



Investigation of bonding properties of denture bases to silicone-based soft denture liner immersed in isobutyl methacrylate and 2-hydroxyethyl methacrylate

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PURPOSE. The purpose of this study was to investigate the bonding properties of denture bases to silicone-based soft denture liners immersed in isobutyl methacrylate (iBMA) and 2-hydroxyethyl methacrylate (HEMA) for various lengths of time. **MATERIALS AND METHODS.** Polymethyl methacrylate (PMMA) test specimens were fabricated (75 mm in length, 12 mm in diameter at the thickest section, and 7 mm at the thinnest section) and then randomly assigned to five groups (n=15); untreated (Group 1), resilient liner immersed in iBMA for 1 minute (Group 2), resilient liner immersed in iBMA for 3 minutes (Group 3), resilient liner immersed in HEMA for 1 minute (Group 4), and resilient liner immersed in HEMA for 3 minutes (Group 5). The resilient liner specimens were processed between 2 PMMA blocks. Bonding strength of the liners to PMMA was compared by tensile test with a universal testing machine at a crosshead speed of 5 mm/min. Data were evaluated by 1-way ANOVA and post hoc Tukey-Kramer multiple comparisons tests ($\alpha=0.05$). **RESULTS.** The highest mean value of force was observed in Group 3 specimens. The differences between groups were statistically significant ($P<.05$), except between Group 1 and Group 4 ($P=.063$). **CONCLUSION.** Immersion of silicone-based soft denture liners in iBMA for 3 minutes doubled the tensile bond strength between the silicone soft liner and PMMA denture base materials compared to the control group. [*J Adv Prosthodont 2014;6:121-5*]

KEY WORDS: Isobutyl methacrylate; 2-hydroxyethyl methacrylate; Soft denture liner; Bond strength

INTRODUCTION

Denture soft lining materials are used in prosthodontics to provide a cushioning layer on the fitting surface of a com-

plete denture¹ in the management of traumatized oral mucosa, bruxism, chronic soreness, residual ridge atrophy or resorption, relatively thin and nonresilient mucosa,² bony undercuts, and for congenital or acquired oral defects requiring obturation.^{3,4} Additional uses of soft denture liners have emerged in the last few years for transitional prostheses after implant surgery⁵ When these materials come into contact with fibromucous membranes, they act as shock absorbers, allowing improved comfort and a more homogeneous distribution of occlusal loading forces.³

There are 2 types of resilient lining materials: plasticized acrylic resins and silicone elastomers.^{2,6} Acrylic resin-based liners contain plasticizers which are responsible for material softness and the leaching of them results in hardening of the liner with time. Silicone-based soft denture liners do not require an external plasticizer⁷ and inherently soft over a long period.^{4,8} Furthermore, both autopolymerizing and heat-polymerizing forms of liners are available.²

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Silicone-based soft denture liners are similar in composition to silicone impression materials. Both are dimethylsiloxane polymers.⁵ Polymethyl methacrylate (PMMA) denture base resins and silicone-based lining materials have different molecular structures and they cannot be chemically bonded. A reliable bond between denture bases and soft liner is required for the denture to function properly. Therefore, researchers have attempted to identify other methods to improve the PMMA/resilient liner bond.^{4,9-16} In the dental literature, the difficulty of obtaining a reliable bond between soft relining materials and PMMA denture base polymers has often been discussed.¹⁷ Several studies have been conducted to increase bond strength between liners and acrylics by improving roughness at the acrylic interface using lasers,^{1,4,9,14} alumina abrading,^{4,9,10,15,18} chemical etching or primers, acrylic burs, and net woven glass fiber.¹⁹

Both 2-hydroxyethyl methacrylate (HEMA)^{20,21} and isobutyl methacrylate (iBMA)^{22,23} were used to improve the mechanical properties of PMMA. According to Johnson and Jones,¹⁸ increasing the concentration of ethyl and butyl methacrylates resulted in a linear decrease in the mechanical properties measured except molecular weight. Moreover, Vargün *et al.*²⁴ researched on PMMA copolymerized with HEMA and reported that glass transition temperatures of copolymers were decreased from 119°C to 100°C with an increasing amount of HEMA. The T_g of PMMA is lowered by copolymerization with HEMA, which may ease the processing conditions.

Many of the studies have measured the bond strength between the resilient liners and the denture base materials with peel, shear, tear, and tensile bond tests.^{11,25-27} The measured bond strength of resilient liners to PMMA is dependent on the nature of the test method used.^{25,28}

The purpose of this study was to investigate the bonding properties of denture bases to silicone-based soft denture liners immersed in iBMA and HEMA for various lengths of time. The hypothesis tested was that immersion of resilient lining materials into HEMA and iBMA is not an effective method to improve the strength of the bond between resilient liners and PMMA.

MATERIALS AND METHODS

A silicone-based soft liner (Lot number: 08034, Permaflex; Kohler, Neuhausen, Germany) and a heat-cured acrylic resin (Lot number: 01.06.30 275, Paladent; Heraeus Kulzer, Hanau, Germany) were used in this study. For tensile bond strength testing of specimens, gypsum (Moldabaster S; Heraeus Kulzer GmbH, Hanau, Germany) molds were prepared with dumbbell-shaped brass patterns, 75 mm in length, 12 mm in diameter at the thickest section, and 7 mm at the thinnest section. The heat-cured specimens were prepared in the molds in denture flasks and were cured in a manner similar to that used in conventional denture construction according to the manufacturer's instructions. Then, 3 mm of the material were cut off from the thin

midsection using a water-cooled diamond edge saw (Model No. 11-1280-250; Buhler Ltd., Lake Bluff, IL, USA). Finally, 120 test specimens were prepared. In addition, the PMMA blocks were placed back into the molds and specimens were randomly assigned to five groups (n=15), according to resilient liners immersed into chemical materials.

- Group 1: No treatment was applied to the resilient liners, this group served as the control.
- Group 2: Resilient liners were immersed into iBMA (lot&filling code:1209946 34506146, Sigma-Aldrich Chemie GmbH; Buchs, Switzerland) for 1 minute.
- Group 3: Resilient liners were immersed into iBMA (Sigma-Aldrich Chemie GmbH; Buchs, Switzerland) for 3 minutes.
- Group 4: Resilient liners were immersed into HEMA (lot number: 64190, Merck KGaA; Darmstadt, Germany) for 1 minute.
- Group 5: Resilient liners were immersed into HEMA (Merck KGaA; Darmstadt, Germany) for 3 minutes.

For each group, 10 g resilient liner was put into a glass and a chemical solution (iBMA or HEMA) was poured in to the glass until the resilient liner was completely covered with the chemical solution. After immersion procedures, relining materials were packed into the space in the molds. The specimens and relining materials were then polymerized according to manufacturer's instructions (2 H in boiling water). The processed molds were left to cool at room temperature for 20 minutes, and then placed under running tap water for 10 minutes. Then, specimens were stored in distilled water at 37°C for one week. All specimens were placed under tension until failure in a universal testing machine (Lloyd LF Plus; Ametek Inc, Lloyd Instruments, Leicester, UK) at a crosshead speed of 5 mm/min. The maximum tensile stress before failure was recorded for each specimen. Failure strength was recorded in Newtons. Modes of failure was visually determined for every specimen after testing and categorized into one of the following types: *Adhesive failure*; refers to total separation at the interface between the resilient liner material and acrylic resin, *cohesive failure*; refers to tears within the resilient liner material, and *mixed failure*; refers to both.

The mean value and standard deviation of the specimens were statistically evaluated by 1-way ANOVA and post hoc Tukey-Kramer multiple comparison tests ($\alpha=0.05$) by using a SPSS statistical software program (version 13.0, SPSS Inc., Chicago, IL, USA).

RESULTS

Statistical results for tensile bond strength measurements of the groups are summarized in Table 1. The results of the 1-way ANOVA was $F=582.184$, $P=.05$. The highest mean value of (tensile) force was observed in Group 3 specimens, followed by Group 2 specimens. Tukey's HSD test showed that the differences between Group 1 and Groups 2, 3, and 5 were found statistically significant ($P<.001$), whereas there was no significant difference in

Table 1. Mean tensile bond strength and SD of each group

Groups	Mean (N)	SD
Group 1	25.25 ^a	2.09
Group 2	39.59 ^b	1.55
Group 3	56.85 ^c	2.24
Group 4	27.26 ^a	1.67
Group 5	33.73 ^d	2.46

*n=15 and groups with same superscripted letters not significantly different ($P > .05$).

Table 2. Mode of failures of groups for each specimen

Groups	n	Adhesive failure	Cohesive failure	Mixed failure
Group 1	15	12	1	2
Group 2	15	15	–	–
Group 3	15	15	–	–
Group 4	15	10	1	4
Group 5	15	10	–	5

bond strength between Groups 1 and 4 ($P = .063$). Analysis of the data also revealed significant differences between Groups 2 and 3 ($P < .001$) and Groups 4 and 5 ($P < .001$).

Modes of failure are presented in Table 2. All specimens of the groups dominated in adhesive failures. 80% of Group 1 specimens, 100% of Group 2 and 3 specimens, and 66% of Group 4 and 5 specimens presented adhesive failures. Moreover, it can be seen that elongation of the resilient liner was the highest degree in Groups 2 and 3 (Fig. 1, Fig. 2, Fig. 3, Fig. 4, and Fig. 5). Both cohesive and mixed failures were prevented by iBMA immersion.

DISCUSSION

The results of the present study support rejection of the hypothesis because immersion of resilient lining materials into HEMA and iBMA is an effective method to improve strength of the bond between resilient liners and PMMA. However, immersion of resilient liner into HEMA for 1 min was found to be ineffective for increasing the strength of the bond. In the literature, there are no studies about resilient liner treatments with chemical materials. However, only a few studies have been conducted on treatment of

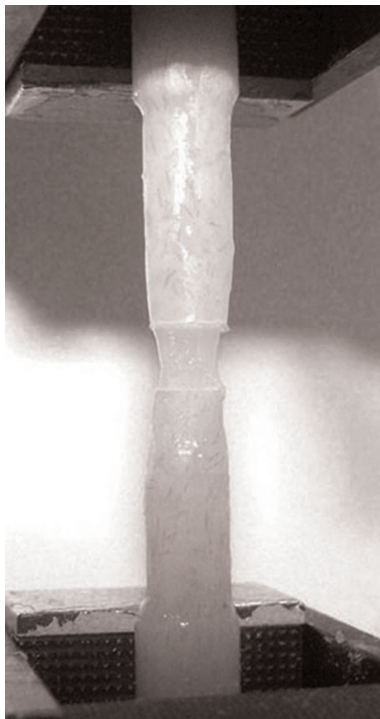


Fig. 1. Elongation of resilient liner in control group.

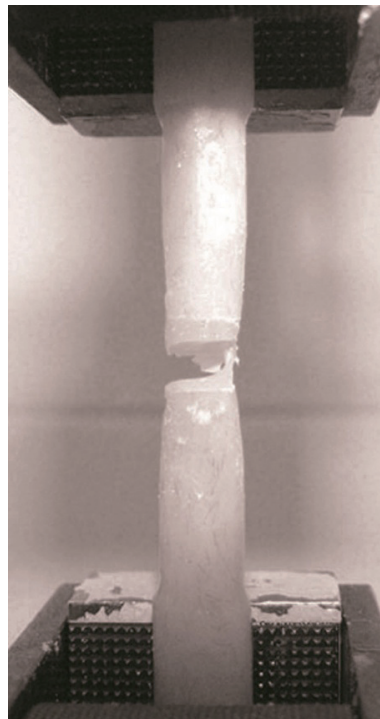


Fig. 2. Cohesive failure of resilient liner in control group.

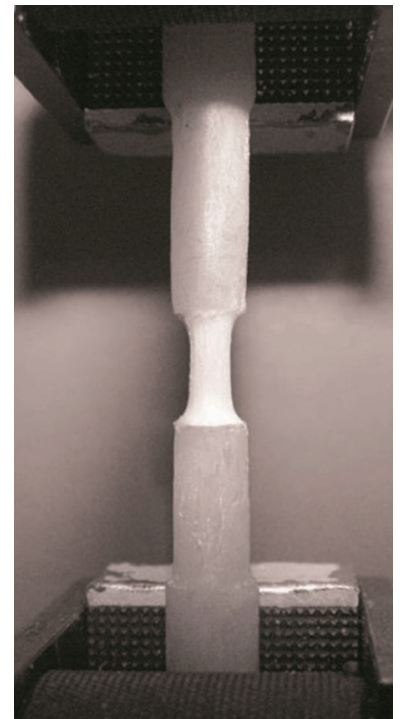


Fig. 3. Elongation of resilient liner in Group 3.

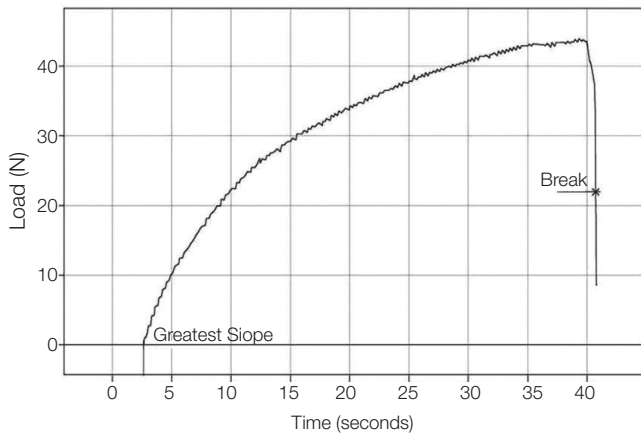


Fig. 4. Time-load graphic of the control group of the specimen under tensile force.

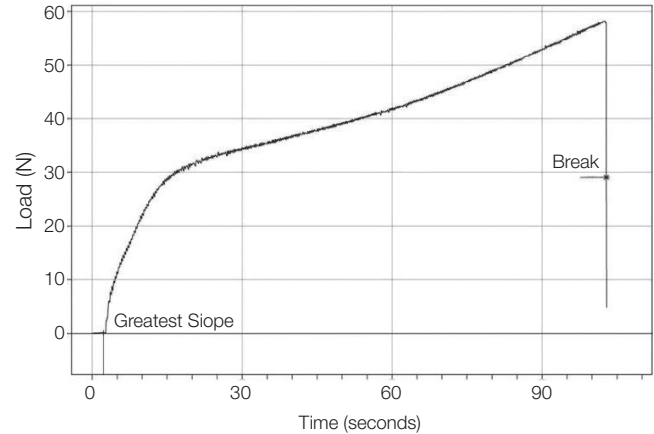


Fig. 5. Time-load graphic of the iBMA group (Group 3) of the specimens under tensile force.

PMMA with chemical materials including HEMA and iBMA.²⁰⁻²³ In addition, Keyf *et al.*²¹ advocated that surface treatment process of glass fiber with HEMA monomer and air atmosphere increased the transverse strength and the maximal deflection of a provisional fixed partial denture resin. Furthermore, a conventional heat-polymerized denture base polymer powder was mixed with ethyl, isobutyl and tert-butyl methacrylate monomers respectively by Doğan *et al.*²² They found that there was no difference in tensile strengths between the polyacrylates and the control group. In addition, Çökeller *et al.*²⁰ evaluates the effect of plasma treated E-glass fiber to improve the mechanical properties of PMMA and used three different types of monomer HEMA, triethyleneglycoldimethylether (TEGDME) and ethylenediamine (EDA). They found that there was no statistical difference in the flexural strength between HEMA treated groups and untreated groups. Moreover, Leles *et al.*²³ treated bonding surfaces of hard chairside relin resin and denture base material with methyl methacrylate (MMA) monomer, iBMA monomer, chloroform, acetone, and experimental adhesive. They reported that MMA monomer and chloroform surface treatments produced the highest mean transverse bond strengths, and this was followed by iBMA monomer. The results of the present study were consistent with that of Keyf *et al.*²¹ however, contradicted with those of Çökeller *et al.*,²⁰ Doğan *et al.*,²² and Leles *et al.*²³ Furthermore, Leles *et al.*²³ performed surface treatment with iBMA for 180 seconds. Thus, in a preliminary study, 1, 2, 3, and 5 minutes were carried out for immersion time of soft liner. Based on the results of this preliminary study, 1 minute and 3 minutes immersion time were used in the present study.

Effective bond strength between liners and denture bases can be characterized by either high bond values or cohesive bond failures within the lining material.¹⁷ Usumez *et al.*⁴

reported that lased specimens predominated in mixed failures, but control and alumina-abraded specimens showed adhesive failures. Moreover, according to Kulak-Ozkan *et al.*⁷ 34 showed adhesive failures, 15 showed cohesive failures, and 23 showed mixed failures out of 72 specimens. In addition, Hatamleh *et al.*¹⁹ reported that all specimens exhibited cohesive failure only because of net fibers. In the present study, in accordance with Usumez *et al.*⁴ iBMA groups showed the highest bond strength and adhesive failure only. This result was not in accordance with those of Kulak-Ozkan *et al.*⁷ and Hatamleh *et al.*¹⁹ These findings are understandable and can be explained in that the molecular binding of the resilient liner was improved. According to the results of the present study, the iBMA immersion of soft liners significantly increased the tensile strength of the specimens, while all the specimens revealed adhesive failure. It is seldom that specimens with the highest bond strength demonstrate adhesive failure. The explanation of these results is that the physical properties of liners are changed after iBMA immersion. Moreover, it can be seen that elongation of the resilient liner after being immersed into iBMA was higher than both the control and HEMA groups. This indicates that iBMA enables resilient liners to be more resistant against tears or ruptures which is greater than tensile bond strength between resilient liners and PMMA. Therefore, 100% adhesive failures were seen in the iBMA specimens. In addition, another explanation takes into account the increase in tensile bond strength between liners and PMMA. The molecules in the PMMA and chemical materials interacted with each other. Methacrylate substances with high numbers of alkyl groups could interact with C-H groups and form hydrogen bonds. Moreover, application of chemical agents possessing solvent effects on the acrylic resin can cause the formation of roughened surfaces, and this in turn, positively affects the strength of the

bond. FTIR is important for determination of the secondary interactions and study of molecular structure.¹² However, FTIR analysis could not be performed on the specimens, because the soft structure of the liner prevents getting samples from it for analysis.

On the other hand, researchers^{2,4,14,17} studied on the bond strength of relining materials to denture base without aging procedures. Furthermore, Kulak-Ozkan *et al.*⁷ investigated the effect of thermocycling on tensile bond strength of six silicone-based soft denture liners and no significant difference in tensile bond strength of Permaflex was found after thermocycling. Thus, in the present study, aging of the specimens was not performed.

CONCLUSION

Within the limitations of this study, chemical treatment of soft denture liner before packing denture base resin could be performed as a part of denture fabrication.

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