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Fibre reinforcement enhances bonding of Soft Lining to Acrylic Dental and Maxillofacial Prostheses

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Abstract - *This study evaluated shear bond strength between Molloplast-B and different acrylic surfaces; smooth (group1), rough (group2) and Stick net fibre-reinforced interfaces (group 3). Shear tests were conducted with a universal testing machine. Bond failure categories were adhesive, cohesive and mixed failures. Mean bond strengths (SD) in MPa were Group 1, 0.59 (0.08); Group 2, 0.61 (0.08) and Group 3, 0.70 (0.09). There was statistically significant difference ($p \leq 0.05$) between group 3 and group 1 only. Modes of failure were different; mixed and cohesive only exhibited. StickTech Net fibre-reinforced surfaces exhibited stronger bond to Molloplast-B over non-reinforced interfaces, indicating promising clinical implications.*

KEY WORDS: Soft lining, Molloplast-B, Stick Net fibres, shear bonding, Bond failures.

INTRODUCTION

In many acrylic and dental prostheses soft liners are bonded to the fitting surfaces serving different functions. They are used to enhance the fit, retention, and comfort of acrylic dentures, to release pressure of the super facial nerve in cases of prominent facial nerves in heavily resorbed ridges [1, 2], to retain the prostheses as in obturators [3-6]. Also they can be used over bar attachments retaining the prosthesis as in overdentures [7-9]. There are different types of liners: silicone based, acrylic based and tissue conditioners [10].

Acrylic prostheses are reported to have many problems with silicone liners, such as low tear strength, porosity, water absorption, and softness with time[11]. The main problem of the liners is lack of a long, sustainable bond with the acrylic surfaces, resulting in frequent debonding from the denture during clinical use [12-14]. For a long lasting prosthesis, the lining material should remain resilient, and well adhered to the acrylic base [1, 15-17].

Another important case of needing a strong bond of silicones to acrylic bases is in facial prostheses. Body secretions, growth of organisms, and aggressive cleaning of the prosthesis may reduce its longevity and silicone may delaminate partially or completely from the retentive acrylic matrix [17, 18].

Many attempts were made to improve the bond strength between the liners and the acrylic substrates. They included alternating the acrylic surfaces by creating roughness at the interface using laser [19, 20], alumina abrading [21], chemical etching [22], using an acrylic bur [23], or by using a primer to increase the bond strength [24]. The results were inconclusive and sometimes contradictory. Such indefinite results were due to variations in materials being tested [24, 25], geometry of the bond interface, and the types of test followed [16].

Many tests have been conducted to test the bond strength between PMMA denture bases and resilient materials, such as tensile tests [20, 26], tensile and shear tests [25], and peel tests [17, 18].

The bond failures can be either adhesive, which results in the complete separation of the liner from acrylic, or cohesive which results in tearing the lining material itself, with no bond separation, or mixed in which parts of the liner are still adhered to the bond interface.

Another aspect of the acrylic based prostheses problem is the low impact strength of acrylic materials. Many attempts have been carried out to repair the fractures and reinforce acrylic structures utilizing different materials like metal wires [27], fibres of polyethylene [28], and glass fibres [29]. When light cured unidirectional and woven fibre-reinforced composites were used to repair fractured acrylic resin dentures, it was reported that the impact strength of heat cured complete dentures resins, was increased. That was by a factor more than 2, when the complete dentures are reinforced using fibres of preimpregnated woven E-glass [30].

Nowadays, the uses of glass fibres (e.g., StickTech fibres) have the potential of forming good chemical bond with the acrylic matrix, and fibres can be cured along the acrylic resin [31]. This lead to their use in repairing prostheses made out of acrylic resins including removable complete and partial dentures, palatal obturators, and retainers for orthodontic treatment [32].

Many studies have examined the bond strength between liners and the heat cured acrylic materials, but no information is available in the literature about bond strength between silicones (whether in the form of liner or facial prosthesis) and fibre-reinforced acrylic interfaces.

The null hypothesis for the present study was that there is no statistical difference in the average shear bond strength of *Molloplast-B* bonded to acrylic interfaces of different geometries (smooth, rough, and *Net*-fibre reinforced interfaces).

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MATERIALS AND METHODS

Fabrication of the specimen was conducted into two stages; the first one was fabricating the acrylic parts, followed by bonding the *Molloplast-B* to them. Brass moulds (specimens holders) (Φ= 14 mm) were used to prepare all the acrylic parts of the test specimens. The powder and monomer of acrylic were mixed according to manufacturer instructions (2.34 gm/1 ml) (powder/liquid ratio). Brass moulds were placed over a flat surface, and a roll of the dough mix was inserted into each one. A flat metal plate was placed over the top of each mould to compress the acrylic resin. The moulds were placed within a pneumatic press, and acrylic was compressed at 50 bars for 5 min. Then the moulds were secured in a clamp, and transferred to a water bath curing unit. A long curing cycle with of 6.5 h duration was followed.

When the curing finished, clamps were opened, moulds were released from the metal surfaces, and acrylic flash over the brass moulds rims was trimmed. The acrylic level was checked to be at the same level of the mould rim *Figure 1*.

43 specimens of smooth acrylic surfaces were obtained. 20 specimens were progressed to the second step of fabricating the soft polymer. The other 23 specimens with smooth acrylic surfaces were roughened using an acrylic bur.

The head of the bur was moved over the acrylic surface using light pressure. Then it was rotated at a speed of 10X (x = 1000 rpm). Interlocking circles were made in a clockwise direction until the whole surface was rough and the acrylic gloss disappeared.

This technique was adopted after trying many modes to create some roughness on acrylic surfaces similar to that being created by the application of *Stick Net* Fibres.

Regarding the fabrication of specimens of net fibre-reinforced interfaces, acrylic surfaces were reinforced at the interfaces by placing circular sheets of the net fibres (Φ= 14 mm) over the acrylic surfaces when the acrylics were pressed in the pneumatic press. Specimens were cured in the curing unit, following the same parameters mentioned previously and 24 specimens of fibre-reinforced interfaces were obtained.

Figure 1. *The cured acrylic at the interface.*

Two consecutive brushes of primo adhesive were brushed over the acrylic surfaces and left for 90 min before proceeding to bond the silicone. Teflon disks (PTFE) (external Φ = 18 mm, internal Φ = 8 mm, thickness = 3 mm) were prepared. The disks acted as moulds for packing the soft lining *Molloplast-B* into them.

For each sample, a small amount of *Molloplast-B* was taken from the container and placed in the disk, and immediately it was pressed against the acrylic surface. Gloves were worn, so that hands did not contaminate the lining material. Flat metal surfaces covered the outer surface of the disks, to press on the *Molloplast-B*.

The brass moulds along, with the lining materials, were inserted between the two grips of a pneumatic press. They were pressed at 5 bars for 5 min, and then the moulds were fixed in clamps, and inserted into water bath. The curing cycle was the same normally followed in curing *Molloplast-B* in Manchester Dental Hospital, UK. The duration of the cycle was 6.5 h.

The specimen fabrication procedure is shown in *Figure 2*. Micrographs of net fibres bonded to *Molloplast-B*, acrylic surfaces and the roughness created on the acrylic surfaces are present in *Figure 3*.

Specimens were stored in an incubator at a fixed temperature of 37 °C ± 1°C for 24 h and then the shear bond test was performed *Table 1*.

The test jig was designed according to the ISO/TR 11405:1994(E) [33]. It was installed on a Universal Testing Machine (Zwick/Roell, Z 020) and the shear test was performed at 2 mm/min *Figure 4*. The lining material projected through the sliding part of the apparatus, which in turn transformed the compression force from the load cell of the Universal Testing Machine, into a shear force at the interface between the two bonded materials.

The bond strength was calculated by the following formula (S= F/A), where F= Maximum force and A= cross section area.

Bond strength values were analysed ($p \leq 0.05$) using One-way Analysis of Variance (ANOVA), and Bonferroni *post hoc* tests (SPSS14, Chicago, USA). Modes of failure were recorded by two trained investigators. Interobserver agreement was statistically analysed ($p \leq 0.05$) using Kappa test (SPSS14, Chicago, USA).

RESULTS

Means (SD) of shear bond strengths for the groups were: 0.59 (0.08), 0.61 (0.08) and 0.70 (0.09) for the smooth, rough and fibre-reinforced interfaces respectively. Net-fibre reinforced acrylic interface exhibited statistically significantly higher bond strength value when compared to smooth acrylic interface ($p \leq 0.05$) *Figure 5*.

Modes of failure are presented in *Table 2*. A Kappa value of 0.746 (*Table 3)* indicated a substantial inter-observer agreement in defining modes of failure. Cohesive failure was predominantly present among all interfaces followed by mixed failures (60 and 7 respectively).

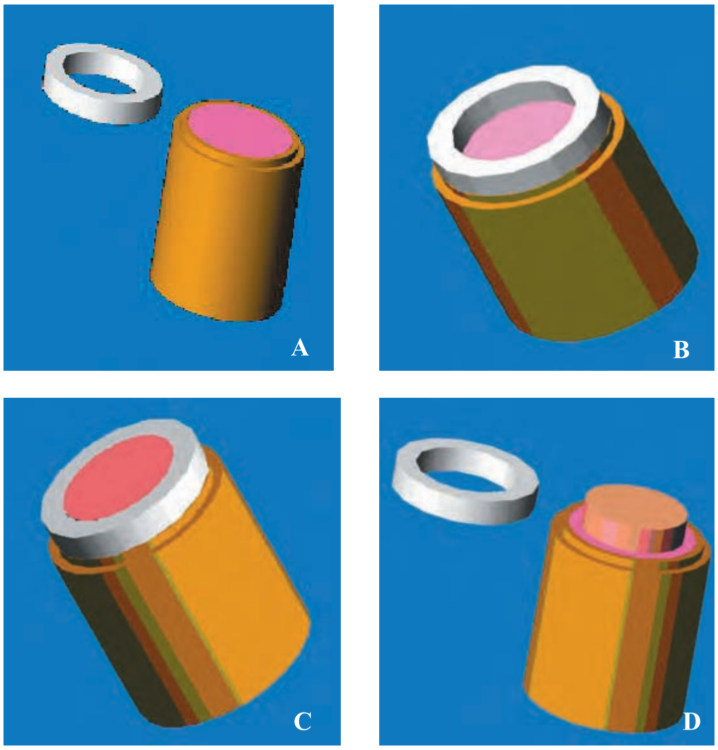

Figure 2. *Steps of packing the liner. Acrylic interface prepared (A). The disk was placed over the brass rim (B). Molloplast-B was packed inside the disk (C), and the specimen after curing (D).*

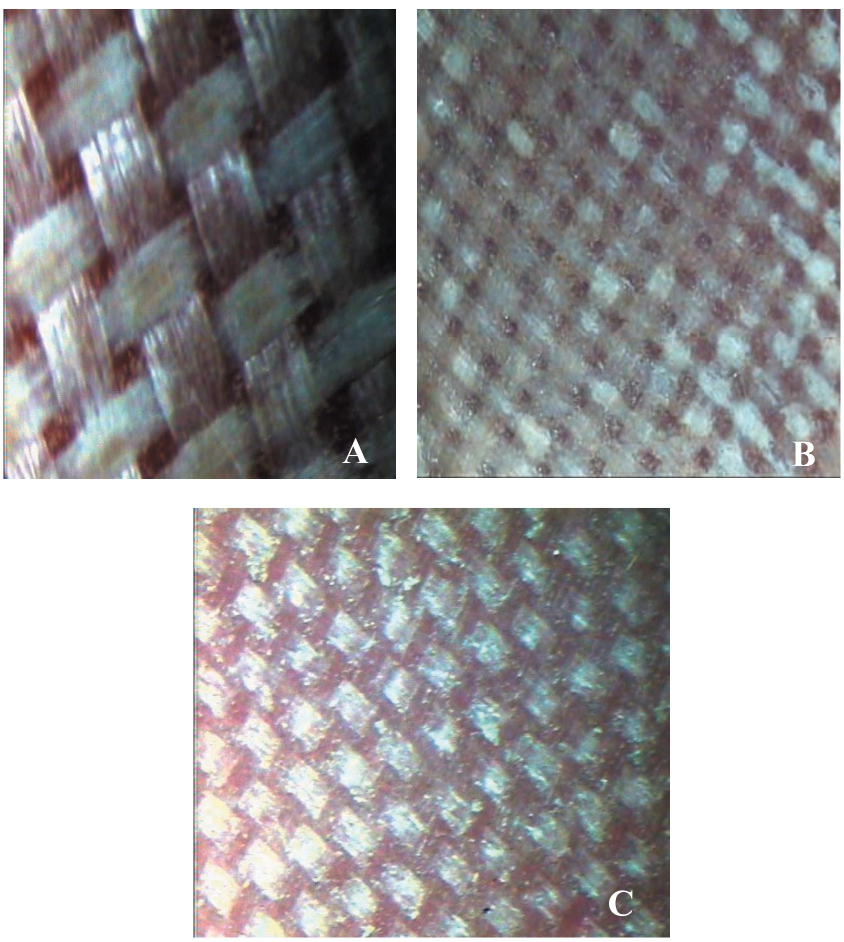

Figure 3. *Images of Net fibres bonded to the liner (A), the acrylic surface (B), and the roughness created at the acrylic surface after peeling off the Net fibres (C).*

Table 1. *Groups of the study.*

Group	*n*	*Acrylic interface*	*Conditioning*
1	20	Smooth	
2	23	Rough	37 °C /24 h
3	24	Net Fibre- reinforced	

Table 2. *Modes of failure presented at bond interfaces*

Group	*Mode of failure*			*Total*
	Adhesive	*Cohesive*	*Mixed*	
Smooth interfaces	0	16	4	20
Rough interfaces	0	20	3	23
Fibre-reinforced interfaces	0	24	0	24

Table 3. *Analysis of interobserver agreement in identifying modes of failure.*

	Value	*Asymp. Std. Error(a)*	*Approx. T(b)*	*Approx. Sig.*
Measure of Agreement Kappa	0.746	0.139	6.362	0.000
N of Valid Cases	68			

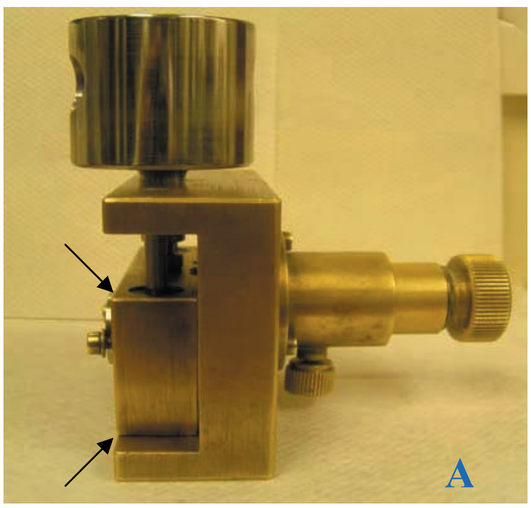

Figure 4. *Shear bond jig used (A) (the sliding part between the two arrows). A specimen fixed into the specimen holder (B).*

DISCUSSION

The shear test was utilized to measure the bond strength of *Molloplast-B* bonded to heat cured fibre-reinforced and non reinforced PMMA acrylic interfaces. The average bond strengths for all groups in MPa, from groups 1 to 3 were as following: 0.59, 0.6 1, and 0.70 MPa. *Molloplast-B* lining material had sufficient bond strength (> 0.44 MPa) to different interfaces of heat cured PMMA acrylic, which made it clinically applicable according to published studies [34,35]. Rough acrylic interfaces gave improved bond strengths with *Molloplast-B* in relation to smooth interfaces, but the increase was not statistically significant ($p \leq 0.05$). This result is in agreement to some studies [20, 34, 37], but not others [14]. Rough interfaces were produced using an acrylic bur in a controlled manner, and a primer adhesive was brushed over the acrylic interfaces. The adhesive was to increase the chemical bond of soft liner to the acrylic structure [36]. This technique was standardized for all rough specimens, and was adopted in some previous studies [16, 23].

The increase in bond strength of rough acrylic interfaces related to smooth interfaces is readily understood as due to micro-mechanical interlocking between the liner and surf ace irregularities. The disagreement with the work of Amin *et al.*[14] may be due to the technique of sandblasting with 250$_{um}$ aluminium oxide. It may also be due to different types of acrylic material since bond strength varies between acrylic resins [24] .

Samples of *Molloplast-B* bonded to *Net* fibre-reinforced acrylic interfaces gave improved bond strength in comparison to both smooth and rough acrylic interfaces.

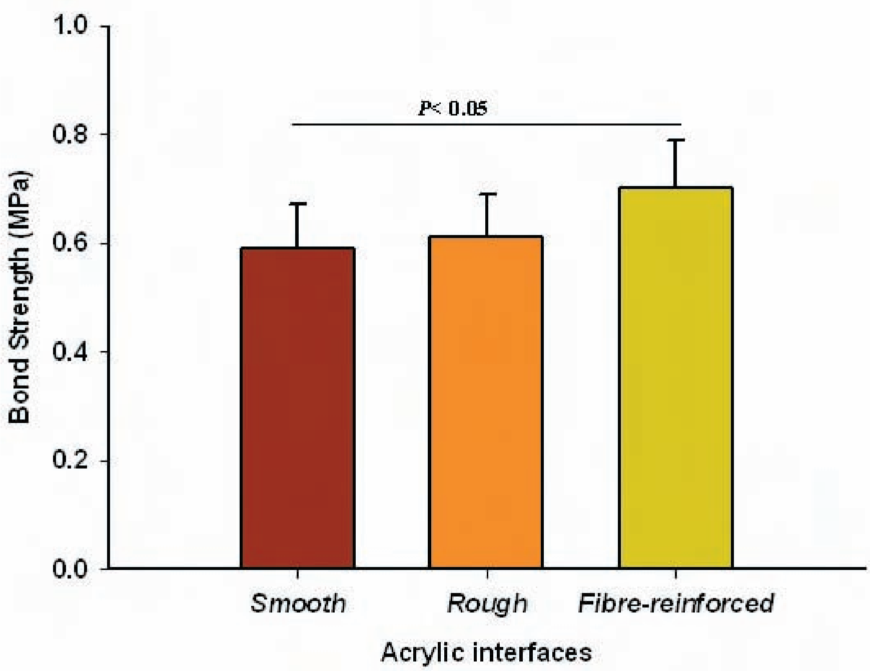

Figure 5. *Grouped bar chart with error bars showing the bond strengths and statistical significances presented between groups.*

The increase was significant ($p \leq 0.05$) when compared to smooth interfaces only. The fibres have a woven shape (net) and are applied directly at the bond interface, a primer adhesive was brushed over them and the liner was bonded to the interface. The change in the topography of the bond interface; by the presence of the fibres (creating different type of roughness), along with the chemical adhesion of the primer lead to the increase in bond strength. But this increase was statistically significant only when compared to the smooth and not to roughened acrylics.

Fibres are used to increase the impact strength of heat cured acrylic bases [38, 39]. They have the advantages of excellent aesthetics, being non-invasive, and having a good bond strength with the surrounding matrix [32].

In comparing the modification of net fibres at the interface to the roughness technique, net fibres were easily applied at the bond interface, reinforcing the acrylics and increasing the bond strength with the liner, while roughening was time consuming, not feasible when the acrylic base is thin (in limited interocclusal spaces), and this may weaken the acrylic structure.

Modes of failure exhibited at debonding sites

The mode of failure for all acrylic interfaces was mainly cohesive within the *Molloplast-B* material, while group 1 and 2 specimens exhibited mixed failures, where a superficial layer of liner adhered to the bond interface. Cohesive failure means that the bond strength of the lining material to the acrylic interface is stronger than the tensile strength of the lining material itself [41].

This result agreed with other studies of bonding 3 mm thickness of *Molloplast-B* liner to acrylics which show mainly cohesive and some mixed failures [16]. This differed from studies indicating entirely cohesive failures within the silicone liner [15], or entirely adhesive failures [40]. Such disagreements may relate to differences in experimental designs.

The presence of net fibres at the bond interface caused all specimens to exhibit cohesive failure only, which means that no separation of the liner from the net-interfaced acrylic occurred and tearing happened within the liner. Consequently, the effective bond strength between *Sticktech Net* fibre-reinforced acrylic bases and silicone was improved.

CONCLUSIONS

1. *Molloplast-B* soft-lining exhibited stronger bond to *StickTech Net* fibre-reinforced PMMA acrylic surfaces than to non-reinforced acrylic surfaces, with either smooth or rough finishes.
2. All of the acrylic interfaces evaluated had clinically acceptable mean bond strengths greater than 0.44 MPa.

MANUFACTURER' DETAILS

- Minacryl Universal (heat cured denture base acrylic powder). Batch number A1572B-1. Minerva Dental limited, Cardiff, UK.
- Minacryl Universal (Heat cured liquid). Batch number L 717-B. Minerva Dental limited, Cardiff, UK.
- *Molloplast –B (*Heat cured silicone lining material). Batch number 050418. DETAX Gmbh & Co. KG,Ettlingen, Germany.

- Primo adhesive (solvent based adhesive for heat cured denture silicone liners). Batch number 050501.DETAX Gmbh & Co. KG, Ettlingen, Germany.
- *Everstick Net (*Glass fibres). Batch number AA 00115, 2050628-EN-081. StickTech, Turku, Finland.
- Pneumatic press. Skillbond Limited, High Wycombe, UK.
- Water-bath heat curing unit (DEROTOR). Eclipse, dental Manf, Worthing, UK.
- Micro-motor. W&H Dental Werk,BÜRMOOS, GmbH, Germany.
- Acrylic bur (steel cutter). Skillbond limited, High Wycombe, UK.
- Zwick Universal Testing Machine. Zwick Testing Machines, Leominster, UK.
- Shear test jig. Manchester medical school engineering workshop, Manchester, UK.

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