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Original Research

Tensile and shear bond strength of hard and soft denture relining materials to the conventional heat cured acrylic denture base resin: An In-vitro study

Mayank Lau[1], G S Amarnath[2], B C Muddugangadhar[3], M U Swetha[4], Kopal Anshuraj Ashok Kumar Das[4]

Contributors:

[1]Senior Lecturer, Department of Prosthodontics, Maharana Pratap College of Dentistry & Research Centre, Gwalior, Madhya Pradesh, India; [2]Professor & Head, Department of Prosthodontics, M R Ambedkar Dental College and Hospital, Bangalore, Karnataka, India; [3]Reader, Department of Prosthodontics, M R Ambedkar Dental College and Hospital, Bangalore, Karnataka, India; [4]Post Graduate Student, Department of Prosthodontics, M R Ambedkar Dental College and Hospital, Bangalore, Karnataka, India.

Correspondence:

Dr. Amarnath G S. Department of Prosthodontics, M R Ambedkar Dental College & Hospital, 1/36, Cline road, Cooke Town, Bangalore, Karnataka, India. Phone: +91 – 9916472790. Email: dramarnathgs@gmail.com

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Abstract:

Background: The condition of the denture bearing tissues may be adversely affected by high stress concentration during function. Chairside Denture (Hard and Soft) reliners are used to distribute forces applied to soft tissues during function. Tensile and shear bond strength has been shown to be dependent on their chemical composition. A weak bond could harbor bacteria, promote staining and delamination of the lining material. To investigate tensile and shear bond strength of 4 different commercially available denture relining materials to conventional heat cured acrylic denture base resin.

Materials & Methods: 4 mm sections in the middle of 160 Acrylic cylindrical specimens (20 mm x 8 mm) were removed, packed with test materials (Mollosil, G C Reline Soft, G C Reline Hard (Kooliner) and Ufi Gel Hard and polymerized. Specimens were divided into 8 groups of 20 each. Tensile and shear bond strength to the conventional heat cured acrylic denture base resin were examined by Instron Universal Tensile Testing Machine using the equation F=N/A (F-maximum force exerted on the specimen (Newton) and A-bonding area= 50.24 mm^2). One-way ANOVA was used for multiple group comparisons followed by Bonferroni Test and Hsu's MCB for multiple pairwise comparisons to asses any significant differences between the groups.

Results: The highest mean Tensile bond strength value was obtained for Ufi Gel Hard (6.49±0.08 MPa) and lowest for G C Reline Soft (0.52±0.01 MPa). The highest mean Shear bond strength value was obtained for Ufi Gel Hard (16.19±0.1 MPa) and lowest for Mollosil (0.59±0.05 MPa). The Benferroni test showed a significant difference in the mean tensile bond strength and the mean shear bond strength when the two denture soft liners were compared as well as when the two denture hard liners were compared. Hsu's MCB implied that Ufi gel hard is better than its other closest competitors.

Conclusion: The Tensile and Shear bond strength values of denture soft reliners were significantly lower than denture hard reliners.

Key Words: G C reline, mollosil, reliners, shear bond strength, tensile bond strength, ufi gel hard

Introduction

Gradual changes of oral tissues require that complete or partial dentures be relined to improve their adaptation to the supporting tissues. The condition of the denture bearing tissues may be adversely affected by high stress concentration during function.[1] Chairside Denture reliners which are intended for relining removable dentures and other maxillofacial prostheses are used to distribute forces applied to soft tissues during function. The tissue contacting surface of prosthesis is covered with the soft liner and this coated structure is expected to have a healing effect on the mucosa as well as giving comfort to the patient. A reliable bond between denture base and soft liner is required for the denture to function properly.[2]

Denture relining is defined as procedure used to resurface the tissue side of denture. It eliminates the need for making new dentures for the patient when changes are minimal and existing denture is in a relatively good condition. These chairside reline materials allow dentist to reline removable prostheses directly in mouth. Two types of chair side denture relining materials are used: Hard and Soft reliners. In hard relining materials there are different sub groups such as heat cured, self cured and light cured. Soft or resilient liners are preferred for sensitive mucosal tissues. Soft reliners are divided into four groups based on chemical structures: plasticized acrylic resins (chemical or heat cured), vinyl resins, rubbers (polyurethane and polyphosphazine type) and silicone rubbers.[1]

Properties such as tensile and shear bond strength has been shown to be dependent on chemical composition of both reline materials and denture base polymers. A weak bond could harbor bacteria, promote staining and delamination of the lining material.[3] Also, it is suggested that the bond strength between the denture reline and denture base resins could affect the mechanical strength of the reline denture base.[4] Hence, this study was undertaken to investigate the tensile and shear bond strength of different commercially available denture relining materials to conventional heat cured acrylic denture base resin.

Materials and Methods

The present study was carried out in the Department of Prosthodontics including Crown and Bridge and Implantology, M R Ambedkar Dental College and Hospital, Bangalore.

Figure 1: Flasked Aluminium cylinders and heat cured PMMA Cylinders.

160 Cylindrical acrylic specimens were made from moulds prepared by solid aluminium cylinders of dimension 20 mm length and 8mm diameter (Figure 1). These solid

Figure 2: 4 mm sectioned PMMA specimens.

aluminium cylinders were flasked conventionally using Dental Flask and clamp (Jabbar & Co.) with dental plaster type II and dental stone type IV mixed in the ratio 1:1. Once set, the flasks were opened and cylinders retrieved.

Conventional heat cure acrylic denture base resin (Dental Products of India, Dentsply) was mixed [ratio 3(polymer): 1(monomer)] and packed according to manufacturers' instructions. It was allowed to bench cure for about 30 minutes and heat cured using short curing cycle 74^0 C for 90 minutes and an additional 30 minutes at 100^0 C. On completion and cooling, the heat cured acrylic cylinders were retrieved. Finishing was done using cherry stone finishing burs and dry emery papers (John Oakey and Sons limited, Wellington, England). Each finished cylinders (20 mm x 8 mm) were placed back to their respective moulds (Figure 1). 4mm in the centre of the cylinders were marked using a marker and were sectioned using the disc. Separating medium was applied over the mould containing these specimens (Figure 2).

Grouping of the samples:

All 160 samples prepared were divided into 8 groups. Each group contained 20 samples.

For Tensile bond strength testing:

Group 1: Denture soft reliner: Mollosil

Figure 3: 4 mm section of PMMA cylinders packed with the test material.

Group 2: Denture soft reliner: G C Reline Soft

Group 3: Denture hard reliner: G C Reline Hard (Kooliner)

Group 4: Denture hard reliner: Ufi Gel Hard

For Shear bond strength testing:

Group 5: Denture soft reliner: Mollosil

Group 6: Denture soft reliner: G C Reline Soft

Group 7: Denture hard reliner: G C Reline Hard (Kooliner)

Group 8: Denture hard reliner: Ufi Gel Hard

Each reliner to be tested was mixed according to the manufacturer's instructions and packed in the 4 mm empty mid portion of the cylinders (8mm x 8mm). The flasks were closed and allowed to cure. Once cured, the cylinders with the test materials were retrieved from the flasks and finished with the scissors and diamond burs (Figure 3).

Each cylinders with the reliners interposed were tested individually for tensile and shear bond strength with the help of INSTRON Universal testing machine (5582 model, UK) made which is digitally controlled and has a software for test control and data acquisition. The vertical uniaxial tensile load (100 kN) was applied to the ends of the cylinder with a cross head speed of 1mm/min until debonding of the test material occurred with respect to conventional heat cured acrylic denture base resin. This force in Newton was recorded by the system (Figure 4).

Typically bond strength was calculated in Megapascals, taking into account the surface area of the adhesive interface. Since the test area was in circular (8 mm x 8 mm) in shape, the area had to be considered as $\pi^2/4$, where 8 mm was taken as diameter of the cylindrical acrylic specimens. The area of the cross section was calculated approximately as 56.26 mm^2.

The following equation was used to calculate the tensile bond strength:

$$F=N/A$$

Where F is the tensile bond strength (MPa), N is the vertical uniaxial load exerted on the specimen (in Newton) and A is the size of bonding area that is 56.26 mm^2.

All the 80 specimens (20 samples for each group) were tested similarly and data was collected by the same operator.

To compare the differences between the groups, obtained results were statistically analyzed. One-way ANOVA was used for multiple group comparisons followed by Bonferroni Test and Hsu's MCB for multiple pairwise comparisons to asses any significant differences between the groups.

Results

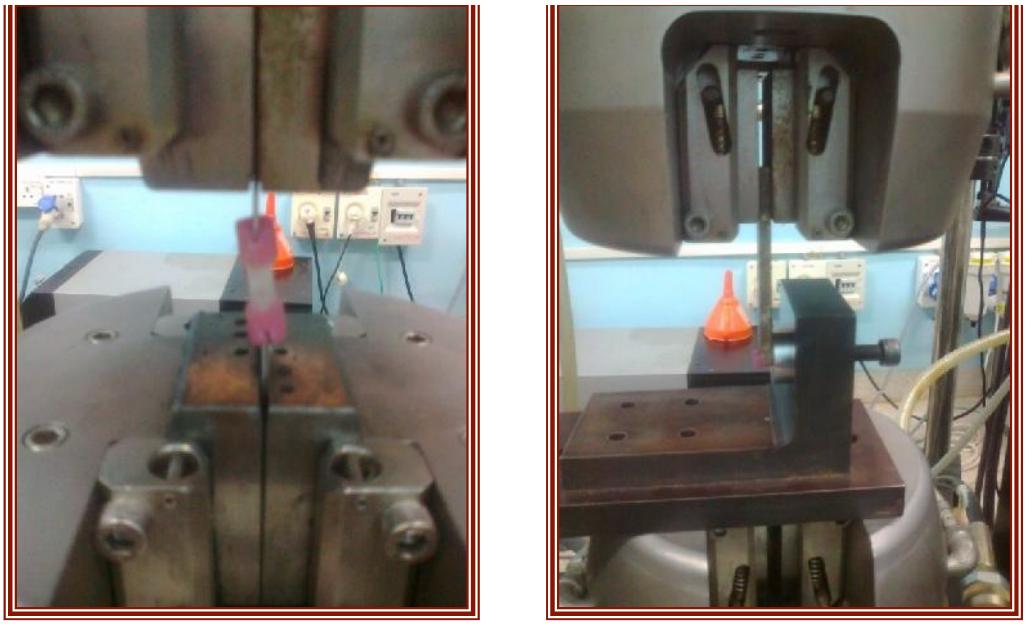

Figure 4: Tensile and Shear bond strength testing of the specimens.

G C Reline soft (0.72±0.02 MPa) had higher values of shear bond strength than Mollosil (0.60±0.05 MPa) whereas Mollosil (0.68±0.01 MPa) showed higher values of tensile bond strength when compared to G C Reline soft (0.54±0.01 MPa). Ufi-Gel-Hard showed higher values of both shear (16.22±0.1 MPa) and tensile bond strength

Table 1: Mean Tensile Bond Strength and Standard Deviation among different groups (MPa)

	Mollosil	GC Reline Soft	GC Reline Hard	Ufi Gel Hard
Mean	0.67	0.52	4.85	6.49
Standard Deviation	0.01	0.02	0.02	0.02

Table 2: Multiple Group Comparisons: One-Way ANOVA.					
Source of Variation	**Sum of Squares (SS)**	**Degree of Freedom (V)**	**Mean sum of Squares (MS)**	**Variance ratio (F)**	**P value**
Between Groups	542.71	3.00	180.90	472119.10	0.0000
Within Groups	0.03	76.00	0.00038	0.006409	<0.001
Total	542.74	79.00	14.4586	0.006409	0.0000
P-value less than 0.05 indicates significant difference between the groups with respect to the mean load					

(6.53±0.08 MPa) as compared to G C Reline Hard (7.80±0.3 MPa), (4.88+0.03 MPa) respectively (Table 1, 5; Figure 5, 6). According to the one way ANOVA test, a highly significant difference was seen between and within the tensile and shear bond strength of the groups with respect to the mean loads (Table 2, 6). The Benferroni test (Table 3, 7) showed a significant difference in the mean tensile bond strength and the mean shear bond strength when the two denture soft liners were compared as well as when the two denture hard liners were compared. Hsu's MCB (Table 4, 8) implied that Ufi gel hard is better than its other closest competitors.

Discussion

According to the current literature, there is no general

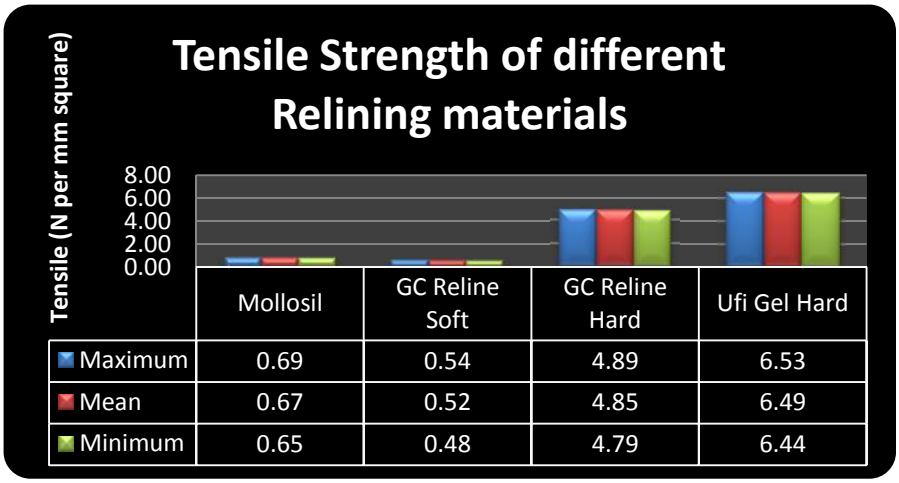

Figure 5: Maximum, Mean and Minimum values of Tensile Bond Strength. (Comparative Evaluation of Mean Tensile Bond Strength)

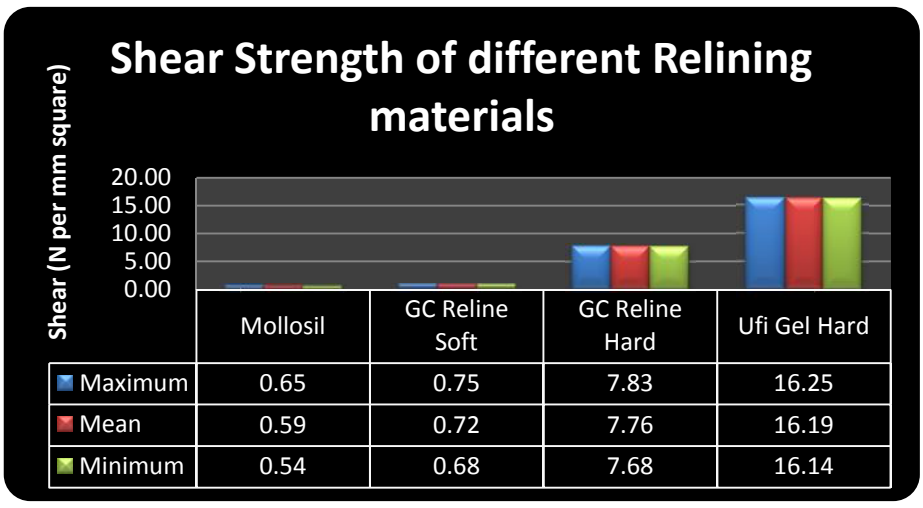

Figure 6: Maximum, Mean and Minimum values of Shear Bond Strength. (Comparative Evaluation of Mean Shear Bond Strength)

agreement about a test method to be used for evaluating the bond strength of denture relining materials.

In the present study, a tensile & shear test method was preferred because it applies a simple load to the joint, which allows for comparison among different materials.

Table 3: Pair-wise comparisons: Bonferroni Test.		
	STATISTIC	**P-value**
Soft Reliners	24.92	0.0000
Hard Reliners	265.48	0.0000
P-value less than 0.05 indicates significant difference between the groups with respect to the mean load Dependent Variable: Load (Newton)		

Denture relining materials were polymerized on dry, fresh conventional heat cure acrylic denture base resin and tested under dry conditions. This is similar to the study done by Mutluay et al.[5] Shear test method was also taken in this study as it simulates the masticatory load intraorally.[6]

Table 4: Hsu's MCB (Multiple Comparisons with the Best)		
Comparison	**Confidence interval**	**P-value**
Mollosil v/s Ufi Gel Hard	-5.84	0.00
GC Reline Soft v/s Ufi Gel Hard	-5.99	0.02
GC Reline Hard v/s Ufi Gel Hard	-1.66	0.00
Since upper limit is zero, there is significant difference between the material and the 'best' mean		

The test of such bond strength has been performed most commonly with a transverse method.[7-9]

Craig and Gibbons and Khan et al. evaluated the bond strength of resilient lining materials and claimed that 10 psi (4.5 kg/cm^2/ 0.45MPa) is an adequate adhesive value for an optimal bond. But Kawano et al. suggested that the force for failure was at least (9.6 kg/cm^2 or 0.96MPa) or higher for all materials tested. If the tensile strength of lining materials in this study is compared with the above studies, Mollosil (0.68±0.01 MPa), G C Reline soft (0.54±0.01 MPa), Ufi-Gel-Hard (6.53±0.08 MPa), G C Reline Hard (4.88±0.03 MPa) were found to be adequate for clinical use.

The mechanisms for adhesion of hard relining materials to PMMA denture base materials are dependent on swelling of the surface by monomer or solvent, diffusion of monomers into the swollen PMMA denture base material, polymerization, and formation of IPN (interprismatic network).[3-5,10-13] This process is reported to be dependent on time, temperature, type of solvent, polymeric structure and glass transition of the polymer.[10,14,15]

Specimens of PMMA denture base were used 24 hours after polymerization. The result of a recent study suggested that bond strength of autopolymerizing resin to denture base polymer is not significantly influenced by water content of the denture base polymer.[10,16]

Table 5: Mean Shear Bond Strength and Standard Deviation among different groups (MPa)				
	Mollosil	**GC Reline Soft**	**GC Reline Hard**	**Ufi Gel Hard**
Mean	0.59	0.72	7.76	16.19
Standard Deviation	0.03	0.02	0.02	0.03

However, the bond strength is influenced by resin type, thermal cycling and surface treatment. The same study also found that bond strength to a water-saturated, solvent-treated PMMA surface was not different from bond strength to a desiccated solvent-treated PMMA surface.[14,16]

Table 6: Multiple Group Comparisons: One-Way ANOVA.					
Source of Variation	**Sum of Squares (SS)**	**Degree of Freedom (V)**	**Mean sum of Squares (MS)**	**Variance ratio (F)**	**P value**
Between Groups	3254.12	3.00	1084.71	1444.59	0.0000
Within Groups	57.07	76.00	0.75	0.004584	<0.001
Total	3311.18	79.00	17.5105	0.004584	0.0000
P-value less than 0.05 indicates significant difference between the groups with respect to the mean load					

Table 7: Pair-wise comparisons: Bonferroni Test		
	STATISTIC	**P-value**
Soft Reliners	-0.46	0.3224
Hard Reliners	32.20	0.0000
P-value less than 0.05 indicates significant difference between the groups with respect to the mean load Dependent Variable: Load (Newton)		

Table 8: Hsu's MCB (Multiple Comparisons with the Best)		
Comparison	**Confidence interval**	**P-value**
Mollosil v/s Ufi Gel Hard	-16.33	0.00
G C Reline Soft v/s Ufi Gel Hard	-16.20	0.00
G C Reline Hard v/s Ufi Gel Hard	-9.55	0.00
Since upper limit is zero, there is significant difference between the material and the 'best' mean		

Generally new denture relining resins have monomers with larger molecules (molecular weight larger than 100) which act slower with respect to swelling PMMA and penetrating the PMMA surface. For the purpose of swelling PMMA, monomers such as MMA and 2-HEMA or solvents such as dichloromethane, acetone and chloroform are used in the bonding liquids or primers.[3,5,11,16]

Dibutyl phthalate in the monomer liquid and diethyl phthalate in the powder have been used for increasing the solubility of the PMMA beads of the denture base powder while the resin dough is prepared.[17] A disadvantage of the use of this system is the possibility of MMA coming in contact with the oral mucosa which has the potential of sensitizing or causing allergic and toxic reactions.

Monomer liquid of Kooliner is IBMA (Isobutyl methacrylate) and does not contain primers and bonding agent. This material softens the denture base. IBMA is bigger in size and does not penetrate the denture base. Hence, Kooliner showed less tensile and shear bond strengths than Ufi Gel Hard.[3]

Bonding between reline acrylic resin and denture base resin is established at the interface where the two materials intermix. Primers that consist of solvents may dissolve the surface of the denture base and promote penetration of reline acrylic resin into the denture base resin. These reactions may result in the formation of a mixed layer of reline acrylic resin and denture base resin.[3]

Kooliner has MMA in the recommended bonding agent, which has good swelling properties and also the ability to introduce the small MMA molecules penetrating into the denture base polymer for good bonding.[14] The bonding agent for Kooliner also has small molecules such as acetone for swelling and 2-HEMA for swelling and penetrating.

Amongst the soft relining materials, Mollosil showed more tensile bond strength due to its adhesive component. GC Reline soft had more shear bond strength. It contains poly(organosiloxane) which gives good handling properties and highest bond strength as also approved by different studies, which can be also used as a tissue conditioner.

G C reline soft does not chemically bond with denture base resins. Therefore, change in denture base composition does not affect bonding properties. Bonding occurs by treatment of surface layer by solvent and partially impregnating the surface layer with polymer solution. Contamination, humidity and surface structure of denture base polymer all negatively affect the bond strength.[2]

For PMMA denture polymer, the higher bond strength was reported with MMA-based resin than non-MMA based material. For the interpretation of bond strength results, a good understanding of the failure mechanisms is essential.

In this study, failure was observed at or very near to the interface involving adhesive failure in the interfacial region. This suggests that even though good interpenetration is obtained by the use of different monomers, stress concentrations and the possible lower cohesive strength of the relining material that existed near the interface caused failure. Despite not being able to produce stronger bonds than the PMMA denture base material when bonded to itself, there are relining materials with relatively high and weak bond strengths. The resins that show interpenetration with a low molecular weight monomer proved to perform better than the others.

MMA and HEMA were observed to be good bonding agents, initially providing high bond strength results and deeper swollen layer formations. Even though a relining material has good mechanical properties that could match PMMA denture base materials, a delaminating of the material combination will still cause the reline to fail and require replacement of the lining. Such failure may result in midline fractures. A clinician must consider using a material with good bonding properties, as well as good flexural properties combined with good handling properties.

Hard reliners are recommended in high stress bearing areas which require high strength. On the other hand, soft reliners should be used in areas of injury, trauma, healing and low stress bearing areas which require good resilient support.

Conclusion

In order to achieve success in the relining process in complete and partial dentures, the same type of heat-cured lining material should be used because of the need for similar tensile strength and bonding properties. Most bonds established between the materials tested appeared to be adequate but delamination of the material will still cause the reline to fail and require replacement of the lining. A clinician must consider using a material with good bonding properties, as well as good flexural properties combined with good handling properties.

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