Effect of thermocycling on bond strength and elasticity of 4 long-term soft denture liners

José Renato Ribeiro Pinto, DDS, MS,a Marcelo Ferraz Mesquita, DDS, PhD,b Guilherme Elias Pessanha Henriques, DDS, PhD,c and Mauro Antônio de Arruda Nóbilo, DDS, PhDb
School of Dentistry, Paulista University, and School of Dentistry, State University of Campinas, Piracicaba, São Paulo, Brazil

Statement of problem. Two problems found in prostheses with soft liners are bond failure to the acrylic resin base and loss of elasticity due to material aging.

Purpose. This in vitro study evaluated the effect of thermocycling on the bond strength and elasticity of 4 long-term soft denture liners to acrylic resin bases.

Material and methods. Four soft lining materials (Molloplast-B, Flexor, Permasoft, and Pro Tech) and 2 acrylic resins (Classico and Lucitone 199) were processed for testing according to manufacturers’ instructions. Twenty rectangular specimens (10 × 10–mm2 cross-sectional area) and twenty cylinder specimens (12.7-mm diameter × 19.0-mm height) for each liner/resin combination were used for the tensile and deformation tests, respectively. Specimen shape and liner thickness were standardized. Samples were divided into a test group that was thermocycled 3000 times and a control group that was stored for 24 hours in water at 37°C. Mean bond strength, expressed in megapascals (MPa), was determined in the tensile test with the use of a universal testing machine at a crosshead speed of 5 mm/min. Elasticity, expressed as percent of permanent deformation, was calculated with an instrument for measuring permanent deformation described in ADA/ANSI specification 18.

Data from both tests were examined with 1-way analysis of variance and a Tukey test, with calculation of a Scheffe interval at a 95% confidence level.

Results. In the tensile test under control conditions, Molloplast-B (1.51 ± 0.28 MPa [mean ± SD]) and Pro Tech (1.44 ± 0.27 MPa) liners had higher bond strength values than the others (P < .05). With regard to the permanent deformation test, the lowest values were observed for Molloplast-B (0.48% ± 0.19%) and Flexor (0.44% ± 0.14%) (P < .05). Under thermocycling conditions, the highest bond strength occurred with Molloplast-B (1.37 ± 0.24 MPa) (P < .05). With regard to the deformation test, Flexor (0.46% ± 0.13%) and Molloplast-B (0.44% ± 0.17%) liners had lower deformation values than the others (P < .05).

Conclusion. The results of this in vitro study indicated that bond strength and permanent deformity values of the 4 soft denture liners tested varied according to their chemical composition. These tests are not completely valid for application to dental restorations because the forces they encounter are more closely related to shear and tear. However, the above protocol serves as a good method of investigation to evaluate differences between thermocycled and control groups. (J Prosthet Dent 2002;88:516-21.)

Clinical implications

Laboratory studies may simulate clinical conditions, but conditions are never exactly the same. With that in mind, the in vitro tests performed in this study were effective in evaluating bond strength and elasticity and ranking the materials accordingly.
liquid components. The composition of the powders and liquids is not well documented, but they are generally thought to be acrylic polymers and copolymers, along with a liquid containing an acrylic monomer and plasticizers (ethyl alcohol and/or ethyl acetate). It has been suggested that the initial softness of the plasticized acrylcs results from the large quantity of plasticizer in the liquid and that these plasticizers are responsible for maintaining material softness. The purpose of the plasticizer is to lower the glass transition temperature of the polymer to a value below mouth temperature so that the modulus of elasticity of the soft material is reduced to a satisfactory level. It is thought that leaching of plasticizers is responsible for hardening of the acrylic resin liner during storage.

Silicone elastomer materials are similar in composition to silicone-type impression materials. They are basically dimethylsiloxane polymers. Polydimethylsiloxane is a viscous liquid that can be cross-linked to form a rubber with good elastic properties. No plasticizer is necessary to produce a softening effect.

Soft denture liners have several problems associated with their use such as loss of softness, water absorption, colonization by Candida albicans, and adhesion failure between the liner and denture base. Bond failure also creates a potential surface for bacterial growth, plaque, and calculus formation; therefore frequent clinical evaluations and periodic replacement of soft denture liners are required.

The purpose of this study was to assess the effect of in vitro accelerated aging reproduced with thermocycling on the bond strength and elasticity of 4 commercially available soft denture liners and 2 heat-polymerized PMMA denture base resins by tensile and permanent deformation tests.

### MATERIAL AND METHODS

Four long-term soft denture liners (Table I) and 2 acrylic resins (Table II) were chosen. For the tensile test, 20 rectangular specimens with a $10 \times 10\text{mm}^2$ cross-sectional area were prepared for each soft liner and acrylic resin. PMMA specimens were prepared by investing brass dies with a 3-mm-thick spacer in a denture flask. The dies and spacers were invested in hard but flexible silicone rubber (Zetalabor; Zhermack, Badia Polesine, Rovigo, Italy) to allow for easy removal of the processed specimens from the flask. All of the dies and spacers were machined to the same dimensions to standardize the shape of the PMMA specimens and the thickness of the soft denture liners. Specimens were made by processing soft denture liners against heat-polymerized PMMA blocks, according to the manufacturer’s directions.

Acrylic resins were mixed, packed into a mold with a brass spacer, and processed in a water bath at 75°C for 9 hours. After heat polymerization, the brass spacer was removed from the mold, the PMMA resin specimens were trimmed, and the surfaces to be bonded were smoothed and treated according to the manufacturers’ directions for each soft denture liner. The PMMA blocks were returned to the molds (Fig. 1), and soft liners packed into the space made by the brass spacer, trial-packed, and heat-polymerized according to the manufacturers’ directions. When indicated, bonding agents supplied by manufacturers were used on the PMMA blocks. After heat polymerization, specimens were removed from the flask and any flash was trimmed with a sharp knife.

For the permanent deformation test, 20 cylindrical matrices ($12.7\text{mm}$ diameter $\times$ $19.0\text{mm}$ height) for each soft liner and acrylic resin were invested in hard but

### Table I. Soft denture liners: Commercial name, type, and manufacturer

<table>
<thead>
<tr>
<th>Brand</th>
<th>Material</th>
<th>Lot No.</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permasoft</td>
<td>Acrylic resin</td>
<td>049051</td>
<td>Austenal Inc. (Chicago, Ill)</td>
</tr>
<tr>
<td>Pro Tech</td>
<td>Acrylic resin</td>
<td>17752208</td>
<td>Professional Products Inc (Boca Raton, Fla)</td>
</tr>
<tr>
<td>Flexor</td>
<td>Silicone</td>
<td>918040</td>
<td>Schütz-Dental GmbH (Rosbach, Germany)</td>
</tr>
<tr>
<td>Molloplast-B</td>
<td>Silicone</td>
<td>990630</td>
<td>Detax GmbH &amp; Co KG (Ettingen, Germany)</td>
</tr>
</tbody>
</table>

### Table II. Acrylic resin bases: Commercial name, type, and manufacture

<table>
<thead>
<tr>
<th>Brand</th>
<th>Material</th>
<th>Lot No.</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classico</td>
<td>Acrylic resin</td>
<td>993040</td>
<td>Artigos Odontológicos Classico LTDA (São Paulo, Brazil)</td>
</tr>
<tr>
<td>Lucitone 199</td>
<td>Acrylic resin</td>
<td>Powder, 990507, liquid, 9905051</td>
<td>Dentsply International Inc (Milford, Del)</td>
</tr>
</tbody>
</table>
Flexible silicone rubber to allow for easy removal of the processed specimens from the flask (Fig. 2). Specimens were made by processing soft lining materials in the resulting mold according to the manufacturers’ directions.

Specimens were equally divided into 2 groups. One group received 3000 cycles in a thermocycler (MCT2 AMM Instrumental; Eríos, São Paulo, Brazil) with temperatures from 5°C to 55°C, followed by 60-second immersions in each bath. The other group acted as a control. Instead of thermocycling, this group was stored in water at 37°C.

For the tensile test, specimens were placed under tension until failure in a universal testing machine (DL-500 MF; EMIC, São José dos Pinhais, Paraná, Brazil), with a crosshead speed of 5 mm/min (Fig. 3). Bond strength was calculated as stress at failure divided by the cross-sectional area of the sample. After observation, failure was recorded as either cohesive, adhesive, or both.

Permanent deformation was measured with an instrument for measuring permanent deformation described in ADA/ANSI specification 18 (Fig. 4) under a compressive load of 750g for 30 seconds.12

Mean values were compared by the Tukey test. The values were compared by 1-way analysis of variance and a Scheffé interval at a 95% confidence level. Mean and SD were determined for all materials.

RESULTS

Figure 5 presents the bond strength of control and thermocycled soft lining materials regardless of acrylic resin. The mean bond strength of the control specimens ranged from 0.61 ± 0.13 MPa to 1.51 ± 0.30 MPa, with Permasoft at the lower end and Molloplast-B at the higher end. The mean bond strength of the thermocycled specimens ranged from 0.52 ± 0.10 MPa to 1.37 ± 0.13 MPa, with Permasoft at the lower end and Molloplast-B at the higher end.

Statistical analysis with a Scheffé interval at a 95% confidence level indicated that the Flexor and Permasoft groups were not statistically different when submitted to thermocycling. On the other hand, the Molloplast-B and Pro Tech groups were statistically different at a 95% confidence level. Consequently, thermocycling had a deleteri-
ous effect on the bond strengths of Molloplast-B and Pro Tech.

The mean bond strength of the 4 soft lining materials to the processed acrylic resins, regardless of thermocycling, was 1.01 ± 0.42 MPa. Statistical analysis with a Scheffe interval at a 95% confidence level indicated that the Classico and Lucitone 199 resins, regardless of thermocycling, were not statistically different. With regard to failure type, the Flexor group presented adhesive failure regardless of the sample treatment. The other groups presented both adhesive and cohesive failure.

Figure 6 presents mean permanent deformation values (in percentages) of control and thermocycled soft lining materials. Mean permanent deformation of control specimens ranged from 0.44% ± 0.14% to 1.62% ± 0.30%). Flexor had the lowest permanent deformation, and Permasoft the highest. Mean permanent deformation of thermocycled specimens ranged from 0.44% ± 0.17% to 3.06% ± 0.22%). Molloplast-B had the lowest permanent deformation, and Pro Tech the highest.

Statistical analysis with a Scheffe interval at a 95% confidence level indicated that Molloplast-B and Flexor groups were not significantly different (P > .05) when submitted to thermocycling; however, the Permasoft and Pro Tech groups were significantly different (P < .05). Thus thermocycling had a deleterious effect on permanent deformation of acrylic soft denture lining materials.

**DISCUSSION**

Debonding of soft denture lining materials and loss of elasticity are common for dentures in service. The bond strength of soft denture liners to PMMA denture base resins is weak. When separation does occur, the area may become unhygienic and nonfunctional. Ideally, soft denture liners should bind well enough to PMMA resin denture bases to avoid interface failure during the service life of the prosthesis. Viscoelastic properties of these materials are important for their cushioning effect, which allows a more even pressure distribution and maintenance of material shape. Results indicated that the bond strength and elasticity values of soft denture liners vary according to their chemical composition.

In this study the bond strength of 4 soft denture liners and 2 polymerized PMMA resins was determined by a tensile test. Elasticity of the soft denture liners was...
determined by a permanent deformation test. Both tests differ from the forces to which soft denture lining materials are clinically subjected; however, this in vitro study could sort the materials based on tensile and permanent deformation test results.9

Results of the tensile test indicated that the stress at failure was 0.52 MPa or higher for all materials investigated. A 4.5-kg/cm² (0.44 MPa) bond strength has been reported as acceptable for clinical use of soft denture lining materials.10 Consequently, all materials tested had satisfactory bond strength to polymerized PMMA denture bases.

Flexor’s failure was adhesive, which implies that the bond strength between the molecules of the liner was greater than that between the liner and PMMA resin. Permasoft had the weakest bond strength to the denture base resin, as failure was both adhesive and cohesive. This may indicate that the bond strengths among the liner molecules as well as between the liner and resin are nearly the same. In this situation, bond strength results must be interpreted with caution. Cohesive failure of soft lining material during testing provides information regarding the material itself instead of an accurate measure of bond strength.

Thermocycling had a deleterious effect on the bond strength of Molloplast-B and Pro Tech. Molloplast-B does not contain a plasticizer; however, it does contain filler. Absorption by the filler could lead to increased softness when stored in water.7 The Pro Tech material presented water absorption with time, and the leaching out of plasticizers from this material is responsible for its hardening during clinical use. This confirms the historical observations of Storer2 that acrylic-based, long-term soft lining materials tend to harden with time. Water absorption in the interface among PMMA denture base materials and soft lining materials decreased bond strength. Water may directly infiltrate the bond site, leading to swelling and consequent stress buildup at the denture base interface.

Thermocycling did not have a deleterious effect on the bond strength of Flexor and Permasoft liners. Flexor is a silicone soft denture liner like Molloplast-B; however, changes in its chemical structure may explain differences between the similar lining materials. Flexor probably absorbed less water than Molloplast-B. The Permasoft kit contains a sealer, which reduces water absorption and plasticizer loss. Surface-sealing soft denture liners may enhance the life of these liners and extend their period of resiliency.3,6

An adhesive is supplied with silicone-based soft denture liners in order to aid in bonding the liner to the resin denture base, as silicone denture base liners have little or no chemical adhesion to PMMA resins. Therefore the bond strength of silicone denture base liners depends on the tensile strength of the material and adhesive used.

Thermocycling does not alter the physical property of permanent deformation of either Flexor or Molloplast-B liners. Both are silicone soft lining materials, which implies that silicone liners have superior elastic recovery. Their softness is controlled by the amount of cross-linking in the rubber, and no plasticizer is necessary to produce a softening effect.3

Thermocycling had a deleterious effect on permanent deformation of acrylic soft lining materials (Permasoft and Pro Tech). These materials became harder with time. Leaching of plasticizers (ethyl alcohol and/or ethyl acetate) from the acrylic resin materials is probably responsible for their hardening during clinical use.4,5

Factors such as processing methods, water absorption, bonding agents, and changes in bond strength in the harsh oral environment need to be investigated further in order to predict which materials will provide the best clinical service.

Hardness, weight change, tensile strength, tear strength, and color stability are all properties of soft denture liners. Selection of a particular liner cannot be based on any single property. Material selection is influenced not only by the properties available but also by the particular situation being treated.10

This study was entirely laboratory-based. Because the most appropriate testing environment is the mouth, long-term clinical studies of these materials are required.

CONCLUSIONS

Within the limitations of this in vitro study, the tensile test indicated that thermocycling had a deleterious effect on bond strengths of Molloplast-B and Pro Tech liners and did not have a deleterious effect on the bond strengths of Flexor and Permasoft liners. However, greater union regardless of thermocycling was always obtained with Molloplast-B and Pro Tech.

The permanent deformation test indicated that, regardless of thermocycling, acrylic soft lining materials (Permasoft and Pro Tech) have more permanent deformation than silicone materials (Molloplast-B and Flexor). Thermocycling had a deleterious effect on the permanent deformation of acrylic soft lining materials and did not have a deleterious effect on the permanent deformation of silicone soft lining materials.

On the basis of this study, it can be anticipated that Molloplast-B would perform better clinically than the other soft lining materials tested, as it had greater bond strength and elasticity regardless of thermocycling.

REFERENCES

Noteworthy Abstracts of the Current Literature


**Purpose.** This study attempted to use clinical panoramic radiograms to determine variations in the vertical measurements in the maxilla and the mandible. It also assessed quantitatively the differences in measurements between dentate and edentulous jaws.

**Material and Methods.** A total of 192 alveolar ridges (96 dentate and 96 edentulous) were examined that included an equal distribution of men and women. The mean ages of the dentate and edentulous groups were 51.05 and 59.98 years, respectively. The author also attempted to account for medical and dental histories in the patient selection. Panoramic radiograms were included if the following criteria were met: (1) radiographic images of anatomic landmarks, such as the inferior and posterior borders of the mandible, must be distinct on at least one side; (2) there must be no gross distortion of images of the jaws; and (3) the space between maxillary and mandibular teeth must form an approximately horizontal space or a gentle arch, with the midpoint lower than the ends. Measurements were made from reference lines drawn from anatomic landmarks on standardized panoramic radiograms. One person was responsible for selecting the panoramic radiograms and performing the measurements.

**Results.** In the dentate group, there was no significant difference between men and women in the height of the maxilla. However, the height of the mandible was significantly greater in men than in women. Reductions in the height of the edentulous mandible and maxilla were significantly more pronounced in women than in men. The decrease in the vertical height of the maxilla was not significant in men.

**Conclusion.** Reductions in the heights of the edentulous mandible and maxilla were more pronounced in women than in men. No significant decrease in the vertical height of the maxilla was found in edentulous men.