Tensile bond strengths of silicone soft liners to two chemically different denture base resins

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Abstract

Silicone-based soft liners can be useful for patients who have difficulty to tolerate the hard-based dentures. However, lack of adhesion to the denture base resin can be a problem that limits their clinical use. This study evaluated the tensile bond strengths (TBS) of four silicone soft liners (GC Soft, GC XSoft, Silagum, Mollisol) to two chemically different denture base resins, polymethyl methacrylate (PMMA) and urethane dimethacrylate (UDMA). Specimens consisted of soft liner material self-cured between two square plates of cured denture base resin measuring 20 x 20 x 4 mm. The circular bonding area of soft liner to each plate was 10 mm in diameter. Proprietary primer was applied to the surface of the denture base specimens before bonding following the manufacturers’ recommendations. Ten specimens for each denture base-soft liner combination were prepared and tested under tension on a Shimadzu Universal Testing Machine at a crosshead speed of 5 mm/min. The mode of failure was determined using a stereo-microscope at magnification of 10x. Two- and one-way ANOVA and post-hoc Dunnett-T3 and t-test were used for statistical analysis. There were significant differences in TBS values for the effect of denture base resins, soft liner and their interaction (p < 0.05). The TBS of soft liners to PMMA was significantly higher than to UDMA denture base resins except for Silagum where no significant difference was observed. A mixed mode of failure was more common for all soft liners bonded to PMMA except for Silagum while adhesive failure was more predominant in the UDMA group.

Keywords: Soft liner, Denture base resin, Tensile bond, Surface treatment

1. Introduction:

Denture soft liner has a considerable role in removable prosthodontics because of its cushioning effect and its ability to redistribute masticatory forces transmitted to the denture bearing area [1–3]. Improved chewing and comfort among denture patients have been reported with soft relined prostheses [4,5]. Contemporary soft lining materials used for short- and long-term can be categorized into plasticized acrylic and silicone types. The major advantage of silicone over acrylic-based soft liners is that the former retains its inherent softness whereas the latter tends to lose its resiliency as the plasticizer leaches out of the material [6,7]. Silicone soft liners are basically dimethylsiloxane polymer and can be of heat- or self-curing type with the latter showing greater tendency to peel away from the denture base [8–10]. On the other hand, self-curing soft liner allows the clinician to reline the prosthesis directly in the mouth without leaving the patient without the prosthesis during laboratory procedures. However it is more difficult to control the thickness of the liner with chairside relining.

Eclipse denture base resin (Dentsply, York, USA) is based on UDMA and it has been suggested as an alternative to patients allergic to conventional PMMA denture resin and its constituents [11]. The material had been reported to demonstrate greater flexural strength than PMMA [12–14], which has been attributed to its shape-stable semi-crystalline resin with high glass transition temperature [12]. An assessment of its bond strength to soft liners is therefore required considering this property still remains elusive. A review of the literature does not provide any documentation on the adhesive behavior between soft liners and this particular light- and heat-activated UDMA denture base resin. This aspect is of clinical relevance if the denture constructed from the material requires soft relining.

It is therefore the aim of the study to evaluate the TBS of selected self-curing silicone liners to UDMA and to compare to the bond strength to conventional heat-curing PMMA denture base resins. Modes of failure at the denture base-soft liner interface were also determined. Surface treatment of denture base resins using proprietary primers of the soft liners were examined under SEM.

2. Material and method

The manufacturers’ information regarding denture base materials and the soft liners with their proprietary primers used in this
study is presented in Table 1. TBS specimen consisted of soft lining material cured between two square plates of denture base resin of similar dimensions (20 × 20 × 4 mm). Denture base specimens were prepared by investing 4 pieces of wax patterns (22 × 22 × 6 mm) in a stone mold in metal flask. PMMA specimens were prepared by mixing acrylic resin powder and liquid monomer in a ratio of 2.34 g:10 ml and the mixture packed into the mold using compression molded technique. Polymerization was carried out in a water bath at 70°C for 7 h followed by 100°C for 1 h. UDMA specimens were prepared using similar stone mold, which was lined with separating agent (Dentsply, York, USA) and warmed in the conditioning oven before the pre-packed resin was finger adapted. The exposed surface of UDMA specimen was lined with air barrier coating (Dentsply, York, USA) and polymerization was carried out in a curing unit (Dentsply, York, USA) for 10 min.

Both PMMA and UDMA specimens were then trimmed and stored in distilled water at 37°C in an incubator chamber (Memmert GmbH, Germany) for 30 days. This was to ensure water saturation and to simulate clinical condition of denture being in mouth before relining. The surface of the specimen to be bonded was wet ground on a grinding and polishing machine (Metaserv® 2000, Buehler Ltd., USA) using 600 grit and 800 grit silicon carbide paper. Eighty specimens were prepared for each denture base material and were divided into four groups.

A square split brass spacer with a circular internal hole of 10 mm diameter and 3 mm height was used to position 2 pieces of denture base specimens during relining procedure. The bonding surfaces were cleaned with spirit, rinsed with distilled water and left to air dry for 30 s before adhesive application. With one of the denture base specimens held in position at the bottom part of the spacer, the soft liner material was syringed to overfill the space within the spacer. The other piece of denture base specimen was then placed on the upper part of brass spacer to confine the bonding area at denture base-soft liner interface.

Shimadzu universal testing machine (Shimadzu corp., Kyoto, Japan) at a crosshead speed of 5 mm/min. The test was performed under uniform atmospheric condition at the temperature of 23°C. Tensile bond strength (MPa) was calculated as maximum load divided by the cross-sectional area of the soft liner. This calculation was appropriate even though the interfacial stress was not uniform since all test specimens were prepared with the same bonding area at denture base-soft liner interface.

Statistical analysis was performed using SPSS for Windows (Release 12.01, SPSS Inc., Chicago, USA). Two-way analysis of variance (ANOVA) was used and since there were significant differences for the effect of denture base resin, soft liners and their interaction, one-way ANOVA was conducted for each denture base group. Post hoc Dunnett T3 test and paired t-test were also employed where appropriate. Significance level was set at \( p = 0.05 \).

The failure mode was inspected for all specimens after testing, using a stereo microscope (Kyowa SD-2PL, Kyowa, Japan) at magnification of 10x. They were classified either as adhesive, cohesive or mixed failure. Adhesive failure refers to total separation at the interface between soft liner and denture base resin, cohesive failure as separation within soft liner while mixed failure

<table>
<thead>
<tr>
<th>Brand names (code)</th>
<th>Material type</th>
<th>Chemical composition&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Manufacturer</th>
<th>Batch no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eclipse (UDMA)</td>
<td>Denture base resin</td>
<td>Single paste component</td>
<td>Dentsply, New York, USA</td>
<td>Lot 070823</td>
</tr>
<tr>
<td>GC relieve soft (GC soft)</td>
<td>Intra-oral reline</td>
<td>Silicon dioxide, vinyl dimethyl polysiloxane, hydrogen polysiloxane.</td>
<td>GC, Tokyo, Japan</td>
<td>Lot 0707111</td>
</tr>
<tr>
<td>GC relieve extra soft (GC XSoft)</td>
<td>Intra-oral reline</td>
<td>Medium stiffness&lt;sup&gt;a&lt;/sup&gt;</td>
<td>GC, Tokyo, Japan</td>
<td>Lot 0711081</td>
</tr>
<tr>
<td>Silagum comfort (Silagum)</td>
<td>Intra-oral reline</td>
<td>Ethyl acetate &gt; 90%</td>
<td>DMG, Hamburg, Germany</td>
<td>Lot 0707091</td>
</tr>
<tr>
<td>Mollosil plus (Mollosil)</td>
<td>Intra-oral liner</td>
<td>Ethyl acetate, modified polyacrylate</td>
<td>Detax GmbH, Ettlingen, Germany</td>
<td>Lot 590853</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ethyl acetate 60–100%</td>
<td></td>
<td>Lot 070705</td>
</tr>
</tbody>
</table>

<sup>a</sup> Classification based on ISO 10139-2 [23].

<sup>b</sup> Based on manufacturers’ information.
refers to combination of both. The manner in which tensile test specimen was prepared, failure could occur in any one of the two denture base-soft liner interfaces. However in this study, it was not found that failure predominated towards one or the other interface.

To determine the surface appearance of both UDMA and PMMA specimens after application of proprietary soft liner adhesives, three samples from each denture base resin were treated and viewed under Scanning Electron Microscope (SEM) (Quanta 200, FEI, USA). Low vacuum image mode was used.

3. Results and discussion:

The tensile bond test used in this study is the method described by the American Society for Testing and Materials (ASTM D429-81) for standard testing of adhesion of rubber to rigid substrates [15]. This test may not necessarily represent the load that dentures are subjected to clinically since masticatory forces are multidirectional. However as with other laboratory tests such as peel and shear bond tests [16–19], the results from TBS test is useful in comparing and ranking the bond strength of soft liners to hard denture base resins [16].

The soft lining materials used in this study are representative of self-curing silicone-based denture liners available in the market. The two denture base materials were selected based on the difference in their chemical compositions and with some interest in the latest UDMA denture resins available. For each of soft liner tested, a higher bond strength to PMMA than to UDMA was observed except for Silagum soft liner (Table 2). The lower TBS observed in UDMA group gave an indication of less effective bonding, which was further supported by higher percentage of adhesive failure for all soft liners in this group (Fig. 2). This was in contrast to PMMA group where combination of cohesive and adhesive failures (Fig. 2) were more common among soft liners indicating that the tensile strengths of soft liners and the interfacial bond strengths were nearly the same. The bond strengths for PMMA in this study ranged from 1.07 to 2.04 MPa. Minami et al. [20] quoted a similar range values of 1.5–2.1 MPa for another brand of self-curing polyvinyl siloxane denture liner (Sofreliner, Tokuyama, Japan), using similar tensile test specimen assembly.

The TBS values obtained for UDMA group in the present study ranged from 0.80 to 1.21 MPa. However, there is not much documentation on the bonding between UDMA resin and soft liners either from the manufacturer or other independent researchers. Previous investigation on hard reline resins [21] has also highlighted the problem of bonding to UDMA denture base resin.

It was also observed that within the same denture material group, different soft liners showed difference bond strength values. This was in agreement with the results obtained in another study where similar TBS test was employed [22]. Their study showed different bond strength results for chemically similar silicone-based soft lining materials. In this study, higher bond strength values were observed with GC Soft and GC XSoft liners both in PMMA and UDMA groups. These two soft liners were chemically identical and were from the same manufacturer. The same primer system provided by the manufacturer was used and considering the important role of primer on the bond strength [23], these materials were expected to show similar result, even though they have different amount of filler contents.

The lowest TBS values was shown by Mollosil soft liner and with its tensile strength reported to be half the tensile strength of GC Soft and Silagum, [22] this may explain for the findings in this study. However the bond strengths of 1.07 MPa for...
PMMA-Mollosil and 0.80 MPa for UDMA-Mollosil found in this study was higher than 0.40 MPa, which was considered as the minimally acceptable value for clinical use [24].

It was also observed in this study that the surface treatment using different primer systems produced variable surface appearance on the denture resin specimens. The three proprietary primers contained ethyl acetate solvent in different concentrations (Table 1). The SEM view of PMMA specimen treated with GC primer showed minute surface pores, which were not well defined (Fig. 3a) while with Silagum primer the surface appeared smoother with more distinct surface pores of larger diameter (Fig. 3b). Specimen treated with Mollosil primer showed partially dissolved surface with pores of various sizes (Fig. 3c). It was thought that 100% adhesive failure exhibited by Silagum in contrast to mixed failure for the other three soft liners in PMMA group could be partially related to the action of its primer. As surface conditions are strongly linked with mechanical interlocking [25], larger pores formation and smoother surface produced by Silagum primer may explain for adhesive mode of failure. Previous SEM findings had demonstrated intimate contact between Silagum and PMMA at the interface but without interpenetration network formation [22].

Surface appearance of UDMA specimens treated with various primers (Fig. 4a, b, c) also varied and similar explanation as in PMMA can be made with regards to the action of ethyl acetate solvent. Both the Silagum and Mollosil primers appeared to create a surface layer with trapped bubbles that would act as fracture initiation sites and would weaken the bond. A cross-sectional view might help to clarify the presence of these bubbles at denture base-soft liner interface. This could be an area for future studies with further investigation on methods to reduce or eliminate air inclusion.

Fig. 3. SEM view of PMMA surface treated with: (a) GC primer (X5000 magnification). (b) Silagum primer (X5000 magnification). (c) Mollosil primer (X5000 magnification).
4. Conclusion

The following conclusion can be drawn from this study:

1. GC Soft and GC XSoft liners showed the highest and Mollosil the lowest TBS values to both PMMA and UDMA denture base resins.
2. The TBS values of soft liners to PMMA was significantly higher than to UDMA denture base resin except for Silagum soft liner where no significant difference in was observed.
3. Mixed mode of failure was more common in PMMA group for all soft liners except for Silagum liner where adhesive failure was observed.
4. Adhesive failure was predominant in UDMA group for all soft liners.

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References