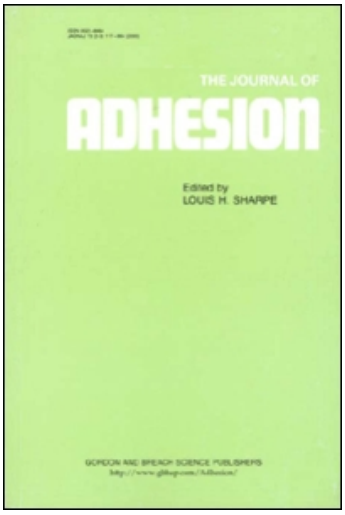

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Effects of Different Denture Cleansers on the Tensile Bond Strength of Denture Liners

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Effects of Different Denture Cleansers on the Tensile Bond Strength of Denture Liners

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The effect of two denture cleansers (Polident® and Protefix®) on the tensile bond strength between four soft liner materials (Molloplast B®, Permaflex®, Sofreliner Tough Medium®, and GC Reline Soft®) and a conventional denture base resin was investigated. For each of the liner materials 35 test specimens were prepared according to test the requirements and assigned into seven groups ($n = 5$). Before tensile testing, five of the liner specimens were kept in water or soaked in two cleansing solutions during 2 and 7 d. Five other samples served as a control group subjected directly to tensile testing. The bond strength values were obtained using a universal testing machine and compared statistically. The type of failure was assessed visually. No significant difference was found between the groups for the tested conditions used ($p > 0.05$). The most frequent failure mode was cohesive for Molloplast and Permaflex specimens, adhesive for Sofreliner Tough Medium, and a mixed type of failure was observed for GC Reline Soft material.

Keywords: Acrylic resin; Denture cleansers; Soft denture liner; Tensile bond strength

INTRODUCTION

Denture soft lining materials are often used for the patients who cannot tolerate a conventional hard denture base [1]. When patients suffer from fragile supporting mucosa, excessive residual ridge resorption, substantial undercuts, and/or traumatic or patholgic tissue loss,

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the clinician may use a soft liner material between the intaglio surface of a denture and supporting tissues [2–4]. This material assists in producing an even distribution of functional load over the whole of the denture-bearing area and improves the fitting denture surface and retention of the denture [5–10].

Soft liner materials can be classified as provisional or definitive, and according to their silicone rubber or plasticised acrylic resin composition. They can be either chemically or heat polymerized [8,11,12]. Silicone liner materials are dimethyl siloxane polymer, which is a viscous liquid that can be cross-linked to form a rubber [6,9,13]. Silicone liners generally demonstrate greater resistance to changes in their physical properties when exposed to solid or liquid chemical substances, and they are more elastic [11]. Furthermore, these materials show excellent tissue tolerance and are more stable over time [14]. A main drawback associated with silicone liner materials is, however, their great propensity for bond failure at the interface with the denture base resin [7,11,14–16]. The loss of adhesion can promote the leakage of fluids between the liner and denture base, creating potential surfaces for bacterial growth, biofilm, and calculus formation [7].

Some factors are expected to affect the bond between the lining materials and denture bases including aging in water, use of a primer with the lining material, and the nature of the denture base materials [6,17]. Dentures are used in an aqueous environment in the oral cavity and when not used, they are kept in water or in an aqueous cleansing solution. As a result of this immersion, water or saliva may be absorbed by the denture base materials and may possibly affect the bond strength between denture base resin and soft liner material. Although the effect of immersion in water on the bond strength of soft liners is well-documented [10,18–20], little information is avaliable in the literature regarding the effect of chemical denture cleansers on this property.

It is well known that appropriate denture hygiene is important in the denture maintenance, but many denture wearers fail to maintain a satisfactory level of hygiene [12]. Soft liner materials have been demonstrated to interact with oral microorganisms because of their surface texture and the physical/chemical affinity between them [21–23]. However, difficulty in cleaning a soft liner remains a disadvantage of these materials. Brushing is not a cleaning option because it can damage the soft lining material. Hence, a chemical soaking technique is primarily the method of choice as an effective means of providing denture cleanliness and of achieving a healthy mucosa beneath the dentures lined with soft materials [12].

Commercial denture cleansers may be classified into the following groups based on their mode of action or components: hyphochlorides, peroxides, neutral peroxides with enzymes, acids, crude drugs, and mouth rinses for dentures [1,12]. Tan *et al.* [4] have stated that after silicone denture liner treatment with certain denture cleansers containing perborate, a greater amount of liner material could leach out, leading to a loss of color if the liner surface is rough. Thus, the selection of denture cleanser is important to avoid or minimize changes in the properties of soft liner materials. However, little information is available about the effect of denture cleansers on the adhesion between soft liner and denture base resin materials. Hence, the present study was performed to assess the effects of two commercial cleansers on the adhesion between four soft liner materials and a denture base resin.

MATERIALS AND METHODS

Four commonly used silicone-based soft liner materials were studied by using two different processing methods (autopolymerizing and heat curing). As the base material, a heat polymerized acrylic resin was used. Tensile specimens of all materials were prepared according to the manufacturers' instructions as described below. The specimens were soaked in two cleanser solutions, a perborate containing cleanser (Protefix®) or an enzymatic cleanser (Polident®), or in distilled water (Table 1).

For the tensile bond strength testing, gypsum (Moldabaster® S, Hereaus Kulzer GmBH, Hanau, Germany) molds were prepared with dumbbell-shaped brass patterns, 75 mm in length, 12 mm in diameter at the thickest section, and 7 mm at the thinnest section. Denture base resin was polymerized in the sealed molds by keeping them in water at 70°C for 1 h followed by boiling in a water bath for 30 min. The polymerized specimens were removed from the molds and a total of 140 acrylic specimens were obtained. Then a 3-mm piece of the resin material was cut off from the thin midsections using a water-cooled diamond edge saw (Model No. 11-1280-250, Buhler Ltd, Lake Bluff, IL, USA), and the surfaces to be bonded were treated according to the manufacturers' instructions for each soft denture liner. For the GC, ST, and MB materials, one coat of bonding agents (primers, supplied by their manufacturers) was applied to the PMMA surfaces, and was then gently air-dried. No treatment was made for the P material because it does not require an adhesive as it forms an excellent bond with the acrylic (manufacturer's manual).

TABLE 1 Materials Used in the Study

Denture materials* Brand names (code)	Compositions	Processing method	Manufacturer
Meliodent®	Methyl methacrylate, ethyl hexyl acrylate, glycol dimethacrylate N-octyl methacrylate dimethyl P-toluidine	Compression mold technique; heat polymerized	Heraeus Kulzer, Hanau, Germany
Molloplast-B® (MB)	Vinyl dimethyl polysiloxane, benzoyl peroxide Primo: γ-methacryloyloxy-propyltrimethoxysilane	Heat polymerized	Detax GmBH, Ettlingen, Germany
Permaflex® (P)	Vinyl dimethyl polysiloxane benzoyl peroxide	Heat polymerized	Kohler Medizintechnik, Neuhausen, Germany
GC Reline Soft® (GC)	Vinyl dimethyl polysiloxane silicone dioxide, platinum catalyst Primer: ethyl acetate (>90%)	Autopolymerizing	GC Corporation, Tokyo, Japan
Softreliner Tough Medium® (ST)	Polyorganosiloxane, silicone dioxide Primer: methylene chloride (99.5%), polymethylmethacrylate with polyorganosiloxane (0.05%)	Autopolymerizing	Tokuyama Dental Corporation, Tokyo, Japan
Denture cleaners		Applications	
Protefix® (PD)	Sodium, bicorbonate, potassium caroate, sodium perborate, citric acid, sodium lauryl sulphate, aroma	Daily soaking in solution for 10 min during 2 d and 7 d	Queisser Pharma, Flensburg, Germany
Polident® (PF)	Sodium perborate, potassium monopersulfate, proteolytic enyzme, detergent, effervescent base	Daily soaking in solution for 3 min during 2 d and 7 d	GlaxoSmithKline, Philadelphia, PA, USA

*According to manufacturers' data.

After waiting for 1 h, the specimens (each including two of the trimmed acrylic blocks) were then secured back into the gypsum molds and one of the soft liners was applied between the acrylic resin blocks. Polymerization was performed as follows: autopolymerizing materials (GC and ST) were pressed for 5 min and were then polymerized at 40°C for 10 min; the heat curing materials (MB and P) were processed for 2 h in a boiling water bath. The molds were left to cool at room temperature for 20 min and were then kept under running tap water for 10 min.

Thirty-five specimens were formed from each of the soft liner materials and these were randomly divided into seven test groups, including an equal number of specimens: (1) a control group subjected to tensile testing at 23 ± 2°C within the first hour following polymerization; (2) specimens immersed in distilled water at 37 ± 2°C for 2 d before tensile testing; (3) specimens immersed in distilled water for 7 d; (4) specimens immersed in distilled water for 2 d, combined with daily soaking for 10 min in sodium perborate effervescent cleansing solution (PF); (5) specimens immersed in distilled water for 7 d, combined with daily soaking for 10 min in sodium perborate effervescent cleansing solution (PF); (6) specimens immersed in distilled water for 2 d combined with daily soaking for 3 min in enzymatic cleansing solution (PD); (7) and specimens immersed in distilled water for 7 d, combined with daily soaking for 3 min in enzymatic cleansing solution (PD). Immersions were performed in fresh solutions at 37 ± 2°C. After completion of the cleansing procedures, the specimens were kept in distilled water, changed daily.

The specimens were air-dried and tensile bond strength tests were performed on a universal testing machine (Lloyd NK 5, Lloyd Instruments Ltd., Fareham, Hampshire, UK), using a crosshead speed of 50 mm/min in the vertical direction. Tensile bond strength was calculated using the following equation [16]:

$$S = F/D,$$

where S is the tensile bond strength (MPa), F is the force at failure (N), and D is the adhesion surface area (mm^2). Following data collection, the mean value and standard deviation of the water sorption values were calculated using the SPSS statistical software program (11.5 version, SPSS Inc., Chicago, USA). The comparison of the groups tested was made by using a multifactorial analysis of variance. A 95% confidence level was used to examine the effects of variables.

After visual inspection of the tested specimens, the types of failure observed in the bonding of base material with soft liners were specified as cohesive (through the liner material), or adhesive (at the interface of liner and denture base materials), or mixed (both adhesive and cohesive).

RESULTS

The bond strength mean values and standard deviations of all groups are shown in Table 2. The multifactorial analysis of variance indicated no statistical differences in the bond strength of all groups due to the influence of immersion in water or the use of cleansers ($p > 0.05$); therefore, no further analysis was made.

As can be seen (Table 2), the highest bond strength was recorded for the specimens associated with MB (2.24 ± 0.28 MPa) and the lowest value was obtained from the specimens lined with P soft material (0.88 ± 0.29 MPa). Immersing in water or soaking in cleansing solutions generally led to a small decrease of the bond strength values for the specimens with ST and MB liners compared with their initial values, whereas the same procedures slightly increased those of P and GC specimens. It can also be seen that the bond strength values of all of the groups increased after soaking the specimens seven times in PF during the course of 7 d, although this increase was not statistically significant ($p > 0.05$). Data also suggested that incubations either in cleansing solutions or in distilled water did not cause any change in the bond strength of materials used.

For the different modes of failure between the interface of acrylic resin and liner materials the following frequencies were found. MB: 72% cohesive, 17% adhesive, and 11% mixed failures; P: 77% cohesive,

TABLE 2 Tensile Bond Strength Mean Values and Standard Deviations (MPa)*

Test groups	Denture Soft Liner Materials			
	MB	P	GC	ST
Control	2.24 ± 0.28	0.88 ± 0.29	1.50 ± 0.38	1.49 ± 0.48
Immersion in water 2 d	2.18 ± 1.36	1.70 ± 0.31	2.21 ± 1.13	1.24 ± 0.20
Immersion in water 7 d	1.82 ± 0.49	1.97 ± 0.51	1.46 ± 0.16	1.11 ± 0.45
Daily soaking in PF solution during 2 d	1.87 ± 0.53	1.95 ± 0.57	1.70 ± 0.63	1.07 ± 0.09
Daily soaking in PF solution during 7 d	2.47 ± 0.59	2.27 ± 0.56	2.14 ± 0.40	1.78 ± 0.55
Daily soaking in PD solution during 2 d	1.86 ± 0.46	1.65 ± 0.65	1.83 ± 0.44	1.49 ± 0.54
Daily soaking in PD solution during 7 d	1.62 ± 0.90	1.86 ± 0.29	2.16 ± 0.98	1.29 ± 0.65

$n = 5$ for each condition tested.

*All values are not statistically different from each other according to multifactorial analysis of variance ($p > 0.05$).

TABLE 3 Failure Modes of the Specimens

	Denture soft liner materials											
	MB			P			CD			ST		
Test groups	A	C	M	A	C	M	A	C	M	A	C	M
Control	–	5	–	5	–	–	2	–	3	5	–	–
Immersion in water 2 d	2	3	–	–	5	–	–	–	5	5	–	–
Immersion in water 7 d	–	4	1	1	4	–	1	–	4	4	1	–
Daily soaking in PF solution during 2 d	1	3	1	1	4	–	2	–	3	4	–	1
Daily soaking in PF solution during 7 d	–	5	–	–	4	1	1	–	4	5	–	–
Daily soaking in PD solution during 2 d	2	2	1	–	5	–	1	–	4	5	–	–
Daily soaking in PD solution during 7 d	1	3	1	–	5	–	2	–	3	5	–	–
Total(%)*	17	72	11	20	77	3	75	–	25	94	3	3

n = 5 for each condition tested.
*Approximately total percentage was given.

20% adhesive, and 3% mixed failures; ST: 94% adhesive, 3% cohesive, 3% mixed failure; and GC: 75% mixed and 25% adhesive failure (Table 3).

DISCUSSION

The bond strength of silicone denture soft liners to denture base resin materials is of importance in view of their clinical serviceability, because many dentures fail due to the lack of adhesion between these two materials. This *in vitro* study was carried out to assess whether significant changes in the bonding properties occur with the chemical cleansing of a denture resin lined with four of the commercially available soft liners. The selection of 2 d immersion in water was representative of the first recall appointment for adjustments after relining. Twice cleansing or immersion in water within 2 d was performed to simulate a clinical procedure conducted when contaminated dentures come from the patient. In order to determine whether extending the time of exposure to water or cleansers would adversely affect the mechanical properties of lined dentures, measurements were also taken after the specimens were immersed in water or daily soaking in cleansing solutions within 7 d.

To measure the bond strength of soft liners to denture base materials the most commonly used test methods have been peel, tensile, and

shear tests [19,24–31]. Al-Athel and Jagger [27] have compared the effect of test methods on the bond strength values of a commonly used poly(dimethyl siloxane) denture liner material to a heat cured acrylic denture base material by using peel, tensile, and shear tests. They concluded that the measured bond strength was highly dependent on the test method used. On the other hand, McCabe *et al.* [29], employing both peel and tensile test methods, have suggested that both test regimes were relevant and suitable for studying bonding and debonding characteristics of soft polymers.

In the current study, a tensile test method was preferred because tensile properties are regarded as a general guide to the assessment of the quality of rubbers. During a tensile bond test the forces applied are distributed over the whole bonding area and, thus, the entire joint becomes under stress. In addition, no allowance is made for the deformation of materials and, thus, the energy necessary to break the bond is also combined with the energy necessary to deform the material [16].

From the current literature it appears that there is no general agreement on the deformation rate of the specimens to be used for evaluating the tensile strength of soft liners, and the tests have used different deformation rates varying from 1 to 60 mm/min [7,12,16, 17,27,28,30,31]. Al-Athel and Jagger [27] have also evaluated the effect of different deformation rates on the bond strength values by using the rates of 20, 40, and 60 mm/min. They have demonstrated a highly significant increase in the tensile strength when specimens were deformed at a rate of 40 mm/min, compared with that obtained by using a 20 mm/min deformation rate. However, the tensile strength decreased significantly when specimens were deformed with deformation rates above 60 mm/min. The authors have reported that at lower rates, the effective modulus of the material is so low that the material falls apart readily, whereas, at higher rates, the material reacts as if it is much stiffer and will support higher loads before failure.

In theory, useful information might be derived by subjecting a specimen to a deformation rate that is equal to the speed of chewing. However, the speed of chewing is so high [32] that test specimens would be subjected to an impact force and invalid bond strength figures might also be obtained [27]. Thus, in the current study, all specimens were placed under tension until failure in a universal testing machine at a crosshead speed of 50 mm/min.

The literature recommends that the tensile bond strength should not be less than 0.45 MPa in order for these materials be clinically used [6]. In the present study, when the materials were evaluated immediately after specimen processing, the values of the tensile bond

strength varied from 2.24 to 0.88 MPa. Consequently, all soft liner materials bonded satisfactorily, meeting this requirement. Although the multiple comparisons revealed no difference between the strength values of the denture base resin specimens with different soft liners used ($p > 0.05$), the highest value was recorded for Molloplast B and the lowest was for the Permaflex.

The strength values of the specimens were also supported by the failure types (Table 3). For example, for Molloplast B specimens cohesive failure was dominating and this indicated that the strength of the liner was lower than that of the bonding to the PMMA [5,6]. Furthermore, although the test protocols including deformation rate and specimen size were different from those of our study, this finding was in agreement with those of the previous studies investigating the same material [5,27]. In the control specimens of Permaflex and Sofreliner Tough Medium liners failure was completely adhesive, but it was more cohesive in other Permaflex test groups. Adhesive failure implies that the bond strength for the liner molecules was higher than the bond strength between the liner and PMMA resin [6,7]. With GC Reline Soft liner, most of the specimens presented dominantly adhesive failure which implies that the cohesive strength of the liner material was greater than the bond strength between the liner and the PMMA resin [6,7].

It has been stated that silicone-based liners are of different molecular structure from PMMA resin; therefore, little or no chemical bonding occurs between these two materials. Thus, the bonding of silicone liners depends on the tensile strength of the liner materials and the adhesive primer used [6,7,13,15,17]. It has also been reported that heat polymerized materials had a high polymerization rate and greater stability of mechanical properties [1]. Although the Permaflex material is heat processed, the weakest union of this liner to acrylic resin could not be due to the presence of a different adhesive primer from those present in the other liner materials used. This material has a brillant varnish, a two-component liquid polish for a high lustre surface. Its manufacturer claims that its mode of packing makes water absorption more difficult, preventing the deterioration of the base and, thus, increasing its the lifetime. Although the tensile test used in the present study is an acceptable method, the test conditions may not simulate the clinical situation as the test specimens had double adhesive surfaces and clinical cases have a single adhesive surface [15].

It has been stated that heat processed liners provide increased resistance to solubility in oral fluid and improved physical and mechanical properties because of more complete polymerization [33]. However, the results showed that immersion in water or soaking in

cleansing solutions did not cause any significant changes between the differently processed soft liner specimens and also within the same soft liner ($p > 0.05$). The bond values of the specimens with Molloplast B and Sofreliner Tough Medium materials tended to decrease a little, whereas for the other materials it tended to increase slightly. However, the bond strength of all materials increased more after soaking the specimens in Protefix cleansing solution for 7 d. These changes may result from the swelling due to water absorption and stress formation at the bond interface, or from a change in the viscolelastic properties of the liners [10,20].

In clinical use, acrylic resin and soft liner materials are immersed in saliva, and during denture storage they are kept in water or in aqueous cleansing solutions. As a result of this immersion, water or cleansing solutions may be absorbed by both acrylic resin and soft liner material. It has been argued that the absorbed water or cleansing solutions could influence some physical and chemical properties of the liner materials such as color, roughness, hardness, and interface adhesion [1,4,7,17]. The effects have been attributed to some changes in the matrices of soft liners such as hydrolysis or inhibition of the polymerization reaction, resulting in main chain scission and branching of cross-linking [1].

Application of the cleansing solutions did not influence the bond strength of any of the liner materials. However, the strength values of all specimens tended to increase after treating the specimens with Protefix cleansing solution for 7 d. This may be due to the longer exposure time. Another contributing factor could be the differences in the chemical composition of the cleansers. According to the manufacturer's data [34], a Protefix tablet includes sodium perborate (16.63%), sodium bicarbonate (41.77%), potassium caroate (35.18%), citric acid (5.65%), sodium lauryl sulfate (0.47%), aroma (0.030%), and Cl 73015-a colorant-(0.07%). When dissolved in water, it becomes an alkaline solution of hydrogen peroxide, which in turn decomposes and releases oxygen. The released oxygen, high concentrations of sodium and potassium ions, as well as the presence of citric acid, might be collectively affecting the bond strength of the lined dentures. On the other hand, Polident is known to be an enzymatic cleanser containing sodium perborate, potassium monopersulfate, proteolytic enzyme, detergent, and effervescent base (Table 1). However, the percentage of these components is not known to the end user.

A direct comparison of the effect of the cleansing solutions on the bond strength of lined dentures could not be made with those of the earlier data because of the lack of studies investigating the same denture materials. However, the findings related to the effect of

Polident are in accordance with the studies by Garcia *et al.* [12]. They have reported that different periods of soaking in Polident cleansing solution did not have any significant influence on the tensile bonding strength of the autopolymerizing plasticized acrylic liners to a microwave-polymerizing acrylic denture base material.

As the bond strength of acrylic resin specimens remained unaffected, it seems that two cleansing products tested in this study could be safely applied in daily practice for the hygiene of the dentures. However, in the study, effects of the cleansers were evaluated for limited time periods. Therefore, the effects of long-term soaking in the solutions on tensile bond of the denture base liner require further investigations. Surface characteristics of the materials should also be studied after soaking.

CONCLUSIONS

Within the scope of this *in vitro* study, comparing with the initial values obtained immediately after polymerization of the specimens, it can be concluded that immersion in water or soaking in the enzymatic- and perborate- containing denture cleansing solutions did not cause significant changes on the tensile bond strength of the four soft denture lining materials for the time period tested.

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