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Original Article

Comparative evaluation of the tensile bond strength of two silicone based denture liners with denture base resins

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ABSTRACT

Background: To evaluate and compare tensile bond strength of two silicone based liners with heat cure and heat cure high impact denture base resin at baseline and after storage in artificial saliva for 30 and 60 days.

Method: Heat cure conventional and high impact acrylic blocks (120 blocks each) prepared with final test specimen of two blocks of each resin with a liner. The baseline samples and those tested after 30 and 60 days interval stored in artificial saliva in thermal incubator, all were pulled apart in UTM at 20 mm/min. The tensile bond strength and mode of failure (adhesive/cohesive) were assessed. Mean, SD determined and analysis using one way ANOVA and paired 't' test.

Results: The highest mean tensile bond strength (1.028 MPa) and the least i.e. 0.289 MPa was observed with Permaflex silicone liner against heat cure PMMA after storage in artificial saliva at $37 \pm 1^\circ\text{C}$.

Conclusion: The study rejected the null hypothesis because storage time in artificial saliva affected the bond strength of the resilient liners examined. The results revealed a statistically significant difference ($p < 0.05$) of artificial saliva storage on the bond strength of both the liners. After storage in artificial saliva for 30 days and 60 days at $37 \pm 1^\circ\text{C}$, all the specimens showed a significant reduction in the tensile bond strength.

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Introduction

Complete denture bases are fabricated commonly from rigid denture base materials like acrylic, vinyl and other resin

polymers. The success of complete or partial dentures depends on esthetics, comfort and function.¹ The fit of the denture base to the alveolar ridge progressively declines as the alveolar ridge resorbs, which affects denture stability, support

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and retention thus jeopardizing denture success. In various clinical conditions like atrophic or resorbed ridges, xerostomia, dentures opposing natural dentition, bony undercuts, relining is indicated to recapture the fit of the denture base, especially when the denture still retains proper vertical dimension, occlusal relationship and esthetics.^{2,3} (Tables 1 and 2).

These resilient materials partially absorb force, equally distribute functional and non functional stresses, reduce localized pressure to the underlying basal seat and provide relief for prominent mid-palatine raphe, anterior nasal spine etc.² They have evolved as a vital treatment modality for geriatrics patients with heavy bruxing, clenching habits leading to considerable damage to the supporting tissues in the form of chronic soreness, pathologic changes and bone loss. Also used in oral cancer patients with postoperative defects requiring obturation and to modify transitional prosthesis after stage I and II implant surgery.⁴

Denture liners have been used in dentistry for more than a century. One of the first synthetic rubbers developed in 1945, as a denture liner was a plasticized polyvinyl resin. This was followed by introduction of silicones in 1958.^{4,5} Permanent soft lining materials like epoxy, acrylic, urethane or silicone polymers, replace the fitting surface of a hard plastic denture. Commonly used silicone liners can be RTV and heat cured.⁶

Soft liners have several problems like loss or varying degree of softness, colonization with *Candida albicans*, staining, porosity, poor tear strength and lack of color stability.⁷ One of the serious problems is the failure of adhesion between the soft liner and the denture base. This creates a potential for bacterial growth, plaque, food debris and calculus accumulation.¹³ Therefore, frequent clinical evaluation and periodic replacement of the soft denture liner is essential.⁷ Serviceability of lining material varies from 6 months to 5 years.

Dentures relined with silicones can only be successful if a satisfactory bond exists with denture base acrylic resin. In use, they are constantly bathed in saliva, when out of the mouth, they are usually stored in either denture cleansers or water. In these situations, water or saliva gets absorbed into the material, and plasticizers of the soft liner leach.⁸ When the material swells, stress builds up between the bonding surfaces and the visco-elastic properties of resilient denture change.

Moist environment of the oral cavity may affect the bonding of the soft liner with the denture base. So this study was undertaken as there is dearth of clinical data about the effectiveness of such bonding.

To evaluate and compare tensile bond strength of two silicone liners with heat cure and heat cure high impact denture base resin at baseline and after storage in artificial saliva for 30 and 60 days.

Materials and methods

1. A preformed rectangular brass test specimen of dimensions 10 mm × 10 mm × 40 mm was taken.
2. The base and catalyst of silicone duplicating rubber (Elite Double 32, Zhermack) were measured and mixed in 1:1 ratio in a vacuum mixer for 30 s and slowly poured in a conventional brass flask and the brass test specimen was placed horizontally in the centre of the mix after the initial preset. The brass specimen was retrieved after the final set of the mix (approx 20 min) to obtain the mould.
3. Wax blocks were prepared from the metal mould after applying oil to facilitate easy removal. The baseplate wax was melted on a Bunsen flame and poured into the silicone mould. The lid of the flask was replaced and any

Table 1 – Comparison of paired subsubgroups of Group 1 and Group 2.

		Mean	Standard deviation	't' value	p value
Pair 1	Group 1 A (I) – Group 1 A (II)	0.2940	0.27126	3.427	0.008
Pair 2	Group 1 A (I) – Group 1 A (III)	0.4090	0.28085	4.605	Significant 0.001
Pair 3	Group 1 A (II) – Group 1 A (III)	0.1150	0.20387	1.784	Significant 0.108
Pair 4	Group 1 B (I) – Group 1 B (II)	0.2610	0.23568	3.502	Non significant 0.007
Pair 5	Group 1 B (I) – Group 1 B (III)	0.3220	0.28224	3.608	Significant 0.006
Pair 6	Group 1 B (II) – Group 1 B (III)	0.0610	0.14700	1.312	Significant 0.222
Pair 7	Group 2 A (I) – Group 2 A (II)	0.23700	0.18921	3.961	Non significant 0.003
Pair 8	Group 2 A (I) – Group 2 A (III)	0.52900	0.27819	6.013	Significant 0.000
Pair 9	Group 2 A (II) – Group 2 A (III)	0.29200	0.27776	3.324	Significant 0.009
Pair 10	Group 2 B (I) – Group 2 B (II)	0.14400	0.15981	2.850	Significant 0.019
Pair 11	Group 2 B (I) – Group 2 B (III)	0.16900	0.30777	1.736	Significant 0.116
Pair 12	Group 2 B (II) – Group 2 B (III)	0.02500	0.26647	0.297	Non significant 0.773
					Non significant

Table 2 – Comparison of mean tensile bond strength between the two subgroups of liners.

		Sum of squares	df	Mean square	F value	p value
Molloplast-B	Between Groups	2.212	2	1.106	22.203	0.000 Significant
	Within Groups	2.840	57	0.050		
	Total	5.052	59			
Permaflex	Between Groups	0.688	2	0.344	11.241	0.000 Significant
	Within Groups	1.743	57	0.031		
	Total	2.430	59			

discrepancy in wax was compensated by a second pour. The mould was then bench cooled for 1 h to prevent any wax distortion. 240 wax block specimens were obtained, washed in soap solution.

- The wax blocks were divided into two groups of 120 wax block specimens each:

Group 1 – Heat cure PMMA denture base resin (Trevalon).

Group 2 – Heat cure high impact PMMA denture base resin (Trevalon Hi).

Group 1 (Trevalon) – The wax blocks were invested horizontally in a denture flask with Type-II gypsum followed by dewaxing and steam cleaning to ascertain complete wax elimination. The flask was bench cooled and separating medium was applied.

Conventional heat cure PMMA (Trevalon) in a ratio of 24 gm:10 ml by volume was mixed, packed into the flask in dough and covered with a thin cellophane sheet. After trial closure, bench cured for 30 min. Then finally immersed in boiling water, turning off the heat for 20 min, reheating and boiling for 20 min. Bench cooled for 10 min and thereafter, the acrylic specimens were retrieved, finished and polished using the conventional technique.

Group 2 (Trevalon Hi) – The investing, dewaxing, packing procedures were similar. The polymer:monomer ratio was 25 gm:11 ml. The dough stage was reached in 15–25 min. The final curing cycle was then initiated by immersing the specimens in boiling water, turning off the heat for 20 min. Low heat was applied to maintain temp at approx 68 °C for further 20 min and finally boiling the specimens for 20 min. Bench cooling, retrieval, finishing and polishing of the acrylic specimens were similar as for Group 1. A caliper was used to verify the dimensions of the acrylicized blocks.

Methodology for preparation of final acrylic resin block with liner

The specimens were cleaned using pumice and air dried. The bonding surface was abraded using sandpaper. Two blocks from same resin were invested horizontally in a rectangular metal flask with a sandwiched baseplate wax spacer (10 mm × 10 mm × 1.8 mm). The flask was placed in boiling water for 5 min, for dewaxing of the spacer. The mould was steam cleaned. The width of the space was verified by placing a metal spacer of dimensions 10 mm × 10 mm × 1.8 mm in between the blocks. The space created by dewaxing was finally occupied by the resilient liner.

Manipulation, trial packing and curing of the denture base material and silicone liners was done as per the manufacturer's instructions.

Sub group A: The Molloplast-B Primo adhesive was applied with a brush onto the entire bonding surface of acrylic resin blocks and air dried for 1 h, then liner was packed into the space created by dewaxing.

Sub group B: Permaflex liner packed in the space created by dewaxing with a clean spatula (Fig. 1).

For both the liners, the flasks were closed, bench pressed for 4 min. The flash was removed and the final specimens were polymerized in boiling water at 100 °C for approx 2 h, followed by bench cooling. The silicone liners were finished with finishing bur and disks.

The final test specimen consisted of two blocks of each resin with a liner in between. Depending upon the time interval at which the specimens (n = 10) were tested, each sub group was sub divided into sub subgroups.

Testing of specimens: The baseline samples for Group 1 and 2 were tested initially for tensile bond strength. The specimens to be tested after 30 and 60 days interval were stored in artificial saliva in borosil beakers in a thermal incubator at 37 ± 1 °C temp (Fig. 2).

Testing for tensile bond strength

The specimens were aligned vertically under tension in Tinius Olsen H10KS Universal Tensile testing machine and were pulled apart at a crosshead speed of 20 mm/min (Fig. 3).

Fig. 1 – Packing of silicone liner between two blocks of same resin invested in POP.

Fig. 2 – Final test specimens for 30 and 60 days in an incubator.

$$\text{Maximumload} = \frac{\text{Tensilebondstrength}}{\text{Crossectionalarea}(\text{mm}^2)}$$

The maximum tensile stress before failure was recorded in MPa.

The type of failure was assessed visually as adhesive/cohesive.

Adhesive: Indicated separation occurring at liner-acrylic interface.

Cohesive: Indicated failure within the liner material.

Mean, SD, minimum and maximum values were determined. The results were charted, tabulated and statistically analyzed. The one way ANOVA was performed across the mean of specimen group for each series of test when the significant statistical difference was detected. Paired sample 't' test was applied to the individual groups to determine

the significance of the statistical difference between two means.

Results

The statistical methods which were employed in the study were:

In the present study, ANOVA was employed to find out the significance of difference between subgroups of denture liners in their mean tensile bond strength. A statistically significant difference was observed in the mean tensile bond strength values of both the silicone liners. F values of 22.203 and 11.241 with 2 and 57 degrees of freedom were found to be significant (p value < 0.05). (Graphs 1–3).

Paired sample 't' test for Group 1 revealed a statistically significant difference (p value < 0.05) in the mean tensile bond strength values of all the pairs compared except for values of 0.108 (pair 3) and 0.222 (pair 6), which were found to be non significant, indicating that mean tensile bond strength values for both the pairs were statistically same.

Paired sample 't' test for Group 2 revealed a statistically significant difference (p value < 0.05) in the mean tensile bond strength values of all the pairs compared except for values of 0.116 (pair 5) and 0.773 (pair 6), which were found to be non significant, indicating that mean tensile bond strength values for both the pairs were statistically same.

The results revealed that storage time in artificial saliva affected the bond strength of the resilient liners examined i.e. Molloplast-B and Permaflex. There was statistically significant difference ($p < 0.05$) of artificial saliva storage on the bond strength of both liners. After storage in artificial saliva for 30 days and 60 days at $37 \pm 1^\circ\text{C}$, all the specimens showed a significant reduction in the tensile bond strength.

Findings of the study and their significance

Molloplast-B silicone liner processed against heat cure high impact PMMA showed the highest tensile bond strength (1.028 MPa) and the least (0.289 MPa) was observed with Permaflex silicone liner processed against heat cure PMMA denture base resin after storage in artificial saliva at $37 \pm 1^\circ\text{C}$.

The baseline samples of both Molloplast-B and Permaflex, when bonded with heat cure PMMA, showed cohesive failure, which turned to adhesive after storage in artificial saliva for 30 and 60 days. This implies that initially the bond strength between the liner and the denture base acrylic resin was greater than the bond strength between the liner molecules, which significantly reduced and turned adhesive due to swelling and stress formation at the bond interface.

Discussion

Resilient lining materials have provided a topic for discussion, research and controversy for many decades. The use of resilient liners is useful in removable prosthodontics because of their capability of restoring health to inflamed mucosa, leading to more equal distribution of functional load on the

Fig. 3 – Final test specimen under tensile bond test.

Graph 1 – Mean tensile bond strength values of various Groups.

Graph 2 – Distribution of mode of failure in test specimens of Group 1.

denture foundation area and improving the fitting denture surface and retention of the prosthesis. This has been reflected from clinical surveys reporting a strong patient preference for them as opposed to hard denture base.¹⁰

Contemporary resilient liner materials whether acrylic/silicone, are available in autopolymerizing or heat-polymerizing forms. Autopolymerizing liners allow the clinician to relin a removable denture directly,^{15,16} intraorally, which is faster

Graph 3 – Distribution of mode of failure in test specimens of Group 2.

and patient is not without the prosthesis during the time required for laboratory procedures. However, it is difficult to produce lining of the optimum thickness with them, essential for good shock absorption.

Soft liners have several problems; serious one of them being failure of adhesion between the resilient liner and the denture base.¹² Debonding of the denture liner results in a localized unhygienic condition and creates potential surface for bacterial growth, plaque and calculus formation, often causing functional failure of the prosthesis.⁷ This requires frequent clinical evaluation and periodic replacement of the soft liner.

When the mode of failure is adhesive and/or cohesive, this indicates that the bond strength is almost the same as the tensile strength of the material. However, when the mode of failure is cohesive, it is assumed that the bond strength higher than the tensile strength of the resilient liner is being measured, which will provide less meaningful information on the adhesive bond.⁹

This study rejects null hypothesis because storage time in artificial saliva affected the bond strength of the liners examined. The results revealed a statistically significant difference ($p < 0.05$) of artificial saliva storage on the bond strength. After storage in artificial saliva for 30 and 60 days at $37 \pm 1^\circ\text{C}$, all specimens showed a significant reduction in the tensile bond strength.

The present results agree with those, who suggested that water storage reduced bond strength.^{14,17,25} This may result from swelling and stress built up at the bond interface, or of a change in the visco-elastic properties of the soft liner, causing the plasticizers to leach out, rendering the material stiffer and thus better able to transmit the external loads to the bond site.^{18–22} The results disagree with those of others, who reported that bond strength of soft liners was unaffected or increased with water storage.¹¹

None of the materials tested exhibited ideal properties of permanent resilience, absence of water sorption and perfect bonding. Although the results obtained were helpful in determining materials which have the best bond strength when processed to denture base resins, they couldn't be compared directly with previous studies because of variation in the techniques, sample sizes, thickness and type of soft lining material, type of denture base resin, conditioning of samples, speed of separation and processing techniques.^{23,24}

The results will serve as a benchmark for studying new materials and other variables affecting bond strength.²⁶ Factors such as processing methods, liner thickness, bonding agents, changes in the bond strength in the harsh oral environment and material chemistry need further investigation to increase the serviceable life of the material and to predict which will provide the best service clinically.^{27–29}

Conclusions

1. Analysis of tensile bond strength values indicated significant differences ($p < 0.05$) among the two liners when bonded with heat cure and heat cure high impact PMMA.
2. Molloplast-B processed against heat cure high impact PMMA showed the highest tensile bond strength

(1.028 MPa) and the least (0.289 MPa) was observed with Permaflex processed against heat cure PMMA after storage in artificial saliva at $37 \pm 1^\circ\text{C}$.

3. The baseline samples of both Molloplast-B and Permaflex, when bonded with heat cure PMMA, showed cohesive failure, which turned to adhesive after storage in artificial saliva for 30 and 60 days. This implies that initially the bond strength between the liner and the denture base acrylic resin was greater than the bond strength between the liner molecules, which significantly reduced and turned adhesive due to swelling and stress formation at the bond interface.

Both Molloplast-B and Permaflex, when bonded with heat cure high impact PMMA showed cohesive failure in all specimens that were tested at baseline, 30 and 60 days, irrespective of water storage. In contrast, all the samples (Baseline, 30 and 60 days) of both the liners bonded with heat cure high impact PMMA depicted the cohesive failure. This data clearly provides information regarding the material itself rather than the accurate measure of bond strength.

Recommendations

1. The highest tensile bond strength was seen with Molloplast-B cured against heat cure high impact PMMA. However, a number of silicone liners are available in the market. So further clinical studies, evaluating large number of liners are required to generalize the results and to verify the denture liner that offers the best intra oral performance.
2. Laboratory tests do not necessarily represent the load that the lining material can withstand clinically because in laboratory test only one type of force is applied at a time, compared with the various masticatory forces that dentures are subjected to clinically. However, laboratory tests are useful in comparing and ranking the bond strength of resilient liners.
3. The selection and use of the denture liners must be made with regard to other handling and physical properties such as tissue compatibility, softness, colour stability, dimensional stability and absence of taste and odour.

Conflicts of interest

The authors have none to declare.

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