# The Effects of Maleic Anhydride Terpolymer and its Ester Derivatives on Tensile Bond Strength Between the Acrylic Resin and Resilient Lining Material

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**ABSTRACT:** The present study investigated the effects on the bonding between the denture base acrylic resin and the soft silicon based lining material of maleic anhydride-styrene-vinyl acetate (MA-St-VA) terpolymer and some of its ester derivatives. These ester derivatives were *n*-propylmaleate-styrene-vinyl acetate (*n*-PrMA-St-VA), *n*-buthylmaleate-styrene-vinyl acetate (*n*-BuMA-St-VA) and *n*-benzylmaleate-styrene-vinyl acetate (*n*-BzMA-St-VA). Fourier Transform infrared spectroscopy method was used to determine interactions between terpolymers with the acrylic resin and soft lining material. The tensile bond strength of all the groups was compared and the obtained differences were statistically significant ($P < 0.05$). The highest value was found for the samples lined with *n*-BuMA-St-VA (2.11 ± 0.21 MPa) and the samples lined with *n*-BzMA-St-VA had the lowest bond strength (0.3 ± 0.12 MPa). © 2007 Wiley Periodicals, Inc. J Appl Polym Sci 104: 1338–1341, 2007

**Key words:** poly (methyl methacrylate); lining material; interfacial adhesion; maleic anhydride

## INTRODUCTION

Acrylic resin is commonly used as a denture base material dentistry. In some cases, for example, if patients are not able to tolerate the hard denture base, the soft lining materials are used in the inner surface of denture base. The resilience of these materials can absorb the occurring active forces during chewing and they disperse these forces from the alveolar ridge to wider surface area. Hence, the use of denture by patients becomes easy.[1,2] Soft denture liners have several problems associated with their use, such as loss of softness, colonization by *Candida albicans*, porosity, debonding of liner from base, etc. Among these problems, adhesion failure between silicone resilient denture lining materials and the denture base is commonly encountered in clinical practice.[3,4]

In general, the bonding between the acrylic resins and silicon based soft liner materials possess poor adhesion characteristics. Several publications have focused on the factors that can affect bonding, including the nature and direction of debonding force, and liner thickness, the nature adhesive agent, and variations in the structure of the acrylic resin denture base.[5–7] Many researchers have measured the bond strength between the soft liner and the acrylic resin materials by using peel, shear and tensile bond tests. It has been shown that the measured bond strength of soft liners to acrylic is dependent on the type of testing method used. The tensile bond strength test is a good method of investigating the bond strength of soft lining materials.[8–10]

Many studies have been performed on the use of reactive interfacial agents to improve interfacial adhesion. The reactive interfacial agents have specific functional groups. However, research on the detailed understanding of the enhancement of interfacial properties resulting from reactive compatibilization is very limited.[11–13]

Maleic functional compounds have wide ranging applications as additives to promote adhesion and compatibility.[14,15] Lee and Char have shown that the interfacial adhesion between polyamide and polystyrene was enhanced by the addition of thin layers of maleic anhydride-styrene random copolymer.[16] On the other hand, we investigated the effects on the bonding between the denture base acrylic resin and the soft silicon based lining material of maleic anhydride-styrene-vinyl acetate (MA-St-VA) terpolymer and some of its ester derivatives.

## EXPERIMENTAL

### Materials

MA-St-VA terpolymer and some of its ester derivatives used in this study were synthesized and char-

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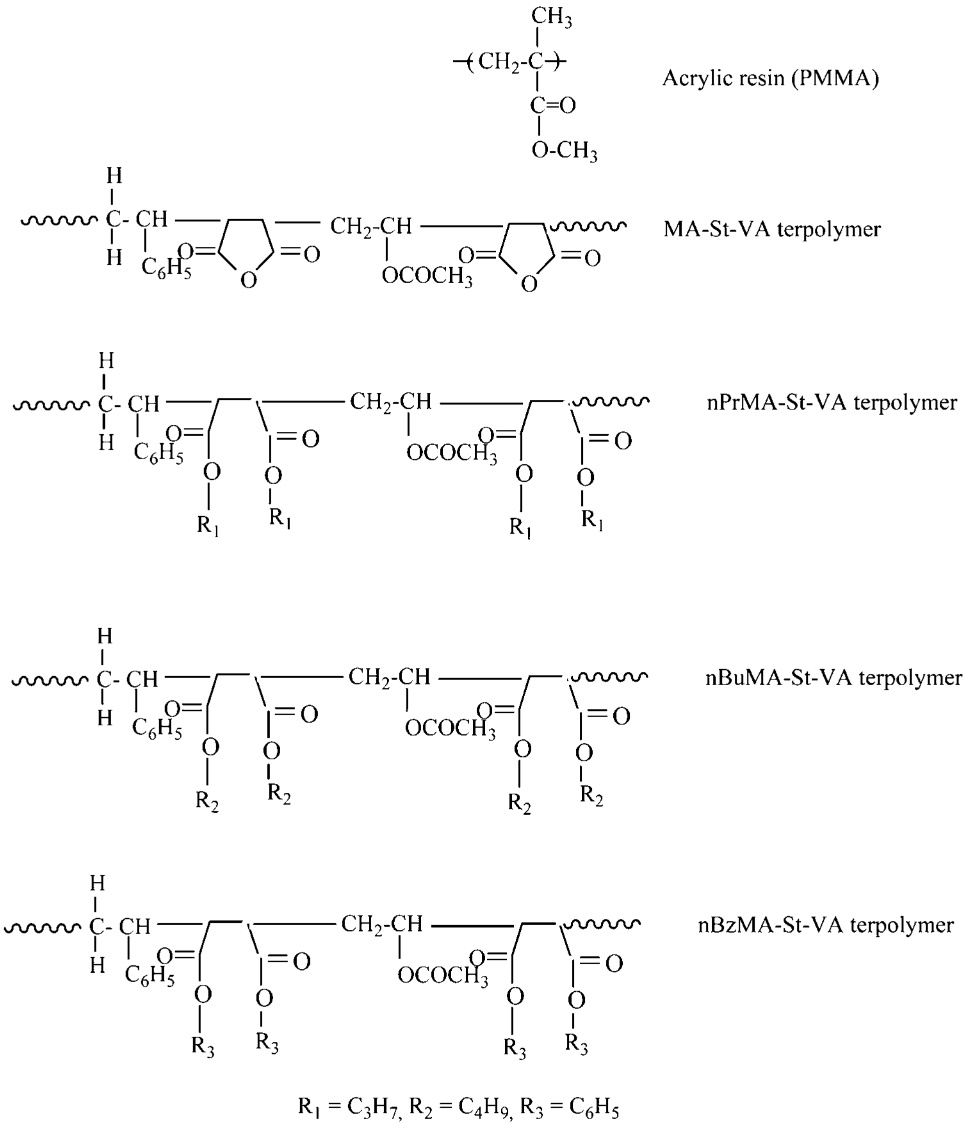


**Scheme 1** The chemical formula of PMMA and the terpolymers.

acterized in our laboratory.[17] The chemical structures of these terpolymers were presented in Scheme 1. The acrylic resin (Paladent) was obtained from Heraeus Kulzer GmbH Company, Germany. Molloplast-B which is soft lining material was obtained from Detax Company, Germany.

### Preparation of the samples by using the terpolymer and ester derivatives

A mold ($40 \times 10 \times 10$ mm$^3$) was prepared from sheet aluminum to produce the wax specimens. The wax specimens were flasked. After wax elimination procedures, polymerization of the acrylic resin was carried out in dental flask keeping them in water at 70°C for 1 h followed by boiling in a water bath for 30 min. The acrylic resin blocks were trimmed, and the surface to be bonded was smoothed using 240-drift silicon carpide paper, cleaned, dried, and 3 mm thicknesses of silicone rubber specimens were prepared. The specimens were placed between acrylic resin blocks and then flasked and given Figure 1. The silicone specimens at 3 mm thickness were placed between acrylic resin blocks and then flasked. After the silicon specimens were removed, it was applied on to the surface of acrylic resin with a brush Primo adhesive which is adhesive of the Molloplast-B and the terpolymer or its ester derivatives. Solutions of the terpolymer and its ester derivatives (100 mg/mL) were prepared separately in 5 mL tetrahydrofuran. The drawing of this statement is represented in Figure 2. The Molloplast-B was applied between the acrylic resin blocks and processed using the recommended procedure for 2 h in water at 100°C. The processed flasks were left to cool at room temperature for 20 min, and then were

**Figure 1** View of the acrylic resin specimens with silicon rubber spacer. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

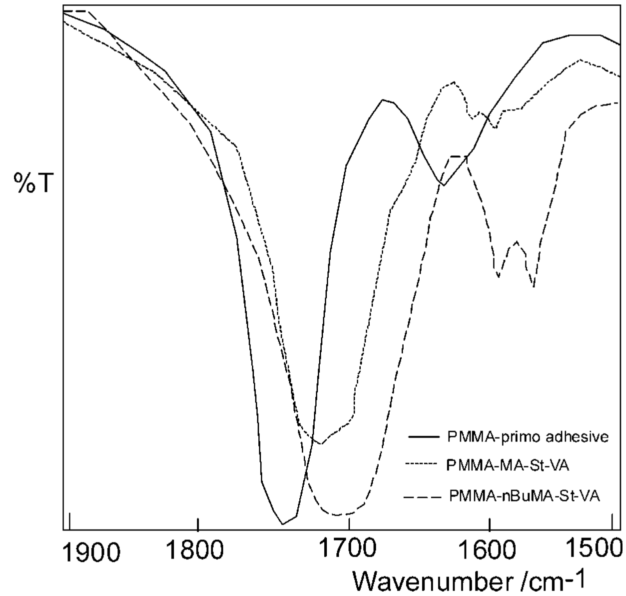


**Figure 3** FTIR spectra of the samples.

put under running tap water for 10 min. All the samples were named as groups 1–6.

### Characterization and tensile bond strength of the samples

The samples were tested in tension using an Instron Universal Testing Machine (Instron, Conton, MA, USA) at a crosshead speed of 1 mm/min. Unicam Mattson 1000 FTIR was used for the spectrophotometric characterization of the samples prepared with KBr to evaluate interactions between the acrylic resin and soft lining material.

## RESULTS AND DISCUSSION

Poly (methyl metacrylate) known as acrylic resin and the chemical formula of MA-St-VA terpolymer and some of its ester derivatives have been given in Scheme 1. As it can be seen, the differences between MA-St-VA terpolymer and its ester derivatives are the alkyl side groups occurred by the opening of the maleic anhyride rings in the MA-St-VA terpolymer. These alkyl groups in the side branches or the ester derivatives affect elastic properties of the acrylic resin (PMMA) when they are used as adhesive for acrylic resin. Infrared spectroscopic technique has been widely used to identify the types of specific interactions different bonds that occur in various polymer systems.[18] To show the hydrogen bonding between the carbonyl group of the PMMA with hydrogens in the terpolymers, FTIR spectra of PMMA/Primo adhesive, PMMA/MA-St-VA, and PMMA/*n*-BuMA-St-VA were recorded and given in Figure 3. The carbonyl bands in the samples PMMA/MA-St-VA and PMMA/*n*-BuMA-St-VA shifted from 1735 to 1720 $cm^{-1}$ because of hydrogen bonding occurred between the hydrogen of the terpolymers with the carbonyl groups of PMMA, as clearly shown in Figure 3.

Data obtained from all tests were analyzed statistically by one-way variance analysis (ANOVA) and Turkey HSD test was used to determine the significance between groups. The SPSS 12.0 (SPSS, Chicago, USA) software was used. The statistical results of the tensile bond strength measurements of the groups were summarized in Table I. The bond strength of

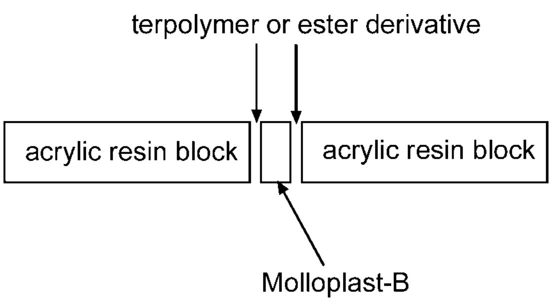


**Figure 2** The brushed of the terpolymer or ester derivative between the acrylic resin and Molloplast-B.

**TABLE I**
**The Effects on the Tensile Bond Strength of the Terpolymers Applied Between Acrylic Resin and Molloplast-B (mean values ± standard deviations)**

| The samples | Tensile bond strength (MPa) |
|---|---|
| PMMA/MA-St-VA | 1.88 ± 0.11* |
| PMMA/*n*-BuMA-St-VA | 2.11 ± 0.21* |
| PMMA/*n*-PrMA-St-VA | 0.38 ± 0.13* |
| PMMA/*n*-BzMA-St-VA | 0.30 ± 0.12* |
| PMMA/Primo adhesive | 0.88 ± 0.11* |
| PMMA/no adhesive | 0.74 ± 0.10* |

* All of them are significantly different ($P < 0.05$).

all the groups were compared and the obtained differences were found statistically significant ($P < 0.05$). The highest value was found for the samples lined with *n*-BuMA-St-VA (2.11 ± 0.21 MPa) and *n*-BzMA-St-VA lined samples had the lowest bond strength (0.3 ± 0.12 MPa).

Soft denture liners have several problems associated with their use. Bonding of the silicon based soft lining materials with acrylic in particular, is much weaker than that of acrylic based soft lining materials. On the other hand, because of the better capacity in water absorption and keeping its elasticity for longer periods of time, silicon based soft lining materials are generally preferred.[19] Thus, to improve the bonding strength of these lining materials, many researches have tried to alter the acrylic surface before the application of soft materials.[20–23]

It was clearly shown from the results in Table I that the bonding strength of PMMA/*n*-BuMA-St-VA was higher than those of all the groups (2.11 ± 0.21 MPa). It has been clearly shown that this value is higher than the value of the tensile bond strength obtained by Kawano et al.[4] Furthermore, it could be said that *n*-BuMA-St-VA increased the wettability of the surface acrylic and thus it helped the Molloplast-B form a better binding on the acrylic surface. Because of the higher stability of silicons at elevated temperatures, it did not interactions chemically with terpolymers; however, some secondary interactions (such as hydrogen bonding) might be possible. As there are the least steric difficult and highest free volume in nBuMA-St-VA ester derivatives obtained with butyl alcohol, strong interactions take place between these materials and acrylic. Furthermore, cyclic structure of benzyl alcohol gives the terpolymer a steric hindrance and restricts its mobility, thus preventing the material's access to acrylic. On account of this, the chemical interactions between *n*-BuMA-St-VA terpolymer with acrylic resin become much more effective because of the chemical structure of terpolymer.

In conclusion, the chemical interactions between MA-St-VA and *n*-BuMA-St-VA terpolymers acrylic together with secondary interactions with the Molloplast B, increased the bonding capacity of Molloplast-B with acrylic. These results were supported by those of bond strength test experiment data.

In consideration of these *in vitro* findings, it is suggested that *n*-BuMA-St-VA could be used for the lining of complete dentures with silicone based lining material. Yet, it is obvious that *in vitro* and clinical researches must be performed further.

## CONCLUSIONS

It was observed that maleic anhydride-styrene-vinyl acetate and its ester derivatives influenced the bonding of acrylic resin to Molloplast-B. The *n*-BzMA-St-VA and *n*-PrMa-St-VA decreased the tensile bond strength but the *n*-MA-St-VA and *n*-BuMA-St-VA increased. The tensile bond strength of the *n*-BzMa-St-VA and *n*-PrMa-St-VA were lower than that of PMMA/Primo adhesive, but the tensile bond strength of the *n*-MA-St-VA and *n*-BuMA-St-VA were higher than those of PMMA/Primo adhesive and PMMA/no adhesive. It can be suggested that *n*-BuMA-St-VA could be used for the lining of acrylic denture base with silicone based lining material for obtaining better bonding.

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