The Effect of Different Solutions on the Bond Strength of Soft Lining Materials to Acrylic Resin

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In this study, we investigated the effect of different solutions – coffee, tea, Turkish coffee, artificial saliva, mouthwash, denture cleanser, and distilled water – on the bond strength of soft lining materials (one acrylic- and three silicone-based) to acrylic resin. Acrylic specimens (40×10×10 mm) were prepared for the bond strength test. The specimens were stored in different solutions and tested after 24 hours, seven days, and 30 days.

Using analysis of variance, the bond strength of soft lining materials to acrylic resin was found to be related to the type of material, storage time, and storage solution. Visco-gel had the lowest bond strength to cured acrylic resin, where its strength ranged from 0.149 MPa to 0.784 MPa. The bond strength of Visco-gel was also found to increase with time.

Molloplast-B and Ufi Gel P demonstrated better bond strength than Visco-gel and Mollosil.

Key words: Soft lining materials, Bond strength, Denture cleanser

INTRODUCTION

Soft lining materials are used to help distribute a functional load evenly on a denture-bearing area so as to avoid local stress concentrations, and thereby improve denture retention by engaging undercuts¹. These materials are used as long-term denture liners for the management of atrophied mucosa or traumatic ulceration and for obturators after maxillafacial surgery². The materials mentioned can be classified as provisional or definitive. Then, depending on their chemical composition – silicone rubber or acrylic resin, they can either be chemically or heat polymerized^{3,4}.

The key requirements for long-term, resilient liners are namely permanent resiliency, high dimensional stability, good adhesion to denture base, adequate tear resistance, and compatibility with oral tissue^{5,6}. One of the major serious problems with soft denture liners is adhesion failure between the soft liner material and denture base^{7–11}. Bond failures also create a potential surface for bacterial growth, plaque accumulation, and calculus formation¹¹. Bonding of resilient lining materials to acrylic resin has been evaluated by several researchers using lap shear, butt tensile and peel tests^{6,12–15}, whereby *in vitro* tensile test was found to be an effective method in determining bond strength¹¹.

The purpose of this study was to evaluate the effect of different solutions (coffee, tea, Turkish coffee, artificial saliva, denture cleanser, mouthwash, and distilled water) on the bond strength of soft lining materials to acrylic resin.

MATERIALS AND METHODS

Blocks of acrylic resin (40 mm in length × 10 mm in height × 10 mm in thickness) were prepared. Individual acrylic samples were prepared by investing brass dies with a 3-mm thick spacer in a denture flask.

A lining less than 1.5 mm thick would appear to be clinically unacceptable because such thin linings would not have sufficient resilience to render the required cushioning effect. To ensure successful use of soft liner materials with dentures, processing techniques must be carefully applied, soft lining material must be adequately thick (2–3 mm), and denture base must be strengthened if it is weakened by lining presence^{16–18}.

Two acrylic specimens (QC-20, heat polymerized, De Trey Weybridge, Surrey, England) were trimmed, and the surfaces to be bonded were abraded with silicone carbide paper (#600, 3M Dental, Minn.) and treated according to the manufacturer's instructions for each soft denture liner. Acrylic resin blocks were placed back into the molds, and the soft denture liners packed into the space provided by the brass spacer and cured in accordance to the manufacturers' instructions. Bonding agents supplied by the manufacturers were used on the acrylic specimens. Only Visco-gel samples were prepared without any bonding agent. As shown in Table 1, four soft denture liners were used in this study. After polymerization was completed, the samples were removed from the flask.

For each soft lining material, 63 specimens were prepared: three specimens for each test solution for each storage period. Therefore, a total of 252 speci-

Table 1 List of materials and manufacturers

Material	Type	Lot Number	Company
Molloplast-B	High temperature vulcanized Silicone-based	030942 2005-09	Detax, GmbH a Co KG, Ettlingen, Germany
Mollosil	Cold-cured silicone-based	030701 2006-07	Detax, GmbH a Co KG, Ettlingen, Germany
Ufi Gel P	Cold-cured silicone-based	330509 2005-03	Voco, Cuxhaven, Germany
Visco-gel	Mouth temperature cured Acrylic resin	0309001608 2005-05	Dentsply, De Trey GmbH, Konstanz, Germany

mens were prepared for the four soft lining materials tested in this study.

One hundred and eighty specimens were immersed in different solutions (coffee, tea, Turkish coffee, artificial saliva, and distilled water) at a constant temperature of $37 \pm 1^\circ\text{C}$ for 24 hours, seven days, and 30 days.

To prepare the coffee solution, 15 g of coffee powder (Nescafe Classic, Nestlé, Société des Produits, SPN, Switzerland) was poured into 500 ml of boiling distilled water. The tea solution was prepared by immersing five prefabricated doses of tea (Lipton, Yellow Label, Çorlu, Turkey) into 500 ml of boiling water for 10 minutes.

Turkish coffee was prepared by adding 5-7g of a commercial brand (Kurukahveci Mehmet Efendi, TS 3117, Y Dudullu, Istanbul) to 65 ml of cold distilled water, and then boiled for a few minutes.

Artificial saliva was prepared with the following composition¹⁹: NaCl, 0.400 g; KCl, 0.400 g; $\text{CaCl}_2\text{H}_2\text{O}$, 0.795 g; NaH_2PO_4 , 0.78 g; $\text{Na}_2\text{S}_9\text{H}_2\text{O}$, 0.005 g; urea 1 g; distilled water, 1000 ml (pH=5.5).

Thirty-six specimens were immersed in a fresh solution of denture cleanser (Fitty Dent Cleansing Tablets, Fittydent International GmbH A-7423, Pinkafeld, Austria) at room temperature for eight hours, and then washed thoroughly with tap and distilled water. Following which, they were immersed in distilled water at 37°C for the remainder of the 24-hour period. The denture cleanser solution was changed weekly.

Thirty-six specimens prepared from each test material were stored in 20 ml of a mouthwash (Andorex, Kim Pa, İstanbul, Turkey) for one, six, and 12 hours. The 12-hour immersion period was reported to be the equivalent time of a two-minute daily mouthwash for a whole year²⁰.

Distilled water was used as a control group. During the test period, all staining solutions were changed once a week.

For tensile bond strength measurement, samples were placed under tension inside a Instron 3344 machine (Instron Corp., 100 Royall St., Canton, Ma.,

02021, USA) using a cross-head speed of 2 cm/mm until failure occurred. Bond strength was calculated by dividing stress at failure by the cross-sectional area of the sample. Means and standard deviations were determined for all materials. Bond strengths were then compared using one-way analysis of variance and LSD (least significant difference) multiple range test.

RESULTS

According to the variance analysis, the type of material, storage time, and storage solution had statistically significant effects on the bond strength of soft lining materials ($p < 0.001$).

The mean values of the bond strength for all materials after stored in the different solutions and distilled water are graphically displayed in Fig. 1 and 2. Lowest bond strength was observed with Visco-gel at 0.149 MPa in coffee after seven days. Highest bond strength, on the other hand, was observed with bonded Molloplast-B at 1.616 MPa in distilled water after seven days. The lowest bond strength of Molloplast-B at 0.639 MPa was observed in denture cleanser after seven days. Based on the results of this study, it could be suggested that Molloplast-B, Mollosil and Ufi Gel P failed adhesively while Visco-gel failed cohesively.

At the end of 30 days, Mollosil registered its lowest bond strength at 0.376 MPa in coffee, and Ufi Gel P at 0.574 MPa in Turkish coffee.

In the mouth wash, Visco gel demonstrated lower bond strengths than the other materials, whereby its bond strength ranged from 0.293 MPa to 0.215 MPa., and the lowest bond strength of Mollosil at 0.380 MPa was observed after 6 hours. At the end of 12 hours, Ufi Gel P was showed the lowest bond strength at 0.634 MPa, Molloplast-B at 0.830 MPa in mouth wash. In general, all materials showed low bond strength in mouthwash.

According to the LSD test:

- The materials showed the same values in ordinary coffee, Turkish coffee and tea.

Fig. 1 Bond strengths (MPa) of soft lining materials in different storage solutions after 1, 7 and 30 days.

Fig. 2 Bond strengths (MPa) of soft lining materials in Mouth wash.

- There were no differences in the bonding resistance of samples kept in distilled water and denture cleanser.
- There was a similarity in the bonding resistance of samples kept in Turkish coffee and ordinary coffee.
- Bond strengths were significantly different between storage solution and storage time.

DISCUSSION

In this study, the bond strength of one acrylic-based and three silicone-based soft lining materials to acrylic resin were determined by a tensile test. Some studies have reported on bond strength between soft lining materials and acrylic resins, and when separation took place the localized area became unhygienic and non-functional^{11,16}.

Heat-cured silicone-based Molloplast-B showed a higher bond strength than the other silicone-based liners, and Molloplast-B – like the other silicone-based liners – also required a bonding agent for adhesion to the cured acrylic resin. According to Aydın *et al.*²¹) and Yanikoğlu *et al.*²²), heat-cured silicone-based Molloplast-B had the highest tensile strength and best filling capacity among the soft lining materials. Further, according to Wright⁶), this higher bond strength was attributable to improved adhesive bonding systems used with silicone-based soft liners, which usually contain a silicone polymer in a volatile solvent that is able to penetrate the acrylic resin. Nevertheless, in another study, Açıkgöz *et al.*¹⁵) suggested that silicone-based Ufi Gel P exhibited the greatest bond strength.

The powder of Visco-gel is a polyethyl methacrylate, and no bonding agents are needed to achieve a bond with acrylic resin¹¹). Visco-gel material failed cohesively, which implied that the tensile strength of the soft liner material was lower than that of the bond strength to the acrylic specimens^{11,22}). The high interfacial strength in this case could be attributed to the mechanical bonding between Visco-gel and the acrylic specimen. Mechanical bonding occurred due to the wet sandpaper treatment of the acrylic resin surface, thus leading to increased surface roughness and mechanical retention^{3,11}).

High sorption and solubility of soft denture liners are associated with distortion, hardening, and debonding of liners from denture bases⁸). Therefore, sorption and solubility properties are important indicators to a liner's longevity²³). Kawano *et al.*¹¹) stated that denture liners demonstrated the best bond strength when they were first bonded to a new acrylic denture base. However, it must be pointed out that bond strength would be comparatively inferior if old dentures are relined. This is because the acrylic denture base might already be contaminated by microorganisms and other materials absorbed into the denture base from food or cleansing agents.

The present study showed that tensile bond strength increased with time for Visco-gel (in distilled water: 0.494 MPa after one day, 0.670 MPa after 30 days). This could have occurred because of the leaching out of the plasticizer, which in turn resulted in increased stiffness²⁴). The deterioration rate of Visco-gel is related to ethanol elution. The absorption or loss of soluble components may cause

failures in bond strength between the soft liner and acrylic resin, thus causing mechanical bonding and chemical adhesion to take form between the soft liner material and acrylic resin³⁾.

In contrast, the bond strengths of Molloplast-B, Mollosil, and Ufi Gel P decreased after storage in distilled water for 30 days. This finding agreed with those of earlier reports by Amin *et al.*²⁴⁾ and Polyzois²⁵⁾, which stated that water storage reduced the bond strength of resilient liners²⁵⁾. Water absorbed by a denture liner material has direct and indirect effects on its bonding to acrylic resins. The water absorbed may indirectly decrease the bond strength by causing plasticizer to leach out from the liner. Diminished plasticizer content will increase stiffness and reduce the cushioning effect of the liner material^{14,15)}.

Wright⁶⁾ indicated that Molloplast-B did not seem to be affected by immersion in water, whereas the bond strength of a natural rubber material was weakened since its adhesion was reduced following immersion in water.

Aydın *et al.*²¹⁾ stated that the bonding strength of soft liners behaved differently. After aging treatment and storage in water, the bond strength of Ufi Gel P decreased but there was barely any change for Molloplast-B. They further recommended that among high temperature vulcanized (HTV) silicone, room temperature vulcanized (RTV) and chemical-cured soft liners, HTV material should be the preferred choice.

Craig²⁾ suggested that storage in water did not affect the bonding of denture liners to PMMA. By roughening the PMMA surface before bonding, it would approximately double the adhesion values of the resilient liners.

The findings of the present study did not agree with those of Wright⁶⁾, Aydın *et al.*²¹⁾ and Craig²⁾. These discrepancies in findings might be a result of different parameters used in each study, namely the acrylic resin, storage time, storage solution, and cross-head speed of the testing machine.

Amin *et al.*¹²⁾ measured the bond strength of four soft denture liners using tensile, shear, compression, and peel tests. They concluded that roughening the acrylic base before applying the lining material had a weakening effect on bonding. While the bond strengths of acrylic and silicone soft lining materials to acrylic resin are tested by tensile stress, this test is not completely valid and applicable to dental restorations because the forces they encounter are more closely related to shear and tear. The *in vitro* tensile test was found to be effective in evaluating bond strength¹¹⁾. The results of this study indicated that the failure force for Mollosil was 0.542 MPa and that of Visco-gel was 0.670 MPa at the end of 30 days. As previously reported, soft denture lining materials with adequate bond strength are acceptable for

clinical use^{14,21)}.

The liner material must remain stable in the salivary oral environment¹⁰⁾. An ideal, processed soft liner should have no soluble components and low water sorption^{10,13)}. During immersion in different solutions, plasticizer and other soluble components are leached out and water or saliva is absorbed by the polymer²⁶⁾. Acrylic resin permanent soft lining materials have higher sorption values than silicone soft lining materials²⁷⁾. High sorption and solubility of soft denture liners are associated with distortion, hardening, and debonding of liners from acrylic denture bases⁸⁾. Lower uptake in artificial saliva can be explained in terms of the ionic impurities in the polymer²⁸⁾. In the present study, Visco-gel showed lower bond strength than Molloplast-B in artificial saliva. In a previous study on the adhesion properties of resilient lining materials to a visible light cured (VLC) acrylic resin, it was shown that adhesive characteristics depended on a variety of factors: chemical properties, physical properties, and mode of polymerization of the resilient lining material, and the bonding agent used^{10,25)}. In an investigation by Polyzois²⁵⁾, all lining materials were acceptable for clinical use but water storage reduced their bond strength to VLC acrylic resins.

Solutions used for denture cleaning can be divided according to their chemical composition: alkaline peroxides, alkaline hypochlorites, acids, disinfectants, and enzymes^{29,30)}. Enzymatic solutions are more effective in preventing microbial invasion and plaque formation^{31,32)}. In the present study, a similarity was found between the bond strength of samples kept in distilled water and that in denture cleanser (0.863 MPa). This finding agreed with the results of an earlier report by Rodrigues Garcia *et al.*³³⁾. They stated that enzymatic denture cleansers, when compared with water, did not cause significant changes in tensile bond strength. In the present study, the denture cleanser used contained sodium bicarbonate and ethylenediamine. It was probable that the higher ionic concentration (potassium and sodium) of denture cleanser – compared to water – led to a higher release of soluble components. In other words, chemical solutions – such as denture cleaner – can cause significant deterioration because they can cause loss of soluble components and plasticizers, or absorption of water or saliva by the resilient lining materials^{26,33,34)}. Loss of plasticizer can alter the bonding surface or the viscoelastic properties of resilient materials, causing the latter to become brittle, hence changing their bond strength properties²⁵⁾.

Use of mouthwash has become increasingly popular³⁵⁾. Besides from being an effective caries and gingivitis control method and a topical relief measure for oral lesions, people also tend to use mouthwash for social and cosmetic reasons^{35–38)}. In this study, soft denture materials placed in mouthwash showed

low bond strength (mean value: 0.641 MPa) – which implied that the chemical composition of mouthwash might significantly affect bond strength. Gurgan *et al.*³⁹⁾ suggested that alcohol-containing and alcohol-free mouthwash affected the hardness of some restorative materials. Gürdal *et al.*⁴⁰⁾, on the other hand, found that mouthwash with varying pH values and alcohol contents had no effect on the microhardness and color stability of esthetic restorative materials which were tested. Since no other literature could be found concerning the effect of mouthwash, discussion on the bond strength of soft lining materials when treated by mouthwash *in vitro* is not possible.

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