°C and 0.5% methylene blue, in a 2:1 ratio) and experimental (I2 = immersion in artificial saliva at 37°C and 0.5% methylene blue, 2:1, combined with daily immersions for 5 minutes

Table 1 Materials used

Commercial name	Material	Manufacturer
Vipi	Heat-polymerized acrylic resin	Dental Vipi Ltda. Ind. Com. Imp. Exp. de Produtos Odont., Ind. Bras., Pirassunga, Brazil
Kooliner	Acrylic resin or polymethyl-methacrylate-based	GC America, Inc., Alsip, IL
Elite Soft	Silicone-based	Kettenbach, Eschenburg, Germany
Mucopren Soft	Silicone-based	Kettenbach
Corega Tabs	Sodium perborate effervescent tablet	Corega, Block Drug Company, Inc-USA, Jersey City, NJ

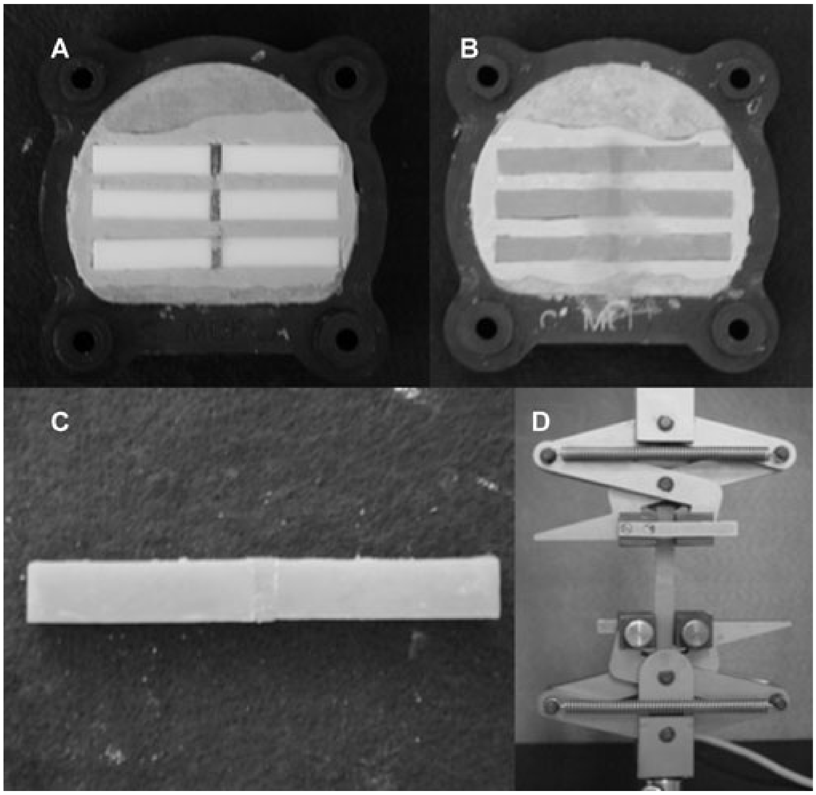

Figure 1 (A) Polyurethane master die and brass spacer flasking;. (B) acrylic resin blocks and denture liner after polymerization in the flask; (C) specimen of acrylic resin liner after finishing; (D) specimen positioned in the Universal Testing Machine.

in an effervescent solution of sodium perborate, Corega Tabs, Table 1) (3 materials × 1 time × 2 groups × 10 repetitions = 60). After 120 days of immersion (T120), the specimens were photographed (Coolpix 750, Nikon, Tokyo, Japan), and with the aid of Image Tool software (version 2.02, UTHSC, San Antonio, TX), the total area and the infiltrated area for methylene blue were measured to attain the infiltration percentage. To analyze Kooliner, it was necessary to separate it from the acrylic resin for shear, because of its opacity, which obstructed the reflection of light. The results were analyzed by the Kruskal–Wallis test to the level of 5%.

Results

The data obtained after the tensile test (Table 2) were evaluated by the Kruskal–Wallis test (100.27; $p < 0.05$), and the comparative averages are presented in Table 3.

For Kooliner, the statistical test did not show a significant difference in the bond strength due to the influence of the immersion period or to the use of sodium perborate. Elite Soft presented a significant increase in the average tension in T7 and in T60 in both TBS1 and TBS2. Inversely, the Mucopren (both TBS1 and TBS 2 groups) suffered a significant decrease in the tension value in the same period. Comparing the materials themselves, Mucopren showed high-tension values by T7, the opposite of Elite soft; however, after 60 days, both materials presented significantly equal values of tension. The Kooliner presented a greater stability of force throughout 60 days.

When examining the types and quantities of failure in the interface acrylic resin and liner, Elite Soft presented 32 (80%) adhesive failures and 8 (20%) adhesive/cohesive failures. Mucopren Soft presented 34 (85%) adhesive failures and 6 (15%) adhesive/cohesive failures. With Kooliner, all 40 specimens (100%) presented adhesive failures.

The infiltration percentage (Table 4) was analyzed with the Kruskal–Wallis test (26.18; $p < 0.05$), which indicated significant differences between the compared averages for the groups (Table 5).

Table 2 Tensile test (MPa): Kooliner, Elite Soft, and Mucopren Soft materials, control (TBS1) and experimental (TBS2) groups

	Kooliner		Elite Soft		Mucopren Soft	
	T7	T60	T7	T60	T7	T60
TBS1	3.5	2.65	0.58	1.0	8.85	1.53
	3.35	4.86	0.14	0.95	11.14	1.38
	2.47	2.96	0.13	1.51	6.44	1.49
	3.02	2.90	0.5	1.52	10.40	1.30
	2.51	2.5	0.25	1.0	5.71	0.7
TBS2	2.78	5.42	0.37	0.7	9.17	1.51
	2.50	1.00	0.30	1.30	9.49	1.18
	3.37	2.26	1.0	1.52	10.04	1.16
	2.48	4.58	0.18	1.2	8.61	0.6
	2.26	2.93	0.34	1.12	12.30	1.37

Table 3 Comparison of the means (MPa) after Kruskal–Wallis test

	TBS1		TBS2	
	T7	T60	T7	T60
Kooliner	2.97 ± 0.47^{aA}	3.17 ± 0.96^{aA}	2.67 ± 0.43^{aA}	3.23 ± 1.78^{aA}
Elite Soft	0.32 ± 0.21^{aB}	1.19 ± 0.29^{bB}	0.43 ± 0.32^{aB}	1.16 ± 0.30^{bB}
Mucopren Soft	8.50 ± 2.38^{aC}	1.28 ± 0.34^{bB}	9.92 ± 1.43^{aC}	1.16 ± 0.35^{bB}

Identical lowercase letters in row and uppercase letters in columns indicate no significant difference.

Table 4 Percentage of infiltration (%) presented by Kooliner, Elite Soft, and Mucopren specimens after 120 days of immersion in the control (I1) and experimental (I2) groups

Kooliner		Elite Soft		Mucopren Soft	
I1 (%)	I2 (%)	I1 (%)	I2 (%)	I1 (%)	I2 (%)
24.27	7.6	22.62	25.5	16.11	64.72
7.69	36.72	13.97	21.8	68.8	60.3
7.74	4.6	12.84	39.8	8.7	60
5.86	9.67	24.6	25	18.8	59.8
4.13	9.81	25.9	8.42	23.18	21.7
6.81	6.64	12.9	21	10.7	40
13.18	12.9	11.5	14.4	18	36.8
5.51	10.54	32	16.9	72.6	19
13.26	10.83	28.62	26	66	18.5
11.67	11.53	20.5	7.5	18.2	24.5

Table 5 Means (%) of the infiltration presented by three materials after 120 days of immersion in the control (I1) and experimental (I2) groups

Materials	I1	I2
Kooliner	10.01 ± 5.96^{aA}	12.08 ± 9.0^{aA}
Elite Soft	20.54 ± 7.37^{aB}	20.63 ± 9.52^{aB}
Mucopren	32.10 ± 25.92^{aB}	40.53 ± 19.15^{aC}

Identical lowercase letters in rows and uppercase letters in columns indicate no significant difference.

Comparing the averages of materials, the statistical test did not show significant differences between the control (I1) and experimental (I2) groups after 120 days.

When analyzing the groups, the Kooliner I1 group showed the lowest degree of infiltration when compared with the other materials in the I1 group. Mucopren Soft presented a greater infiltration percentage than Elite Soft, though not statistically significant. For the I2 group, the three materials presented significantly different behaviors; the greatest percentage of infiltration occurred with Mucopren and the lowest with Kooliner after 120 days of immersion (Fig 2).

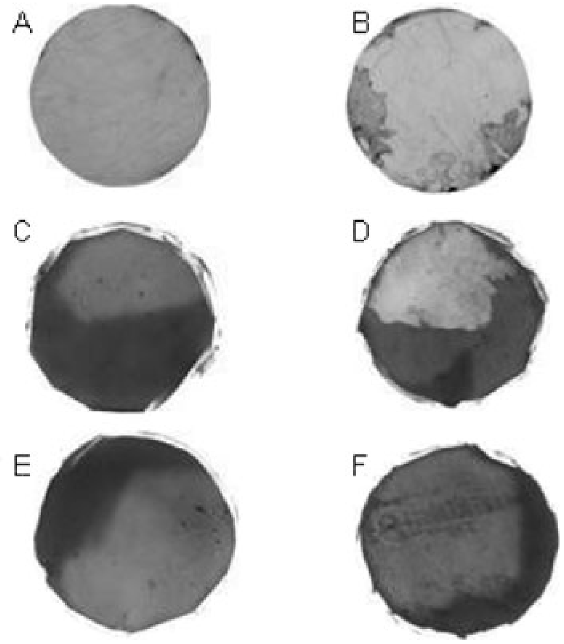

Figure 2 Specimens after immersion: (A) Kooliner control; (B) Kooliner experimental; (C) Mucopren control; (D) Mucopren experimental; (E) Elite control; (F) Elite experimental.

Discussion

The bond strength of denture lining materials to acrylic resin base has been evaluated by some researchers using tensile,[10-12] tensile and tear,[13,14] and peel tests.[15] In the present study, bond strength was measured by the tensile test.

Many techniques have been used to determine microleakage between dental materials: use of bacteria, compressed air, chemical tracers, electrochemical changes, autoradiographic studies, scanning electron microscopy (SEM), and die penetration.[16] Use of radioisotopes can provide finer detail in leakage patterns, as well as serve as a method to quantify and compare leakage values.[17] Radionuclide imaging is accepted as a gold standard in the physiological visualization of the human body and is a part of routine diagnostic imaging procedures.[18]

The infiltration property was also an objective of this study, in view of the fact that literature on this subject is limited.[4] To quantify the infiltration percentage, it was used a photographic methodology and measurement with the aid of Software Image Tool. For analysis of Kooliner, the separation of the two materials by means of shear was necessary, because the opacity of the material did not allow the passage of light for analysis of infiltration; however, after separation, it was possible to verify the infiltrated area (Fig 2).

In the present study, structurally different materials were selected for the comparison of the tensile strength values; each one possesses a distinct method of adhesion with the acrylic resin. Kooliner, which contains polymethylmethacrylate, presents chemical linking with the acrylic resin. Elite Soft and Mucopren Soft, silicon-based materials, need adhesive for attainment of the union. Sodium perborate (Corega Tabs) was used as an effervescent cleanser, because it has not been currently tested when compared with other solutions such as sodium hypochlorite and peroxides.[19-24] Moreover, Corega Tabs are the only commercially available material in the Brazil.

In relation to the period of analysis of the bond strength, the evaluation was made after 7 and 60 days, and infiltration after 120 days. The tested materials are recommended for permanent use (more than 1 year of use); longer periods of immersion should be the objective of other studies.

Elite Soft presented the lowest values of tension, with a significant increase after 60 days (Table 3). Mucopren Soft showed a rapid fall in the tension averages during the analyzed period, and Kooliner showed greater stability of force. When evaluating the silicon-based and acrylic resin-based lining materials, Aydin et al[25] found similar results; however, other authors have found inverse results.[14,26,27]

The causes that affect the union between the lining material and the acrylic resin can be the action of the water, the use of primer with the lining material, and the nature of the denture base material.[28,29] Kooliner does not possess an adhesive in its kit, but it has a surface sealant whose purpose is to produce a pack that makes water absorption difficult, avoiding the deterioration of the base, and thus increasing the lifetime of this material.[30] Elite Soft and Mucopren present the adhesive and the sealant. The use of adhesive has the objective of raising the values of the bond strength of the resilient lining material to the silicon base and the acrylic resin.

In addition to this, the acrylic resin-based lining materials present similar components to the acrylic resin that formed a molecule net that penetrates simultaneously into the two union surfaces of similar compositions;[29] this finding can explain the results found in this work. The results indicate that the necessary tension where failure occurred in the union was at least 0.32 MPa (Elite Soft), when observing all the investigated materials and groups. The literature recommends that the tension resistance not be lower than 0.45 MPa so that these lining materials can be used adequately.[5] Considering this, Elite Soft presented unsatisfactory initial values of tension resistance.

It is interesting to observe that, despite Kooliner having presented stability of force and high values of tension, the failures were all of the adhesive type (100%); similar results were found by Cucci et al[31] and Leles et al.[32] Elite Soft presented adhesive failures (n = 32, 80%) and adhesives/cohesive failures (n = 8, 20%). Mucopren Soft presented adhesive (n = 34, 85%) and (n = 6, 15%) adhesive/cohesive failures. Adhesive failure indicates a very satisfactory cohesive force of the mass of the material. This means that the cohesive resistance of the Mucopren Soft is superior to its adhesive resistance, indicating that the acrylic resin-based resilient lining materials, even when structurally similar to the acrylic resin, could contain in its kit an adhesive agent aiming to increase the union force. For Elite Soft, adhesive ruptures and adhesive/cohesive ruptures occurred. The adhesive/cohesive failures indicate that the balance between cohesive/adhesive force at the moment when the material starts to become unglued from the rigid base promotes the tearing of the material, indicating that its resilience is greater than its force of adhesion.[33]

The union bond strength increased during the 60 days for Kooliner and Elite Soft, even though it was not statistically significant. A similar result was also found by other authors,[12,25,34] and could have occurred due to the release of plasticizer resulting in the increase of the rigidity of the material.

The favorable results with the use of sodium perborate obtained in this study can be attributed to the fact that the immersion solution did not contain chemicals that affected the dissolution of the materials. Moreover, heat-cured acrylic resin, which contains "cross-linking" agents that have the ability to increase the resistance solvent and surface stresses,[35] was used. Other authors,[29,36-39] however, have observed a weakness in the adhesion of the interface between the acrylic resin bases and the lining in the presence of water. Other authors[14,25] cite that the diffusion of water in the place of union between the acrylic resin and the lining material did not have a deleterious effect on the capacity of adhesion between the materials.

Results of infiltration when the materials were compared with each other did not indicate influence of the immersion solution; neither did the values found for the control and experimental groups present significant differences. Mucopren demonstrated the highest values of infiltration; Elite presented intermediate values and Kooliner the lowest values.

The analyses of the adhesion force and degree of infiltration can be interrelated. For all materials, the use of sodium perborate did not cause alteration in both properties. Elite Soft presented minor values of tension and intermediate values of infiltration with the elapse of the time. The results are in accordance with those of Kulak-Ozkan et al[11] regarding the loss of plasticizer and other soluble components and water absorption and saliva for immersed relining in effervescent solutions for hygienic cleaning. The final balance of this process relates to how high the resilience is, which influences how much the dimensional stability of the prosthesis is affected. Polyzois[38] stated that the storage in water reduced adhesive force, consequently increasing the degree of infiltration of the resilient liner, similar to the occurrence with Mucopren Soft in this present research. Kooliner, being a similar material to the acrylic resin base, possesses good adhesion to the base material of the total prosthesis, indicating high values of tension, greater stability of force with the increase of the immersion time and, consequently, minor values of infiltration in the acrylic resin and liner interface. Although laboratory studies of the adhesive properties of the resilient materials try to simulate the clinical conditions in which the material would endure, tests in vitro cannot adequately simulate the clinical conditions in every detail. Clinical factors such as the oral environment and the conformation at the base of the set of teeth were not considered. The final evaluation of the performance of the material would have to be determined using in vivo clinical tests for a longer period in addition to the accomplishment of the physical tests.

Conclusions

Within the limitations of the current experiments, the following were concluded:

(1) Regarding bond strength, Mucopren Soft presented the highest values of tension in the initial period for control and experimental groups, and the bond strength fell for

both the groups throughout 60 days. Kooliner presented the highest values of tension, with a fast increase during the period and a greater stability of force. Elite Soft presented the lowest values of tension in the initial period for the control and experimental group, with a rapid increase during the period. The immersion time was relevant for alteration of the tension for all the materials, except for Kooliner.

(2) Concerning the degree of infiltration in the interface acrylic resin/resilient liner, Mucopren Soft presented the highest values of infiltration, while intermediate values were presented by Elite Soft, and the lowest values by the Kooliner. The immersion solution was not significantly relevant for the infiltration.

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