ORIGINAL ARTICLE

A Comparative Evaluation of Shear Bond Strength between Silicone Soft Liners and Processed Denture Base Resin Conditioned by a Surface Treatment

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Abstract

Background and objectives: Soft denture liners act as a cushion for denture-bearing mucosa through absorption and redistribution of the masticatory forces. The most common problem encountered using soft denture liners is lack of interfacial bond strength. The objective of this study was to evaluate and compare the effect of surface pretreatments by the methyl methacrylate monomer on shear bond strengths of two silicone-based soft liners.

Materials and methods: A total of 240 heat-polymerized acrylic resin blocks of dimension 30 mm × 10 mm × 10 mm, were fabricated using stainless steel die. Each sample consisted of two resin blocks with the liner embedded in-between them. The study was divided in two different groups that were lined with Mollosil and Sofreliner Tough M. Each having two different subgroups: No surface treatment and surface treatment with methyl methacrylate monomer wetting. After surface treatment, the adjacent two blocks were joined with their respective reliners. After 24 hours storage, all specimens were placed under shear stress until failure occurred. The shear bond strength values obtained were tabulated and analyzed for statistical significance using ANOVA and the Tukey's Honesty significance difference (HSD) test.

Results: The results of the study revealed when no surface treatment was done, Mollosil showed mean shear bond strength of 0.5507 MPa and Sofreliner Tough M showed 1.6020 MPa. When monomer wetting was done, Mollosil showed a mean shear bond strength of 0.6200 MPa and Sofreliner Tough M showed 1.8073 MPa. Irrespective of the surface treatment, Sofreliner Tough M showed the higher shear bond strength. There was statistical significance ($p < 0.001$) between all groups when subjected to surface treatments.

Interpretation and conclusion: Within the limitations of this *in vitro* study, surface treatment with methyl methacrylate monomer enhanced the shear bond strength significantly in both groups and group II, Sofreliner Tough M, showed the higher shear bond strength.

Keywords: Monomer wetting, Polymethyl methacrylate, Shear bond strength, Silicone soft liners, Surface treatments.

CODS Journal of Dentistry (2019): 10.5005/jp-journals-10063-0054

Introduction

In an individual with a complete or partial denture prosthesis, the masticatory load and functional stresses are transmitted to the bone through mucoperiosteum. These functional stresses lead to gradual changes resulting in loss of accurate adaptation of the denture. High stress concentrations during function can also lead to chronic soreness, pathologic changes, and bone loss. These problems can be solved by relining the intaglio surface of the denture with a soft denture liner.

A soft (resilient) lining material may be defined as a soft elastic and resilient material that acts as a cushion for denture-bearing mucosa through absorption and redistribution of the masticatory forces.[1] It provides comfort for the patient and may reduce residual ridge resorption by reducing the impact force during function.[2] Soft liners are also used for treating patients with thin and nonresilient mucosal tissue, bony undercuts, bruxing tendencies, congenital or acquired oral defects requiring obturation, xerostomia, and to modify transitional prosthesis after stage 1 and 2 implant surgery.[3]

Primarily soft liners may be resin based, silicone based, or polyurethane based. The silicone-based materials retain their elastic properties for a comparatively longer period. They are available in two forms: room temperature vulcanizing (RTV) silicones and heat temperature vulcanizing (HTV) silicones.[4]

The most common problem encountered using soft denture liners is lack of interfacial bond strength. Weakened bond strength encourages the ingress of oral fluids and microorganisms at their junction, which when further weakened can result in the delamination of reline material from the denture base.[2] It is therefore important that the bond strength of the lining material to the denture base is optimized.

It is well known that the bonding efficiency of a denture reline material to a denture base polymer depends on the propensity of the contents of the reline material to penetrate the denture polymer and establish an interwoven polymer network. Adhesion between soft liners and denture base resin can be improved by treating the denture surface with appropriate chemical such as

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How to cite this article: Jagadeesh K, Vinay Kumar G. A Comparative Evaluation of Shear Bond Strength between Silicone Soft Liners and Processed Denture Base Resin Conditioned by a Surface Treatment. CODS J Dent 2019;11(1):2–6.

Source of support: Nil

Conflict of interest: None

methyl methacrylate (MMA) before applying the soft liner; it etches the surface by changing morphology and chemical properties of the denture base resin.[5]

The shear test is considered to be a useful method for testing bond strength because it is more closely related to clinical settings than the tensile test, as the oral cavity is subjected to shear stress more than tensile stress.[3]

The need for study is to evaluate and compare the shear bond strength of two commercially available silicone liner materials (soft liners) to the processed denture base resin surface treated by MMA.

While the properties of shear bond strength of silicone liners have been studied, to the best of our knowledge, a comparison between Mollosil and Sofreliner Tough M after surface treatment with MMA has not been considered.

Materials and Methods

Fabrication of Specimen

The study included 120 samples divided between two groups where each sample consisted of two heat-polymerized acrylic resin blocks; therefore, a total of 240 resin blocks were fabricated. Stainless steel dies (Fig. 1) measuring 50 mm in length, 10 mm in width, and 3 mm in height (50 × 10 × 3) were machined to prepare standardized polymethyl methacrylate resin blocks.

Impressions of the stainless steel dies were made using addition silicone putty material (Aquasil, Dentsply). The wax blocks were made from the mold with modelling wax (Golden Modelling Wax) and cured with heat-polymerizing acrylic resin **(**DPI Heat Cure, Dental products of India Ltd.) All the polymerized acrylic samples (Fig. 1) were finished and polished leaving the testing surface. They were then ultrasonically cleaned with distilled water and dried with compressed air to remove the surface impurities.

Surface Treatment of Acrylic Resin Blocks

Subgroup 1—No Surface Treatment

The bonding area of the heat-polymerized acrylic resin blocks was not treated with any solution.

Subgroup 2—Surface Treatment with MMA Monomer

The surface treatment of the blocks along the area to be relined was done with MMA monomer of DPI heat cure for 180 seconds.

The surface was swabbed unidirectionally and two coats were applied using a camel hair brush after which they were washed with water and air-dried.

Application of the Soft Liner

Glass spacer dies measuring 10 mm long, 10 mm wide, and 3 mm thick (10 × 10 × 3) were prepared as spacer to ensure uniformity of the soft liner being tested. The dies for PMMA blocks and glass spacer were invested in addition silicone putty to provide uniform space for the lining material and for easy removal of the processed samples (Fig. 2). The arrangement of the specimen is schematically shown in Figure 3 to enable the testing of shear bond strength of the liner. The acrylic blocks were then joined using the following relining materials.

Group I—Mollosil

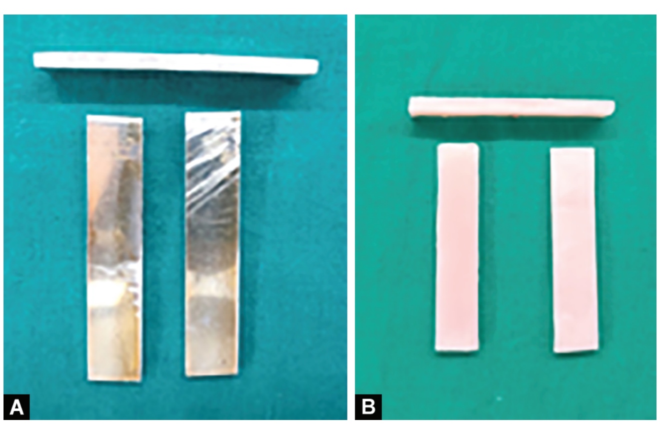
After surface treatment of the bonding surface of the acrylic blocks, 60 samples were made from 120 acrylic blocks using Mollosil as the liner between them. Following steps were undertaken:

- The area to be bonded was thoroughly air-dried and Mollosil adhesive was applied and was allowed to dry for approximately 1 minute, as per manufacturer's instructions.
- The stainless steel dies were replaced with acrylic blocks and the glass spacer was removed from the putty mold.
- Equal lengths of Mollosil base material and catalyst were mixed hemogeneously for 30 seconds. The material was aspirated into a 2 mL empty syringe and dispensed into the uniform space created by the glass die. As per the manufacturer's instructions, the working time of this material is approximately 1 minute 30 seconds and the setting time is approximately 7 minutes. After the curing, the excess material was removed with a sharp scalpel.

Group II—Sofreliner Tough M

Similarly, 60 samples were made from 120 acrylic blocks using Sofreliner Tough M as the liner between them. Following steps were undertaken:

- The area to be bonded was thoroughly air-dried and a thin layer of Sofreliner Tough M primer was applied and allowed to dry.
- The Sofreliner Tough M Paste cartridge was then loaded to the mixing gun and the mixing tip was attached. The material was then extruded in the uniform space created by the glass spacer. After the curing, the excess material was removed with a sharp scalpel.
- The manufacturer's instructions were followed and the shaping of the material was done using the Shape Adjustment Point



Figs 1A and B: (A) Customized stainless steel dies; (B) Finished polymerized acrylic blocks

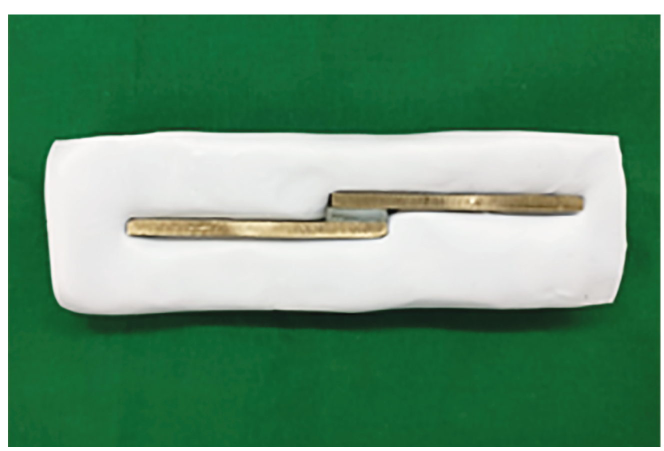


Fig. 2: Dies of PMMA blocks and spacer invested in putty

(White), not exceeding more than 15,000 rpm, and the finishing was done with Finishing Point (Brown), not exceeding more than 4,000 rpm.

Thus, the final specimens obtained were two polymethyl methacrylate blocks with soft liner in-between. The specimens were stored in sterile water and kept in incubator at 37°C before testing.

Distribution of the Samples

A total of 120 test samples were prepared; of which 60 specimens were prepared for group I, Mollosil, and 60 specimens for group II, Sofreliner Tough M (Fig. 4). Each of these groups, based on pretreatment of acrylic resin specimens, was subdivided into two subgroups of 30 samples each.

Group I Mollosil $n = 60$	Subgroup 1—no treatment, $n = 30$
	Subgroup 2—monomer wetting, $n = 30$
Group II Sofreliner Tough M $n = 60$	Subgroup 1—no treatment, $n = 30$
	Subgroup 2—monomer wetting, $n = 30$

Testing of Specimens

All the specimens (group I and group II) were subjected to the shear bond test. All the specimens were aligned in Universal testing machine with one end of the acrylic specimen attached to the upper clamp and other end of the acrylic specimen to the lower clamp. The specimens were pulled in the opposing direction (Fig. 5) with a crosshead speed of 40 mm/minute. The maximum force indicating the point of separation was recorded. The readings obtained were in kilograms, which were later converted to Newton by using the conversion of 1 kg = 9.81 Newton.

The peak load was converted to shear bond strength values in megapascal (MPa), by the formula,

$$\text{Shear bond strength} = \frac{\text{Maximum load } (N) \text{ at debonding}}{\textit{Cross} - \textit{sectional area}\left(\text{mm}^2\right) \text{ of the interface}}$$

Results were then subjected to appropriate statistical analysis.

The statistical analysis in-between the groups was carried out using the ANOVA test followed by the Tukey's *post hoc* analysis.

Results

The shear bond strength values obtained from various groups were tabulated and analyzed for statistical significance.

The mean between two groups was compared using one-way analysis of variance (ANOVA) and the intercomparison between each group was done using the Tukey's Honesty significance difference (HSD) test.

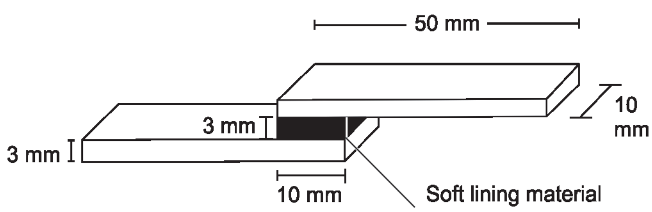


Fig. 3: Two polymethyl methacrylate blocks (50 mm in length, 10 mm in width, and 3 mm in height) with soft liner (10 mm in length, 10 mm in width, and 3 mm in height) in-between them

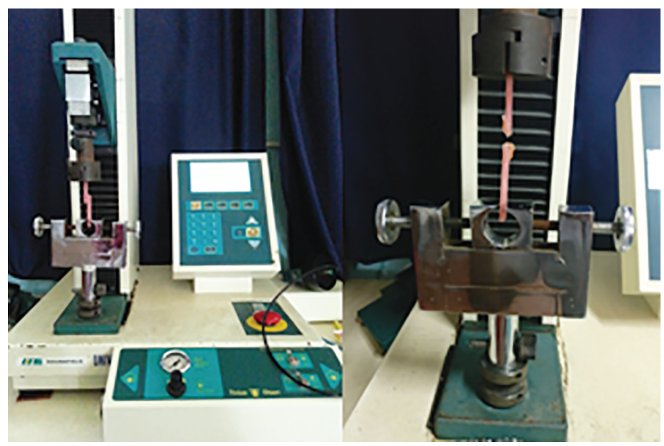


Fig. 5: Specimen in Universal testing machine and point of separation recorded

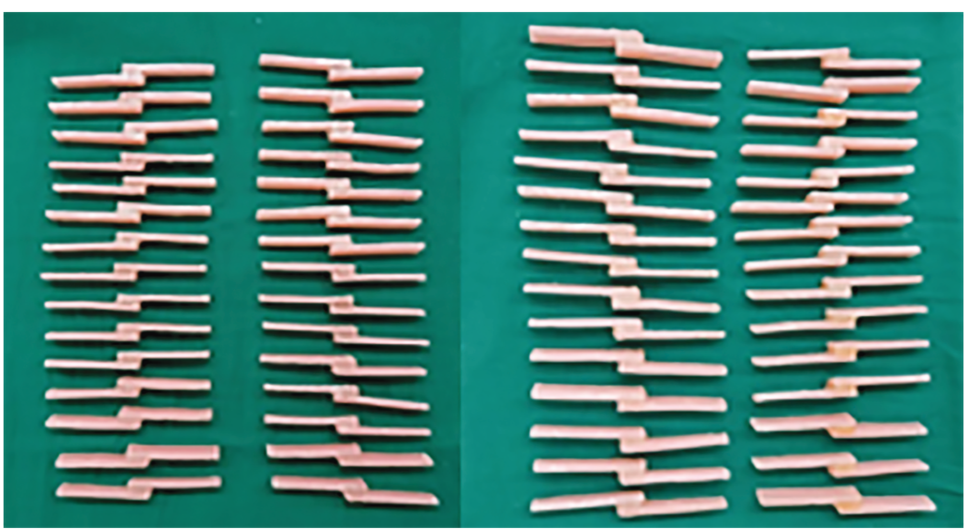


Fig. 4: Specimens of group A, Mollosil® and specimens of group B, sofreliner tough m

Table 1: Mean shear bond strength of all the specimens lined by Mollosil, group I, and Sofreliner Tough M, group II, and comparison between the surface treatments

	1. No surface treatment (MPa)	*2. Monomer wetting (MPa)*	*ANOVA*
A. Mollosil	0.5507 ± 0.03	0.6200 ± 0.02	$p < 0.001$ (HS) 2 > 1
B. Sofreliner Tough M	1.6020 ± 0.04	1.8073 ± 0.04	$p < 0.001$ (HS) 2 > 1

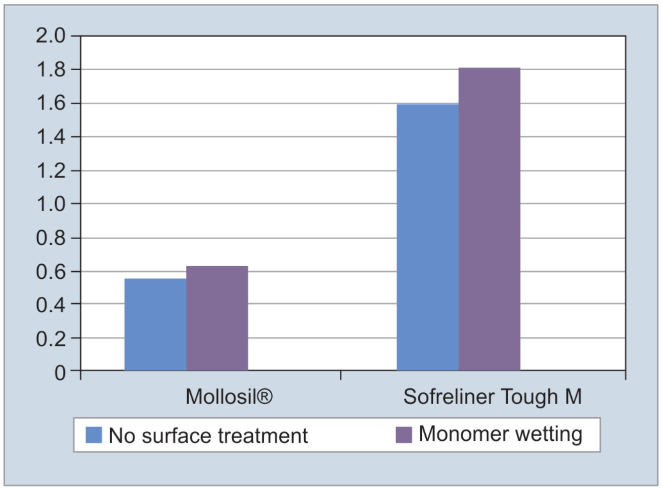


Fig. 6: Comparison of shear bond strength between silicone liners conditioned by surface treatment

The results obtained are tabulated below (all shear bond strength values in MPa).

Table 1 shows the mean shear bond strength of all the specimens lined by Mollosil and Sofreliner Tough M.

When monomer wetting was done, the shear bond strength was higher than when no treatment was done in both the groups.

There was statistical high significance ($p < 0.001$) when surface treatments were carried out.

Figure 6 shows the shear bond strength between silicone liners conditioned by surface treatment.

There was statistical high significance ($p < 0.001$) between both groups when subjected to surface treatments.

Discussion

Lining materials are used to regain the optimal adaptation of the denture base to residual ridges and to achieve a more uniform and equal distribution of functional stresses. Depending on their consistency, denture reliners can either be of hard or soft types. Kawano et al.[6] evaluated the cushioning effect of six commercially available soft denture liners. He indicated that a soft liner as compared to a hard liner reduced the impact force during function.

Soft or resilient silicone base liners are classified as room temperature vulcanized (RTV) and heat temperature vulcanized (HTV) and also as temporary denture liners or permanent denture liners.[7] Although being a valuable asset, these liners have a major drawback of lack of durable bond to denture. Debonding of the silicone liner from the denture is a common clinical occurrence, which can lead to localized unhygienic conditions at the debonded regions and often causing functional failure of the prosthesis. It has been shown that the measured bond strengths depend on the test methods employed.[4] Different surface treatments by various workers have been done to improve the shear bond strength of denture reliners to the polymethyl methacrylate denture base resin of which some showed enhancement of bond strength with conflicting results.

This study was undertaken to evaluate an effective way of enhancing the shear bond strength of commercially available silicone-based soft denture reliners (Mollosil and Sofreliner Tough M) to polymethyl methacrylate denture base resin (DPI HEATCURE). Each having two different subgroups following surface treatments of the bonding surface: no surface treatment and surface treatment with MMA monomer wetting.

The denture lining material is clinically more exposed to shear and tear forces. Chladek et al.[8] stated that shear bond strength is more closely related to clinical settings than the tensile test. However, the stresses in soft linings are unevenly distributed and concentrated near the edges, resulting in lower shear strength values.

The crosshead speed can also affect the results. Jagger et al.[9] pointed out that tensile failure was not caused by tensile forces alone, because some shear forces are also developed in the tensile test. This occurs because of the high Poisson's ratio of silicone lining materials, where a reduction occurs in the cross-sectional area of a lining material when it stretches after the application of a tensile load, whereas the bonded portion maintains a constant area.[7] After surface treatment of the bonding surface of the acrylic blocks, the adjacent two blocks are joined with their respective reliners by mixing the material to uniform consistency and then packing it into the uniform 3 mm space between the acrylic blocks. Loney et al.[10] studied the finishing and polishing of resilient denture liners. They found that increasing the thickness of reliner by more than 3 mm on the denture base resin greatly reduced the bond strength and other physical properties. Hence, in this study a uniform thickness of 3 mm of reliner was used.

The analysis for statistical significance was done with caution. There was high significant increase in the shear bond strength when specimens were surface treated with MMA compared to those with no surface treatment. Al-Athel MS et al.[11] in their study have shown that denture base monomers are polymerizable. The penetration of these materials into the denture base theoretically improves bonding by participation in polymerization.

The bond is enhanced by the diffusion of the MMA monomer across the denture base resin and thereby creating surface irregularities. It has been suggested that wetting heat-polymerized acrylic resin surfaces with the MMA monomer for 180 seconds dissolves the surface structure of polymethyl methacrylate, increasing the bond strength of the heat-polymerized resin to the reliner.[12] As per manufacturers' instruction, before the application of reliner all the surfaces were conditioned with adhesive. The adhesive contains ethyl acetate that acts as a chemical etchant. Application of adhesive further improves the wettability of the surface. This surface when relined with silicone reliner formed interpenetrating polymer networks that enhance the shear bond strength by providing mechanical interlocking. This study showed that irrespective of the company of the liner, pretreatment with the MMA monomer significantly increased the shear bond strength.

The reason that can be suggested for higher bond strength value in MMA monomer wetting is that the MMA monomer most probably reaches deep into the polymer chains and facilitates the penetration of adhesive primer. Presence of significant bond strength values is a sign of absence or less microleakage.[13]

This study showed that the surface treatment with the MMA monomer enhanced the shear bond strength significantly in both groups, and Sofreliner Tough M showed the higher shear bond strength. This study focused on the surface treatment of the denture base resin in order to enhance the shear bond strength to the reliner; further studies are needed to investigate the effect of combination of various surface treatments on the bond strength. The effect of making macro mechanical undercuts in combination with different surface treatments on the bond strength also requires an evaluation.

Conclusion

Soft denture liners have a key role in modern prosthodontics because of their capability of restoring health to inflamed and distorted mucosa. They provide comfort for patients who cannot tolerate occlusal pressures, such as in cases of alveolar ridge resorption, soreness, and knife edge ridges. Bond failure leads to delamination of the reline material and thus in the loss of denture adaptation to the mucosa. Hence, a good bonding to the underlying denture base is essential for the clinical success of these materials.

This study evaluated the shear bond strength between silicone-based soft liner and heat-polymerized denture base acrylic resin after surface treatment.

Within the limits of the present study and on the basis of results obtained, it was concluded that the subgroup that was surface treated with the MMA monomer and the group relined Sofreliner Tough M produced the strongest bond.

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