Tensile Bond Strength between Soft Liners and Two Chemically Different Denture Base Materials: Effect of Thermocycling

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Abstract

Purpose: The bond strength of soft denture liner to a recently introduced denture base resin after thermocycling has not been compared to traditional denture base materials. The objective of this study was to investigate the effects of thermocycling on the tensile bond strength of soft denture liners to two chemically different denture base resins, polymethyl methacrylate (PMMA) and urethane dimethacrylate (UDMA).

Materials and Methods: A total of 48 PMMA and UDMA tensile test specimens were fabricated by attaching two different soft denture liners (Molloplast-B, Permaflex) according to the manufacturers’ instructions and assigned to two groups. Half of the specimens for each group were stored in water for 1 week, and the other half were thermocycled (5000 cycles) between baths of 5°C and 55°C. Specimens were mounted on a universal testing machine with a 5 mm/min crosshead speed. The data were analyzed with three-way ANOVA and post hoc Tukey–Kramer multiple comparisons tests (α = 0.05).

Results: The highest bond strength was measured in the specimens from the UDMA/Molloplast groups, and the lowest was seen in the PMMA/Permaflex group. No significant difference in bond strength was detected in PMMA/Permaflex groups after thermocycling (p = 0.082), whereas other groups exhibited significant differences after thermocycling (p < 0.05).

Conclusions: Thermocycling decreased the bond strength values in both the PMMA and UDMA groups. Regardless of types of soft liners, PMMA specimens presented lower bond strength values than UDMA specimens, both before and after thermocycling.

Over the past century, polymethyl methacrylate (PMMA) denture base resin has been the first choice of clinicians for denture fabrication due to its low cost, adequate esthetic properties, and ease of manipulation.1,2 In the 1980s, to overcome contact allergies and to eliminate flasking, boiling out, packing, and water-bath polymerization, light-activated urethane dimethacrylate (UDMA) denture base resin was developed as an alternative to PMMA.3–7 Furthermore, light-activated UDMA resin exhibited significantly improved mechanical properties such as transverse strength,8 impact strength,9 surface hardness,9 flexural modulus,9 and flexural strength,3,6,9 when compared to PMMA denture base polymers.

Denture base resin should have good mechanical properties and be able to be used together with denture teeth and a soft denture liner. To achieve more equal force distribution and reduce localized pressure by providing a cushion between the denture base and the supporting tissues, a soft denture liner is used on the intaglio surface of dentures.7–16 The optimum thickness for a liner is approximately 2.5 to 3 mm, which is needed to provide good shock absorption.13 In addition, liners aid in the retention of extraoral prostheses and intraoral devices by engaging overdenture-bar attachments and undercuts present in defect sites such as in maxillofacial obturators.11 There are two types of soft denture liner: plasticized acrylic resins and silicone elastomers.14,15 Silicone elastomer soft denture liner materials include dimethyl siloxane polymers, a viscous liquid that can be cross-linked to form a rubber with good elastic properties.7,17 Frequent debonding from denture bases due to the basic structural difference of the two materials is the primary weakness of silicone materials.7,18 Many researchers have attempted to provide a reliable bond between denture base resin and soft liner by using alumina abrading,14,16,18–21 lasers,7,14,15,18–21
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Table 1 Denture base materials and resilient liners used

<table>
<thead>
<tr>
<th>Brand name</th>
<th>Material type</th>
<th>Main composition</th>
<th>Manufacturer</th>
<th>Batch number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meliodent</td>
<td>Heat-cured denture base resin</td>
<td>PMMA</td>
<td>Bayer Dental, Newbury, UK</td>
<td>012335</td>
</tr>
<tr>
<td>Eclipse</td>
<td>Light-activated denture base resin</td>
<td>UDMA</td>
<td>Dentsply Trubyte, York, PA</td>
<td>090722</td>
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<tr>
<td>Molloplast-B</td>
<td>Heat-cured soft denture liner</td>
<td>Vinyl dimethyl polysiloxane</td>
<td>Detax GmbH &amp; Co KG, Ettlingen, Germany</td>
<td>130208</td>
</tr>
<tr>
<td>Permaflex</td>
<td>Heat-cured soft denture liner</td>
<td>Vinyl dimethyl polysiloxane</td>
<td>Kohler, Neuhausen, Germany</td>
<td>130101</td>
</tr>
</tbody>
</table>

chemical etching or primers, acrylic burs, and net woven glass fiber. Machado et al state, “Denture resins are routinely subjected to thermal stresses in the oral cavity, especially during the ingestion of hot and cold foods and beverages.” In an attempt to mimic the natural aging process of a dental restoration, thermocycling protocols have been suggested as efficient methods to provide in vitro simulation of in vivo conditions. The ISO/TR 11450 standard indicates that a thermocycling regimen comprising 500 cycles in water between 5°C and 55°C is an appropriate artificial aging test. Bonding properties of soft denture liners to both PMMA and UDMA denture base resins has been investigated. However, effects of thermocycling on bonding properties of specimens have not been evaluated. Therefore, the purpose of this study was to determine the effects of thermocycling on the tensile bond strength of two silicone-based soft denture liners and two chemically different denture base resins, heat-activated PMMA and light-activated UDMA. The null hypotheses were as follows: (1) the bond strength between soft denture liner and denture base resin is independent of the type of denture base resin and soft liner; and (2) the bond strength between soft denture liner and denture base resin is independent of thermocycling.

Materials and methods

Heat-cured PMMA resin, light-activated UDMA denture base system, and two silicone-based soft denture liners were used (Table 1).

Preparation of PMMA specimens

Specimen fabrication was described in a previous study. Dumbbell-shaped specimens (75 mm in length, 12 mm in diameter at the thickest section, and 7 mm at the thinnest section) were prepared in a manner similar to that used in conventional denture construction according to the manufacturer’s instructions. Then, 3 mm of the material was cut from the thin midsection (Fig 1) using a water-cooled diamond-edged saw (model no. 11-1280-250, Buhler Ltd., Lake Bluff, IL). The PMMA blocks were placed back into the molds, and Primo Adhesive (Detax GmbH & Co KG, Ettlingen, Germany) was applied on the surface of half the acrylic resins with a brush for Molloplast-B. The remaining acrylic resins received Permaflex (Kohler, Neuhausen, Germany) and no treatment: it does not require an adhesive, according to the manufacturer’s manual. The resilient denture liners were then packed into the space made by the brass spacer, trial packed, and polymerized according
Preparation of UDMA specimens

Specimen fabrication was described in a previous study. For easier adaptation of the material, the Eclipse baseplate resin and silicone mold were preheated (for 2 and 10 minutes, respectively) in a special oven (Eclipse Conditioning Oven; Dentsply Trubyte, York, PA) to 55°C. After the separating agent (Al-Cote; Dentsply Trubyte) was applied to the mold, the warmed resin was adapted into the mold using finger pressure. At that time, setup resin flowed into the center of the mold via a hot instrument (Electric Waxer; Dentsply). Specimens were warmed in a 55°C oven for 1 hour and coated with air barrier coating (Eclipse ABC, Dentsply Trubyte) to prevent oxygen from inhibiting polymerization. Specimens were placed in the center of the rotating table of the light-curing unit (Eclipse Processing Unit; Dentsply Trubyte), and a baseplate processing program was selected. High-intensity visible light (halogen lamps of 41 V) of a 400- to 500-nm wavelength resulted in deep polymerization of the material up to 8-mm thickness in 10 minutes. After polymerization of the specimens, finishing was performed. The procedures were the same as those used to prepare the PMMA specimens. A total of 24 UDMA test specimens were obtained.

Aging procedure

The specimens retrieved at 1 week of water storage were used as controls. They were left in distilled water at 37°C in a water bath machine (BM 402; Nüve, Ankara, Turkey). Half of the specimens in the groups were subjected to thermocycling (5000 cycles between 5°C and 55°C; Gökçeler Mechanical, Sivas, Turkey). The dwell time in the water bath was 30 seconds, and the transfer time was 7 seconds.

Tensile testing

Tensile debonding tests were performed on a universal testing machine (Lloyd LF Plus; Ametek Inc., Lloyd Instruments, Leicester, UK) at a 5 mm/min crosshead speed. For each specimen, the maximum tensile stress before failure was recorded, and the bond strength was calculated using the following equation:

$$ S = \frac{F}{A}, $$

where $F$ is the maximum force (N), and $A$ is a cross-sectional area (mm$^2$). Furthermore, debonded specimens were examined under a stereomicroscope (SMZ 800; Nikon, Tokyo, Japan) at $40\times$ magnification to evaluate the failure pattern and specified as cohesive (tearing within the resilient liner material), adhesive (total separation at the interface between the resilient liner material and the acrylic resin), or mixed (both adhesive and cohesive). All failure observations were conducted by one person. Three-way ANOVA and post hoc Tukey–Kramer multiple comparisons tests were used to compare results of the bond strength at a 95% confidence level ($p = 0.05$).

Results

The recorded tensile bond strength values for each treatment group are presented in Table 2. The highest bond strength was measured in the specimens from UDMA/Molloplast groups, and the lowest was seen in the PMMA/Permaflex group. Molloplast specimens exhibited higher bond strength values than Permaflex specimens. Bond strength values of PMMA/Molloplast, UDMA/Molloplast, and UDMA/Permaflex groups significantly decreased after thermocycling ($p = 0.016$, $p < 0.001$, and $p \leq 0.001$, respectively); however, no significant differences were found among the bond strength results for PMMA/Permaflex groups after thermocycling ($p = 0.082$).

Analysis of the data revealed significant differences in bond strength values when denture base resins were compared ($p < 0.001$, $F = 132.473$). PMMA specimens presented lower bond strength values than UDMA specimens both before and after thermocycling, regardless of the type of soft liner ($p < 0.001$, $F = 55.186$). In addition, bond strength values of specimens were affected by the type of soft denture liner, regardless of the type of denture base resin.

Failure types are presented in Table 3. Although there were some percentages of mixed failures in PMMA/Molloplast specimens, most of the failures were adhesive. Similarly, PMMA/Permaflex specimen failures were primarily adhesive. Moreover, most of the failures in UDMA/Permaflex specimens were adhesive (83.3% before thermocycling, 100% after thermocycling); however, mixed failure was predominantly present among UDMA/Molloplast specimens (66.6% before thermocycling and 75% after thermocycling).
Discussion

On the basis of the results, the first hypothesis that the bond strength between soft denture liner and denture base resin is independent of the type of denture base resin and soft liner was rejected. Furthermore, thermocycling adversely affected the bond between soft liner and denture base resin in all groups except the PMMA/Permaflex groups. Despite the bond strength of PMMA/Permaflex groups weakening after thermocycling, the difference was not statistically significant. Thus, the second hypothesis was partially accepted.

Effects of thermocycling on the bond strength of resilient liner and denture base resins are well-documented, and heat-cured PMMA denture base resins have frequently been investigated. To date, no studies have investigated the effect of thermocycling on the bond strength of the Eclipse denture base resin and soft denture liner. Thus, no direct comparisons can be made. Machado et al. investigated effects of thermocycling on flexural and impact strengths of the light-activated UDMA denture base resin, and they reported that thermocycling weakened the flexural and impact strengths of UDMA and high-impact denture base resins.

Kulak-Ozkan et al. found that tensile bond strength between Molloplast B liners and PMMA denture base resin showed a significant decrease after thermocycling (p = 0.01). The tensile bond strength of Permaflex also decreased after thermocycling, but this decrease was not found to be statistically significant. These results were in accordance with this study. Contrarily, Botega et al. found that thermocycling (3000 cycles) significantly increased bond strength in Dentuflex and PermaSoft liners, whereas it had no effect on Ufi-gel. Both Dentuflex and PermaSoft liners are cold-cure plasticized acrylic resins, which accounts for this difference. Thus, liner compositions were different than those used in this study. In addition, a chemical bond is constructed between the conventional PMMA denture base resin and the plasticized acrylic resin.

It has been reported that 3000 thermocycles correspond to a prosthesis in service for 33 months in vivo, assuming that patients consume three meals daily. Heat-cured silicone lining materials can last for 3 to 6 years. Resilient denture lining materials with 10 pounds per inch (0.45 MPa) bond strength are acceptable for clinical use. Considering this criterion, soft denture liners tested had satisfactory bond strength for both PMMA and UDMA denture base resins. Moreover, in this study, 5000 thermocycles were carried out for soft liners, and based on the results, they can be in service within clinically acceptable bond strength limits during their lifespan. Consistent with this study, Kulak-Ozkan et al. demonstrated that soft denture liners showed clinically acceptable bond strength values after 5000 thermocycles. Similar results were found by Leon et al. after 2000 thermocycles. In addition, the specimens underwent 3000 cycles in Hatamleh et al.’s study, and soft denture liners (Molloplast B) presented satisfactory bond strength values (0.71 MPa).

Reduction of the bond strength between soft liner and denture base resin can occur due to swelling and stress buildup at the bond interface or changed viscoelastic properties of the soft liner, which makes the material stiffer and transmits the external loads to the bond site. The results of this study are in accordance with the results of Mese and Guzel, who presented a decreased bond between soft liner and denture base resin after 6 months of water storage. Nevertheless, this study contradicts Aydin et al., who reported that the bond strength between soft liner and denture base resin is independent of 3 months of water storage.

Failure types of soft liners are important in interpreting the results of bond strength tests. When the material fails cohesively, it may be concluded that the strength of the material is lower than the strength of the bond. Consistent with Akin et al., UDMA/Molloplast specimens predominantly presented mixed failures, both before and after thermocycling (66.6% and 75%, respectively). Nevertheless, failures of the other groups of specimens were adhesive.

In this study, Molloplast B and Permaflex soft liner materials were used. According to the manufacturer’s instructions, Molloplast B should be used with an adhesive resin (Primo). This resin consists of γ-methacryloxy-propyltrimethoxysilane, which is a trialkoxysilane and one of the most studied silane compounds, especially for composite resin. However, Permaflex can be directly applied on the denture base resin. Thus, this study investigated the effects of long-term aging procedures on the bond strength of these soft liners and two chemically different denture base resins. In addition, the UDMA denture base resin system requires special equipment such as a special oven and a light-curing unit. The UDMA resin application procedure is more sophisticated and more expensive when compared to conventional PMMA resin because of this special equipment.

Various test methods have been used for the mechanical properties of soft relining materials and their bonding characteristics. Three methods are widely accepted: peel, lap-shear, and tensile testing. McCabe et al., employing both peel and tensile test methods, suggested that both test regimens are relevant and suitable for studying the bonding and debonding characteristics of soft polymers. The tensile test method, which was described by the American Society for Testing and Materials, was preferred in this study, and data obtained from such specimens were found significant for testing the effectiveness of different processing techniques and adhesive systems.

Conclusion

Within the limitations of this study, the following conclusions were drawn:

1. Thermocycling has a weakening effect on the bond strength values in both PMMA and UDMA groups.
2. UDMA groups presented higher bond strength values than PMMA groups.
3. Regardless of denture base resin (PMMA or UDMA), the Molloplast soft denture liner has more favorable bonding properties than the Permaflex soft denture liner.

Clinical relevance: Tested soft denture liners demonstrated clinically acceptable bond strength values before and after thermocycling for both heat-cured PMMA and light-activated UDMA denture base resins.
References