Effect of Net Fiber Reinforcement Surface Treatment on Soft Denture Liner Retention and Longevity

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Abstract

Purpose: To evaluate shear bond strength of Molloplast-B soft liner attached to different acrylic surfaces (smooth, rough, and Sticktech net fiber-reinforced interfaces) after 3000 thermal cycles.
Materials and Methods: Sixty-nine specimens were fabricated by attaching Molloplast-B soft liner to acrylic bases of three interfaces ($n = 23$); smooth (Group 1, control), rough (Group 2), and Sticktech net fiber-reinforced interface (Group 3). The specimens underwent 3000 thermocycles (5 and 55°C) before being subject to a shear bond test at 2 mm/min crosshead speed. Debonding sites were investigated using an optical microscope at 40× magnification. Bond failures were categorized as adhesive, cohesive, or mixed.
Results: Mean (SD) bond strength values (MPa) were: 0.71 (0.15); 0.63 (0.07); and 0.83 (0.12) for smooth, rough, and fiber-reinforced acrylic interfaces, respectively. The mean values were analyzed using one-way ANOVA and Bonferroni post hoc test for pairwise comparisons ($p \leq 0.05$). The net fiber-reinforced acrylic interface exhibited a statistically significantly higher bond strength value when compared to smooth and rough acrylic interfaces ($P = 0.003$ and $P = 0.000$, respectively). Modes of failure were mainly cohesive (91%), followed by mixed failures (9%).
Conclusions: Molloplast-B exhibited a stronger bond to StickTech Net fiber-reinforced surfaces when compared to smooth and rough acrylic interfaces after thermocycling. This may enhance prosthesis serviceability during clinical use.

Denture liners have been used in dentistry for many years. They are classified into hard reline materials, permanent tissue liners, and tissue conditioners.[1] They are used to enhance the fit of poor fitting dentures and prevent trauma to sensitive mucosa, by forming a cushioned layer between the denture base and the oral mucosa.[2–4] They aid in the retention of extraoral prostheses and intraoral devices by engaging overdenture-bar attachments[5,6] or modified abutments[7] and undercuts present in defect sites such as in maxillofacial obturators.[8] Denture liners should be elastic, nontoxic, and nonirritant to oral tissues.

Liners suffer from low tear strength, porosity, water absorption, and frequent debonding from dentures during clinical use, thus reducing the longevity of such prostheses.[9–11] Several studies have been conducted to improve bond strength between liners and acrylics. Some studies introduced roughness at the acrylic interface using lasers,[12] alumina abrading,[13] chemical etching,[14] and acrylic burs.[15] Others used chemical primers[16,17] or reinforced the acrylic interface with net woven glass fiber, which improved bond strength.[18]

Bond strength between denture bases and resilient materials has been evaluated by several tests such as tensile,[4,12,19–21] tensile and shear,[18] and peel tests.[22] Each test type should relate closely to the way that the bonds are loaded in clinical service.[23] Shear tests are suitable for examining bond strength of liners to acrylics, as masticatory forces in the oral cavity are similar to tear and shear forces,[24] rather than tensile forces.

Serviceability of lining materials varies from 6 months to 5 years. Heat-cured silicone lining materials can last for 3 to 6 years.[25–27] During service, the liner/denture interface is affected by various cyclic chewing forces and temperature changes. In vitro simulation of intraoral changes using thermal cycling can greatly affect the mechanical integrity of the liner/denture interface, initiating crack propagation;[28,29] however, the effect of thermocycling is inconclusive and material dependent.[9] It may increase or decrease bond strength.[19,28,30–34]

Fibers are used to increase the impact strength of heat-cured acrylic denture bases,[35] especially when the minimum required acrylic thickness is unobtainable. This can occur in cases of reduced interocclusal space in complete and partial dentures, especially lower dentures.[36] Also, in hollow bulb obturators, it is favorable to have thin acrylic walls, and in some facial prostheses it is important to have a strong retentive acrylic baseplate of controlled thickness. Fibers have the advantages of excellent esthetics and may form effective bonds to the surrounding matrix.[35]

The present study is not concerned with fiber reinforcement of acrylic. Rather, the focus is on the potential for a fiber mesh, integrated at or on the fitting (basal) surface of the acrylic, to facilitate improved bonding of silicone liner to the acrylic substrate. Hence, the objective of this study was to evaluate shear bond strength of Molloplast-B soft liner attached to different acrylic surfaces (smooth, rough, and Sticktech net fiber-reinforced interfaces) after 3000 thermal cycles. The null hypothesis was that there is no difference in bond strength between Molloplast-B and the three acrylic surfaces after 3000 thermal cycles.

Materials and methods

Specimen fabrication was described in a previous study.[18] Cylindrical specimen molds were used to construct the acrylic body of the specimens (14-mm diameter). The acrylic monomer and powder were mixed according to manufacturer's instructions (2.34 g/ml) (powder/liquid ratio) (Minerva Dental Ltd, Cardiff, UK) into a dough consistency. This was inserted into the molds. Each mold was fixed over a flat metal surface, and the acrylic was compressed for 5 minutes at 50 bar, using a pneumatic press (Skillbond Limited, High Wycombe, UK). The specimens were cured by immersion in a water-bath curing unit (Derotor, Dental Manufacturer, Worthing, UK) at 90°C for 6.3 hours and left to bench cool.

Sixty-nine specimens (Table 1) were constructed and divided into three groups ($n = 23$). In Group 1 (control) the acrylic surfaces were smoothed by pressing the acrylic against the smooth metal surface. In Group 2, an acrylic bur (Jota, Steel Cutters-75 070, Skillbond Ltd) was used to roughen the acrylic surfaces using a micro-motor (W&H Dental Work, GmbH, Burmoos, Austria) at 10× speed. In Group 3, before curing, circular sheets of net-shaped bidirectional glass fibers (Everstick Net, StickTech, Turku, Finland) were pressed into the dough acrylic interface, and specimens were cured. Micrographs of the three acrylic surfaces were obtained using an optical microscope at 40× magnification (Fig 1).

Mollopast-B soft lining was used. It is composed of condensation silicone material, polymethylmethacrylate (PMMA), and methacryloyloxypropyltrimethoxysilane (Safety data sheet, Molloplast B®, Detax GmbH, Ettlingen, Germany). Two consecutive brushes of primo adhesive, which is a mixture of methoxy and ethoxy silane derivatives (Safety data sheet, Primo Adhesive, Detax GmbH), were applied over the three interfaces of the specimens and left for 90 minutes. Mollopast-B soft lining was packed over the acrylic surfaces using a custom-made Teflon mold (8 mm diameter, 3 mm thickness). Each mold was placed on the top margin of the specimen holder, and the liner was packed inside it over the acrylic surface. A flat metal plate was placed over the Teflon molds, and specimens were pressed in a pneumatic press for 5 minutes at 50 bars, and cured as explained previously. Then specimens were bench cooled, and the liner molds were retrieved, leaving liner disks (8 mm diameter, 3 mm thickness) bonded to the acrylic surfaces.

All specimens were thermocycled (Manchester Medical School Engineering Workshop, Manchester, UK) for 500 cycles per 12 hours at temperatures ranging between 55 (hot bath) and 5°C (cold bath) and then incubated for 12 hours at 37 ± 1°C. Each thermal cycle lasted for 60 ± 2 seconds[11,19,37] (17 seconds in each cold and hot baths, 26 ± 2 seconds as transverse time between baths). The specimens underwent 3000 cycles in total. Then specimens were incubated for 24 hours at 37 ± 1°C, and shear bond tests were performed using a custom-made shear-bond jig designed according to ISO/TR 11405:1994(E).[38] It was installed on a universal testing machine, Zwick/Roell (Z 020, Zwick Testing Machines, Leominster, UK), and the shear test was performed at 2 mm/min crosshead speed. For each specimen, the bond strength was calculated using the following formula:

$$\text{bond strength} = \frac{\mathrm{F}}{\mathrm{A}}$$

where F is maximum force (N), and A is cross-sectional area (mm^2). Bond strength values were analyzed using one-way ANOVA and Bonferroni post hoc tests ($p < 0.05$) (SPSS14, Chicago, IL). Modes of failure were recorded by two specialized observers. Inter-observer agreement was statistically analyzed ($p < 0.05$) using Kappa test (SPSS14).

Results

Means and standard deviations of shear bond strengths for the groups are presented in Figure 2. The net fiber-reinforced acrylic interface exhibited a statistically significantly higher bond strength value when compared to smooth and rough acrylic interfaces ($P = 0.003$, $P = 0.000$, respectively). There was no statistically significant difference between smooth and rough acrylic interfaces ($P = 0.099$).

Modes of failure are presented in Table 2. A Kappa value of 0.95 indicated an almost perfect inter-observer agreement in defining modes of failure. Cohesive failure was predominantly present among all interfaces (91.3%), followed by mixed failures (8.7%).

Discussion

The integration of glass net fibers with acrylic interfaces significantly increased the mechanical integrity between the soft liner and acrylic base when compared to acrylic interfaces of smooth or rough finishes;[18] however, the bond strength of liners to such glass fiber-reinforced acrylic bases after clinical

Table 1 Groups tested

Group ($n = 23$)	Acrylic interface	Conditioning
1	Smooth	3000 thermal cycles
2	Rough	3000 thermal cycles
3	Net fiber-reinforced	3000 thermal cycles

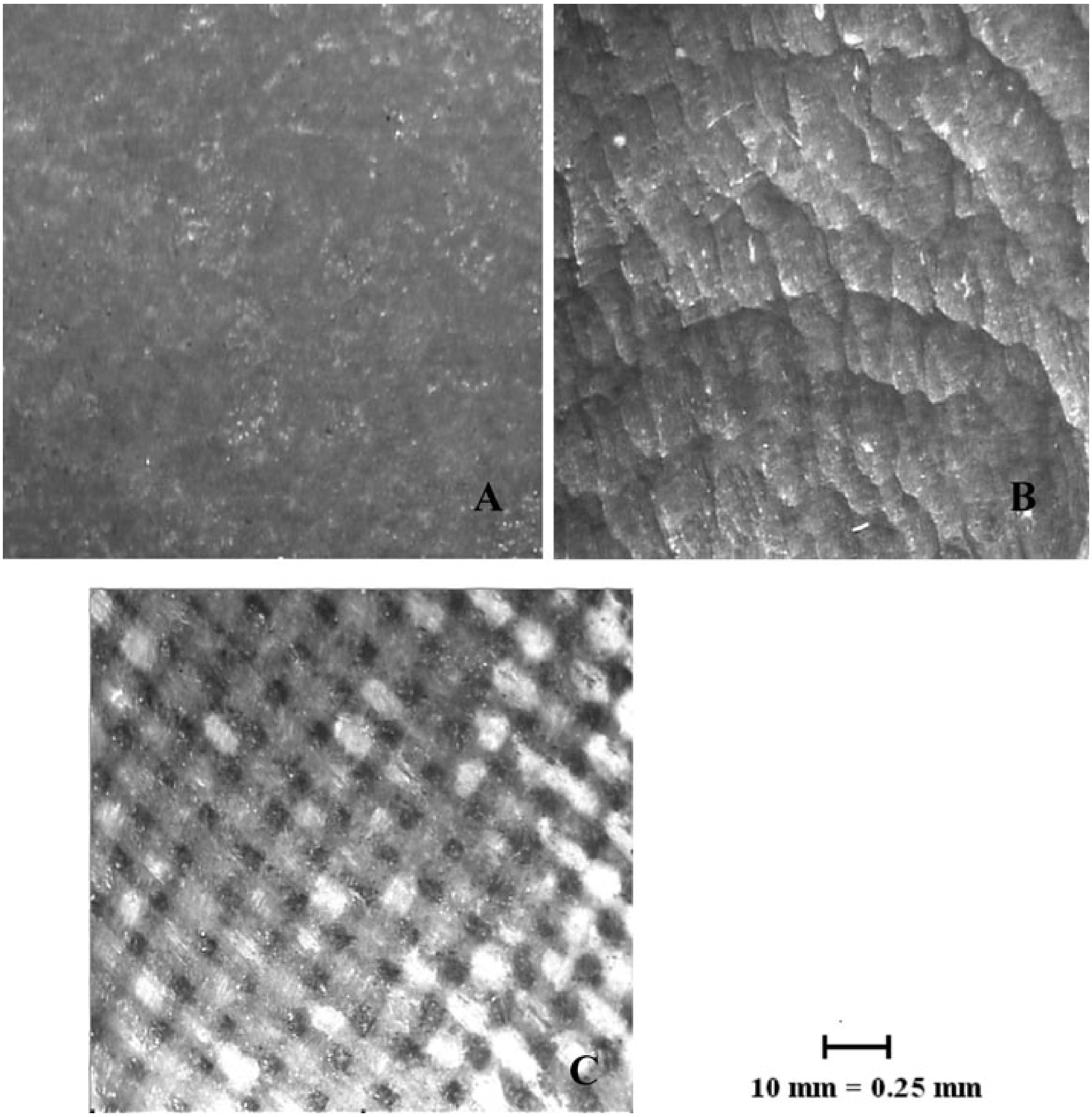

Figure 1 Optical micrographs (40×) of the smooth (A), rough (B), and net-modified (C) acrylic surfaces.

use has not been studied. A thermocycling machine was used to simulate intraoral temperatures that affect prostheses during function. It induces thermal stresses on the restorative materials, which have different coefficients of thermal expansions, simulating those generated intraorally during food and liquid consumption. Thermocycling can be justifiably criticized as a rather severe process, nevertheless it is widely accepted as a mode of accelerated treatment of specimens.[28] In this study, specimens were thermocycled for 3000 thermal cycles, which resembles a prosthesis being in service for 33 months, on the assumption that patients consume three meals daily.

After 3000 thermal cycles the bond strength between Molloplast-B material and the different interfaces of heat-cured PMMA acrylic was sufficient to make the liner clinically serviceable. It has been previously shown that a lining material that has a bond strength value around 0.44 MPa can be effective for use in clinical practice.[39]

Roughening the acrylic surfaces had no significant effect on bond strength when compared to smooth acrylic interfaces. This result is in agreement with other studies,[12] but disagrees with a previous study.[20] Disagreement can be attributed to different types of acrylic material used, as bond strength varies between types of acrylic resins.[16]

Net fiber-reinforced acrylic interfaces had statistically significantly higher bond strength than did both smooth and rough acrylic interfaces ($p < 0.05$). The increase in bond strength can be attributed to changes in topography of the acrylic interface due to the presence of woven fibers. The bond strengths

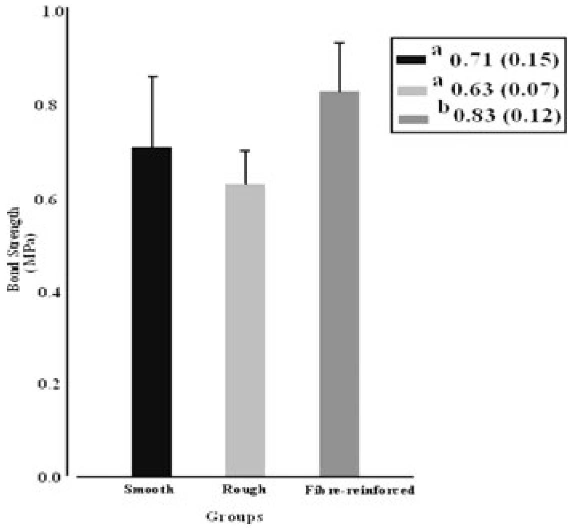

Figure 2 Shear bond strengths (MPa) of the test and control groups. Standard deviations in parentheses. Superscript letters indicate homogenous subsets ($p < 0.05$).

at all acrylic interfaces were higher than bond values of similar unconditioned groups,[18] and this disagrees with other studies.[11,30-33] The disagreement may be attributed to the type of test used elsewhere (tensile test) and the parameters set for the test. The type of test is directly associated with values of the bond strength.[23,24] Tensile loading gives information about bond strength in comparison to the tensile strength of the liner itself;[13,17] however, the increase in bond strength is attributable to the heat-activated polymerization of the solvent-based primo adhesive from the elevated temperature phase of the thermocycler as the adhesive is reported to enhance the bond of the Molloplast-B to the acrylic bases.[16,17,23]

Solvent-based bonding adhesives enhance bond strength by swelling the surface and improving wettability of the substrate. Also, solvents clean the surface from environmental pollutants and disperse loose particles covering the substrate surface.[3,21] The adhesive used likely penetrated the resin matrix that impregnates the net-shaped glass fibers leading to enhanced chemical adhesion with the liner.

In this in vitro study, Molloplast-B soft liner bonded to reinforced acrylic had higher bond values than with the unreinforced acrylic. This may indicate extended functionality of a prosthesis lined with Molloplast-B for up to 3 years. This result agrees with a retrospective clinical study of increased serviceability of dentures lined with Molloplast-B up to 3 years[25] or even 6 years.[27]

Table 2 Types and numbers of bond failures

	Failure mode		
Acrylic interfaces	Adhesive	Cohesive	Mixed
Smooth	0	21	2
Rough	0	19	4
Fiber-reinforced	0	23	0
Total (%)	0	63 (91%)	6 (9%)

The modes of failure exhibited by both smooth and rough interfaces were mainly cohesive (21 and 19, respectively) followed by mixed failures. This result is in agreement with other studies,[24,31,34] and disagrees with other studies that showed either entirely cohesive failures within Molloplast-B liner,[33] or entirely adhesive failures.[37] Such disagreement is due to differences in the experimental protocol followed (where a 2 mm liner thickness was created and tensile test was carried out).

An effective bond strength between liners and denture bases can be characterized either by high bond values or cohesive bond failures within the lining material.[3] The presence of net fibers at the bond interface caused all specimens to exhibit cohesive failure only. This indicated that the bond strength between Sticktech Net fiber-reinforced acrylic bases was improved and greater than the tensile strength of Molloplast-B.[1]

It is important that intraoral prostheses remain in function for a long period of time. The incorporation of woven glass fibers at the acrylic interface improves bond strength with the Molloplast-B silicone liner; however, properties of silicone liners are expected to be affected during service and need to be further investigated.

Conclusions

Within the limitations of this study, it can be concluded that

1. StickTech Net fiber-reinforced surfaces exhibited a significantly stronger bond to Molloplast-B when compared to smooth and rough acrylic interfaces after thermocycling ($p = 0.003$ and $p = 0.000$, respectively), which may enhance prosthesis serviceability during clinical use.
2. The bond improvement qualifiers were 17% and 32% for smooth and rough acrylic interfaces, respectively.

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