ORIGINAL RESEARCH

Tensile Bond Strength of Hypoallergenic Acetal Resin and Heat-cured Acrylic Resin to Soft Denture Liners

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Abstract

Purpose: The purpose of this research was to evaluate the tensile strength of hypoallergenic acetal resin, heat-cured polymethylmethacrylate (PMMA) resin, to acrylic and silicone-based lining materials.

Materials and methods: Heat-cured PMMA resins and acetal resins (pink) were used as denture base materials and samples were prepared with a dimension of 10 x 10 x 43 mm blocks (n = 16 each). Silicone-based liner (soft-liner tough) and acrylic resin-based liner (Visco-gel) specimens were processed between heat-cured PMMA resin blocks and acetal resin blocks (3 x 10 x 10 mm). The groups were denoted as HCAS—heat cure-soft-liner tough group, n = 8; HCAV—heat cure-Visco-gel group, n = 8; ACS—acetal resin-soft-liner tough group, n = 8; ACV—acetal resin-Visco-gel group, n = 8. On a universal testing machine with a crosshead speed of 1 mm/minute, the tensile bond strength was determined. Bonferroni HSD and one-way analysis of variance (ANOVA) test were used for data analysis ($p < 0.05$ was considered significant).

Results: There were significant differences in bond strength across groups ($p < 0.001$). The acetal resin group exhibited lower bonding strength values than the heat cure PMMA resin group. The tensile bond strength of Visco-gel [0.88 ± 0.09 megapascals (MPa), HCAV group; 0.29 ± 0.04 MPa, ACV group] was higher than Soft-liner Tough (0.62 ± 0.38 Mpa, HCAS group; 0.19 ± 0.34 MPa, ACS group) in both resins. Mostly adhesive failures were seen in all groups. Intergroup comparison showed significant differences between all groups except for ACV vs ACS (p = 1.000).

Conclusion: Regardless of the liner type, acetal resin demonstrated the lowest tensile strength values. Heat-cured acrylic with Visco-gel liners performed better than silicone-based liners and was preferred in patients who did not exhibit hypersensitivity.

Keywords: Acetal resin, Acrylic resin, Hypoallergenic, Soft relining materials, Tensile bond strength.

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Introduction

Due to their advantageous physical and chemical characteristics, cheap cost, simplicity of processing, and reparability, PMMA resins are frequently used as denture base material in the field of dentistry.[1] During the curing phase, PMMA may contain unpolymerized residual monomers such as methylmethacrylate (MMA), which can cause allergic reactions.[2,3] Patients and dental staff are susceptible to allergen-induced allergic reactions[4,5]

Hypoallergenic denture base resins were produced to make the treatment of prosthodontic conditions safer for patients who have demonstrated material incompatibility. Their formulations contain either no MMA at all or a negligible amount of the substance.[6] MMA is substituted with polyoxymethylene, diurethane dimethacrylate, and polyurethane in hypoallergenic resins.[7] Resin composition can influence the chemical and physical properties of hypoallergenic resins to vary degrees.[8] In dentistry, polyoxymethylene resins, often termed acetal resins, are commonly used as hypoallergenic denture base resins.

Relining removable dentures, oral and maxillofacial prostheses using soft-liners cushions the fitting surface to distribute force, minimize regional pressure, and improve denture retention by engaging undercuts.[9,10] The lack of denture bonding is a common clinical phenomenon and a major cause for concern.[9,11] Fundamental structural differences between materials are the major cause of soft-lined denture failure.

Soft-liners may be categorized based on their chemical compositions as plasticized acrylic resins, polyurethane, or silicone rubbers. Inadequate attachment between the soft lining material and the denture base may promote the growth of microorganisms and hasten the soft lining material's decomposition.[12] It is crucial to evaluate the bonding properties of soft-liners.

The growing use of acetal resins for hypoallergenic patients' needs researchers to evaluate their mechanical and physical properties. No research to our knowledge has evaluated the adhesion of hypoallergenic denture base resins (acetal resin) and soft relining material. The purpose of this research was to determine the tensile bonding strength of two chairside soft-liners to heat-polymerized acrylic and acetal resin. The null hypothesis suggested that the tensile strength values of acrylic, acetal resins and relining materials would not differ.

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Materials and Methods

The following materials were chosen for this study—autopolymerized acrylic-based relining material, silicone-based relining material, heat-polymerized acrylic resin, and hypoallergenic denture base material (acetal resin). All samples were manufactured according to the manufacturer's specifications. A 10 x 10 x 43 mm silicone mold (Zetalabor, Zhermack, Polesine, Rovigo, Italy) was used to prepare specimens. Wax (Cavex dental waxes, Haarlem, Netherlands) specimens were prepared using the silicone mold ($n = 32$).

For heat-cured acrylic resin specimens, wax was melted and poured into the silicone molds ($n = 16$). Once wax specimens sets, they were invested in dental stone (Alston Dental Stone, Alston, Turkey) using a metal denture flask. The separating media (IMICRYL, Imibase, Konya, Turkey) was applied and allowed the flasks were set. The dewaxing was done following the conventional method. The heat-cured acrylic resins (Paladon 65, Heraeus Kulzer GmbH, Hanau, Germany) were manipulated by mixing powder and liquid as per the manufacturer's recommendation and placed in the mold. The polymerization was done at 74°C for 8 hours and then at 100°C for 2 hours. Allow the mold to cool.[9] Following the removal of the resin samples from the molds, they were polished for 5 minutes using 400 and 600-grit paper to produce a standard surface (Abrasives Ltd., London, United Kingdom).

The acetal resin samples were prepared according to the manufacturer's guidelines ($n = 16$). There are twenty colors of acetal resin that correspond to the Vita color guide (Vitapan, Germany). Similar to acrylic resin, pink-colored acetal resin was used (TMS Acetal Dental, San Marino, Italy). The wax specimens were flasked with dental stone (Type IV, Marble Stone, Pressing Dental, San Marino, Italy) and dewaxed in a special flask (Muffle-Type 100, Pressing Dental, San Marino, Italy) by placing about 2.5 cm from the flask's top. One block of the desired color of acetal resin was inserted into the injection tube, which was then placed on the J-100 injection machine (Pressing Dental, San Marino, Italy). It was programmed using the settings listed—injection pressure = 4 bar; melting temperature = 220°C; preinjection temperature control time = 20 minutes; postinjection temperature control time = 3 minutes; and preinjection temperature setup time = 20 minutes. After polymerization, the samples were retrieved and polished, as explained for PMMA resin.[8]

A water-cooled precision saw was used to cut each material in half. A space of 3 mm was created using 10 x 10 x 3 mm stainless steel dies. After that, two sliced samples were inserted into silicone molds (10 x 10 x 43 mm). According to the manufacturer's specifications, relining materials were used to fill the space.

The resilient denture liners were processed against the resin specimens in order to produce specimens. The adhesive (Soft-liner Tough Primer, Tokuyama Dental, Tokyo, Japan) was put on the specimens and dried for 60 minutes. The polymer monomer (Soft-liner Tough, Tokuyama Dental, Tokyo Japan) was prepared, inserted in the molds, and then subjected to 15 minutes of pressure in the mold press. In the process of producing Visco-gel (Dentsply DeTrey, Konstanz, Germany) specimens, the polymer monomer was mixed and subjected to 15 minutes of pressure in a flask press. The denture liners were autopolymerized and after that, removed from the mold.[11]

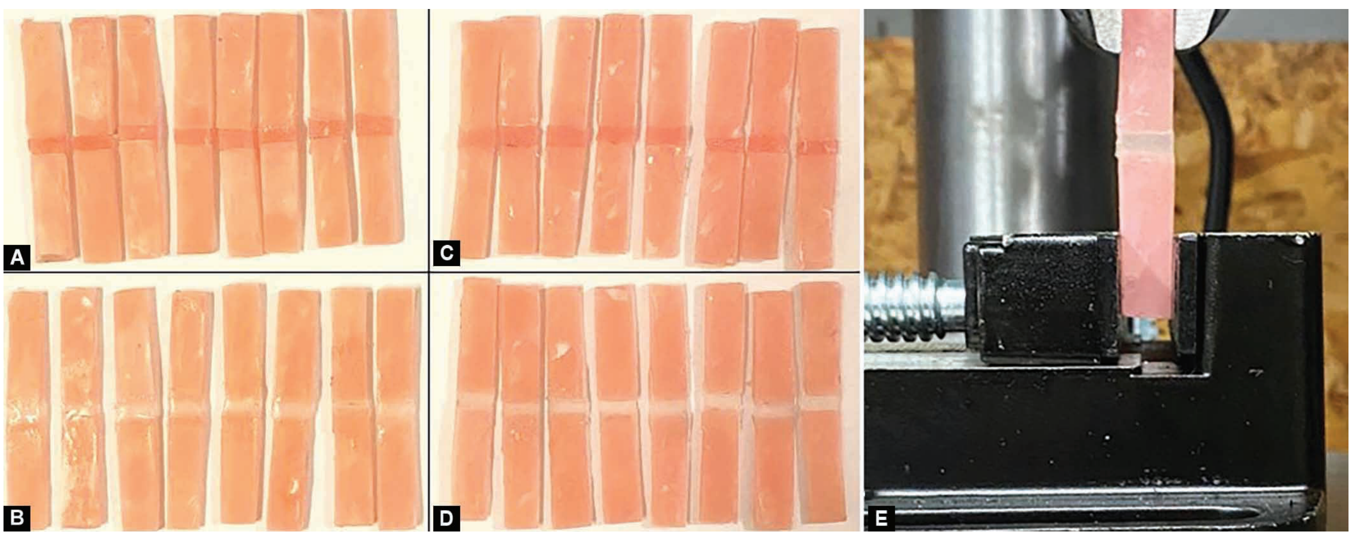
The specimens obtained were denoted as ACS—acetal resin-soft-liner tough group, $n = 8$; ACV—acetal resin-Visco-gel group, $n = 8$; HCAS—heat cure-soft-liner tough group, $n = 8$; HCAV—heat cure-Visco-gel group, $n = 8$ (Figs 1A to D).

Tensile Test

Using a universal testing machine (Lloyd Instruments, Fareham, United Kingdom) with a test speed of 1 mm/minute and a test span of 23 mm, tensile testing was conducted (Fig. 1E). The specimens were put in the testing machine and gripped in the acrylic resin block section. Using the following formula, the tensile strength "x" in MPa was calculated, where "F" is the maximum force in newtons, and "A°" is the specimen's cross-section in mm^2: $X = F/A°$. After the test, the failure type was defined as either adhesive or cohesive or both.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) software program (IBM SPSS, Version 24.0., New York: IBM Corp) was used. Descriptive sampling analyzes were used (mean, standard deviation, minimum–maximum) for analyzing. The Shapiro–Wilk test was used to determine whether data had a normal distribution. To identify any significant differences between groups, a one-way ANOVA was performed. The *post hoc* Bonferroni analysis was also



Figs 1A to E: Samples used in this study. (A) Acetal resin-Softliner Tough group; (B) Acetal resin-Viscogel group; (C) Heatcure-Softliner Tough group; (D) Heatcure-Viscogel group and (E) Representative photograph of sample during tensile test used to compare groups. The $p < 0.05$ was regarded as statistically significant.

Results

The tensile bond strength with different groups is presented in Table 1 and Figure 2. The means and standard deviations of samples were estimated and followed by parametric testing.

One-way ANOVA with *post hoc* Bonferroni analysis demonstrated that resin type had a substantial effect on tensile strength. The bonding strength varied significantly across groups ($p < 0.001$). The PMMA resin group exhibited greater bonding strength than the acetal resin group. The bonding strength of Visco-gel (0.88 ± 0.09 MPa, HCAV group; 0.29 ± 0.04 MPa, ACV group) was higher than soft-liner tough (0.62 ± 0.38 MPa, HCAS group; 0.19 ± 0.34 MPa, ACS group) in both resins.

Intergroup comparison showed significant differences between all groups except for ACV vs ACS ($p = 1.000$). Regardless of the soft relining material, the heat-cured acrylic resin exhibited the highest tensile strength values (Table 2).

The adhesion of the heat-cured resin to soft relining materials (HCAS—0.62 ± 0.38 MPa; HCAV—0.88 ± 0.09 MPa) was almost twice as strong as that of ACS (0.19 ± 0.34 MPa) and ACV (0.29 ± 0.04 MPa). Acetal resin samples exhibited mostly adhesive failures, but HCAS and HCAV exhibited mixed, cohesive, and adhesive failures (Fig. 3).

Discussion

In this research, a tensile test was used to measure the bonding strength of two soft denture liners, heat-polymerized acrylic resin and acetal resin. Since acetal resin specimens exhibited much lower tensile strength values than heat-cured acrylic resin specimens, the hypothesis was rejected.

The cytotoxicity of silica and acrylic-based soft denture lining materials was compared in previous studies. It was determined that acrylic-based soft-liners were more cytotoxic than silica-based liners and that silicone-based soft liner may have more acceptable biological properties and lower risk of harmful effects in clinical usages.[12] In contrast, Song et al.[12] studied the variations in the biocompatibility of soft reliners depending on their component types. They concluded that Visco-gel was "weakly cytotoxic" and soft-liner was "tolerably cytotoxic." In this research, the adhesive strength of acrylic and silica-based soft lining materials to acetal resins was tested. It was found that acrylic-based soft liners

Table 1: Mean bond strength of different groups using one-way ANOVA

Groups	*Mean ± standard deviation*	*Minimum*	*Maximum*	*F-value*	*p-value*
HCAS	0.62 ± 0.38	0.49	0.79	11.822	0.001*
HCAV	0.88 ± 0.09	0.45	1.30		
ACS	0.19 ± 0.34	0.07	0.34		
ACV	0.29 ± 0.04	0.12	0.45		

ACS, acetal resin-softliner tough group; ACV, acetal resin-Visco-gel group; HCAS, heatcure-softliner tough group; HCAV, heatcure-Visco-gel group; * *p*-value < 0.05 is significant

Table 2: Bonferroni HSD test for intergroup comparison

Groups	*HCAS*	*HCAV*	*ACS*	*ACV*
HCAS	–	0.012*	0.001*	0.002*
HCAV	0.012*	–	0.001*	0.001*
ACS	0.001*	0.001*	–	1.000
ACV	0.002*	0.001*	1.000	–

ACS, acetal resin-softliner tough group; ACV, acetal resin-Visco-gel group; HCAS, heatcure-softliner tough group; HCAV, heatcure-Visco-gel group; * *p*-value < 0.05 is significant

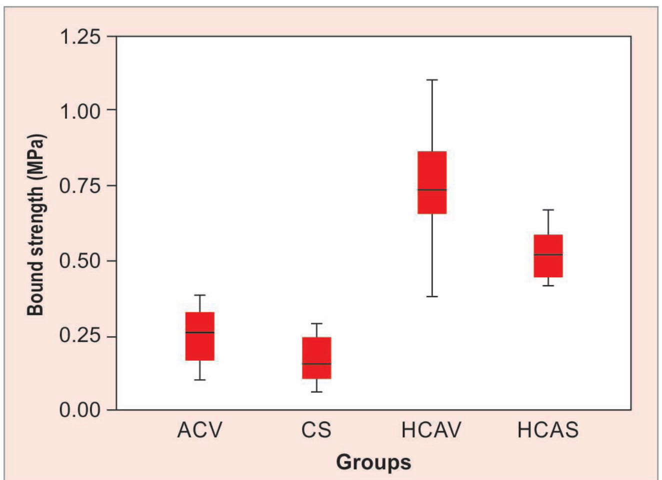


Fig. 2: Boxplot graph of tensile bond strength values of each group

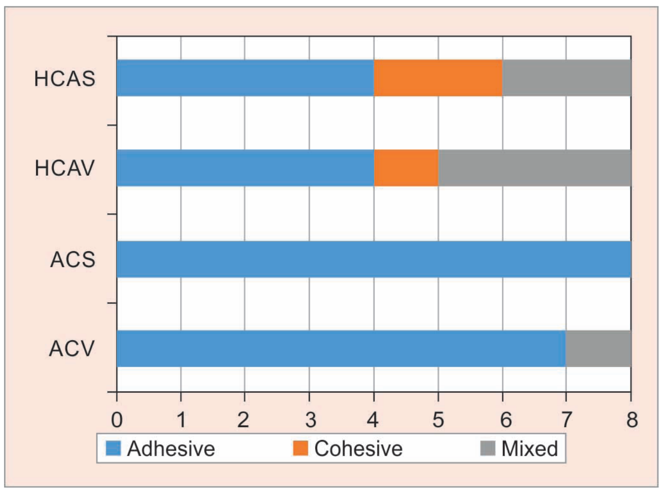


Fig. 3: Results of the failure patterns

showed the highest adhesion to acrylic resins, which is similar to other research.[13,14] It may be explained as the main composition of acrylic-based relining materials is comparable to that of acrylic resin monomer, it is expected that the bonding strength between acrylic resin and acrylic-based reliners would be higher than that of the other materials. Furthermore, the adhesion strength of silicone-based soft liners depends on both the adhesion strength of the soft liners and the adhesive utilized.[9]

As silicone-based liners have little or no chemical adhesion to acrylic resins, an adhesive is applied to aid in adhering the liner to the resin.[15] On the contrary, the adhesive used for silica-based reliners does not seem to be effective on acetal resin. All acetal resin samples exhibited adhesive failure. A study revealed that the surface roughness of acetal resin was less than that of PMMA. In addition to the chemical composition of the acetal resin, the surface roughness characteristics may have influenced the tensile bond strength values found in this study.[15] More research is needed for the bond strength of hypoallergenic resin-based materials to denture soft lining materials.

Cohesive failure of a soft liner provides material-specific information rather than a high degree of precision about bonding strength.[15] As the interim autopolymerized acrylic resin-based Visco-gel has a similar chemical content to PMMA and the observed failure was both adhesive and cohesive, this might have been caused by the polymerization process of this resilient liner material.

In the clinical setting, it is common to notice soft lining materials detaching from the denture base; This is one of the most serious issues associated with soft lining materials.[16] The adhesion of soft-liners to resins was established with various methodologies, including peel strength, shear strength, and tensile strength tests.[17–21]

Thus, it is difficult to compare the bonding strengths of soft-liners. Emmer et al.[22] emphasized that self-alignment of the sample axis is crucial for accurately assessing tensile bond strength. These methods are an ideal starting point for scientific investigation. The findings of bond strength tests may be affected by the various experimental techniques.[16] Due to the fact that test specimens had two adhesive surfaces, but clinical examples had only one, it is probable that the process parameters may not precisely represent the clinical situation.

This study assessed the bonding strength of acetal resins to acrylic and silica-based soft linings. Even though acrylic-based soft linings are more cytotoxic in studies, they are favored in clinical settings due to their superior adhesion strength on the occasion that patients do not exhibit hypersensitivity.

The results of acetal resins could not be compared to those found in the literature since there were no *in vitro* data available on the tensile bond strength of hypoallergenic denture resins. The study's limitations are as follows—factors such as saliva and its composition, the patient's nutrition, temperature variations, and oral hygiene could be considered since they may affect the longevity of the liners, hence altering the bond strength value. Soft dentures liner parameters such as manufacturing processes, water absorption, thermal stresses, hardness, tear strength, and color stability could be examined to determine the best material. Consequently, more research is required to evaluate the bonding strength of acetal and acrylic resins under clinical situations that are more precisely mimicked.

Conclusion

Regardless of the liner type, acetal resin demonstrated the lowest tensile strength values. Heat-cured acrylic with Visco-gel liners performed better than silicone-based liners and was preferred in patients who did not exhibit hypersensitivity.

References

1. Pagano S, Lombardo G, Caponi S, et al. Bio-mechanical characterization of a CAD/CAM PMMA resin for digital removable prostheses. Dent Mater 2021;37(3):118–130. DOI: 10.1016/j.dental.2020.11.003
2. Boeckler AF, Morton D, Poser S, et al. Release of dibenzoyl peroxide from polymethyl methacrylate denture base resins: an in vitro evaluation. Dent Mater 2008;24(12):1602–1607. DOI: 10.1016/j.dental.2008.03.019
3. Lung CY, Darvell BW. Minimization of the inevitable residual monomer in denture base acrylic. Dent Mater 2005;21(12):1119–1128. DOI: 10.1016/j.dental.2005.03.003
4. Uter W, Geier J. Contact allergy to acrylates and methacrylates in consumers and nail artists - data of the information network of departments of dermatology. Contact Derm 2015;72(4):224–228. DOI: 10.1111/cod.12348
5. Stoeva IL. Work-related skin symptoms among Bulgarian dentists. Contact Derm 2020; 82(6):380–386. DOI: 10.1111/cod.13523
6. Pfeiffer P, Rolleke C, Sherif L. Flexural strength and moduli of hypoallergenic denture base materials. J Prosthet Dent 2005;93(4):372–377. DOI: 10.1016/j.prosdent.2005.01.011
7. Pfeiffer P, An N, Schmage P. Repair strength of hypoallergenic denture base materials. J Prosthet Dent 2008;100(4):292–301. DOI: 10.1016/S0022-3913(08)60209-7
8. Hinz S, Bensel T, Bömicke W, et al. In vitro analysis of the mechanical properties of hypoallergenic denture base resins. Materials (Basel) 2022;15(10):3611. DOI: 10.3390/ma15103611
9. Mese A, Guzel KG. Effect of storage duration on the hardness and tensile bond strength of silicone- and acrylic resin-based resilient denture liners to a processed denture base acrylic resin. J Prosthet Dent 2008;99(2):153–159. DOI: 10.1016/S0022-3913(08)60032-3
10. Jacobsen NL, Mitchell DL, Johnson DL, et al. Lased and sandblasted denture base surface preparations affecting resilient liner bonding. J Prosthet Dent 1997;78(2):153–158. DOI: 10.1016/s0022-3913(97)70119-7
11. Botega DM, Sanchez JL, Mesquita MF, et al. Effects of thermocycling on the tensile bond strength of three permanent soft denture liners. J Prosthodont 2008;17(7):550–554. DOI: 10.1111/j.1532-849X.2008.00342.x
12. Song YH, Song HJ, Han MK, et al. Cytotoxicity of soft denture lining materials depending on their component types. Int J Prosthodont 2014;27(3):229–235. DOI: 10.11607/ijp.3848
13. Jepson NJ, McGill JT, McCabe JF. Influence of dietary simulating solvents on the viscoelasticity of temporary soft lining materials. J Prosthet Dent 2000;83(1):25–31. DOI: 10.1016/s0022-3913(00)70085-0
14. Kulak-Ozkan Y, Sertgoz A, Gedik H. Effect of thermocycling on tensile bond strength of six silicone-based, resilient denture liners. J Prosthet Dent 2003;89(3):303–310. DOI: 10.1067/mpr.2003.41
15. Hamedirad F, Alikhasi M, Hasanzade M. The effect of sandblasting on bond strength of soft liners to denture base resins: a systematic review and meta-analysis of in vitro studies. Int J Dent 2021;2021:5674155. DOI: 10.1155/2021/5674155
16. Kim BJ, Yang HS, Chun MG, et al. Shore hardness and tensile bond strength of long-term soft denture lining materials. J Prosthet Dent 2014;112(5):1289–1297. DOI: 10.1016/j.prosdent.2014.04.018
17. Kawano F, Dootz ER, Koran A 3rd, et al. Craig RG comparison of bond strength of six soft denture liners to denture base resin. J Prosthet Dent 1992;68(2):368–371. DOI: 10.1016/0022-3913(92)90347-d

18. Tasopoulos T, Jagger RG, Jagger DC. Bond strength of chair-side denture soft lining materials. Strength, Fracture and Complexity 2010;6(3):141–148. DOI: 10.3233/SFC-2010-0112
19. Hong G, Murata H, Hamada T. Relationship between plasticizer content and tensile bond strength of soft denture liners to a denture base resin. Dent Mater J 2004; 23(2):94–99. DOI: 10.4012/dmj.23.94
20. Takahashi JM, Consani RL, Henriques GE, et al. Effect of accelerated aging on permanent deformation and tensile bond strength of autopolymerizing soft denture liners. J Prosthodont 2011;20(3):200–204. DOI: 10.1111/j.1532-849X.2010.00679.x
21. Pinto JR, Mesquita MF, Henriques GE, et al. Effect of thermocycling on bond strength and elasticity of 4 long-term soft denture liners. J Prosthet Dent 2002;88(5):516–521. DOI: 10.1067/mpr.2002.128953
22. Emmer TJ Jr, Emmer TJ Sr, Vaidynathan J, et al. Bond strength of permanent soft denture liners bonded to the denture base. J Prosthet Dent 1995;74(6):595–601. DOI: 10.1016/s0022-3913(05)80311-7