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ORIGINAL ARTICLE

Effect of storage duration on tensile bond strength of acrylic or silicone-based soft denture liners to a processed denture base polymer

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Abstract

Objective. To investigate the effect of storage duration on the tensile bond strength of acrylic and silicone-based denture base materials with liners either heat-cured or auto-cured. ***Material and Methods.*** The denture liners investigated were Vertex soft (acrylic-based, heat-cured), Coe soft (acrylic-based, auto-cured), Molloplast-B (silicone-based, heat-cured), and Mollosil plus (silicone-based, auto-cured). The soft liner specimens were $10 \times 10 \times 3$ mm and were processed between two PMMA blocks. They were tested following immersion in water at 37°C for 1 day, 1 week, and 1, 3, and 6 months. Tensile bond strength was measured using a universal testing machine (Testometric Micro 500) at a crosshead speed of 20 mm/min ($n = 10$ specimens per experimental group). Multiple ANOVA and Tukey HSD were used to analyse the data at a pre-set alpha of 0.05. ***Results.*** The results indicate that the tensile bond strength of acrylic-based soft liners is greater than that of silicone-based materials. The bond strength of all lining materials decreases with storage duration; the decrease being greatest for the acrylic-based soft liners. The decrease in bond strength of the auto-cured materials is greater than that of the heat-cured products. ***Clinical significance.*** Comparison of the materials in this study indicates that the silicone-based, heat-cured soft liner is superior, based on the tensile bond strength property. Use of silicone-based, heat-cured soft liners may provide better clinical success over a long period. These laboratory results need to be verified by clinical testing.

Key Words: *Bond strength, soft denture lining material*

Introduction

Denture soft lining materials are applied to the tissue surface of dentures to achieve a more equal force distribution and to reduce local point pressures [1]. The liners are used to provide an even distribution of functional load on the denture-bearing area, avoiding local stress concentrations and improving denture retention by engaging undercuts [2]. The most favorable properties of soft liners are resiliency, which is desired over a long period of time, and good adhesion to the denture base [3].

Soft denture liners have been used in dentistry for more than a century, the earliest being natural rubbers. One of the first synthetic resins used as a soft liner was developed in 1945 as a plasticized polyvinyl resin. Silicone-based materials were introduced in 1958 [4]. Contemporary soft lining materials can be divided into two main groups: acrylic-based and silicone-based. Both groups are available in auto-cured or heat-cured forms [1,4]. Auto-cured soft lining materials allow the dentist to reline a removable denture directly in the mouth. This method is faster than the heat-cured (laboratory-processed) system and the patient is not without the prosthesis during the time required for the laboratory procedures [5]. However, it is difficult to produce the optimum thickness of the liner materials with the auto-cured system [6].

Acrylic-based soft lining materials are usually supplied in powder/liquid form, the powder consisting of a higher methacrylate polymer and a liquid of a higher methacrylate monomer. In addition, there is a plasticizer (commonly a phthalate). These materials undergo two processes when immersed in water, i.e. leaching of plasticizers and other soluble materials into the water and water imbibition by the polymer.

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Table I. Soft lining materials and denture base material used

Type	Lot no.	Product	Manufacturer
Conventional (heat-cured) Denture-based polymer	012087	Melliodent	Bayer Dental Germany
Heat-cured Acrylic-based soft liner	100001	Vertex soft	Dentimex Zeist Holland
Auto-cured Acrylic-based soft liner	0101292	Coe soft	Coe Lab., Illinois USA
Heat-cured Silicon-based soft liner	010527	Molloplast-B	Detax, GmbH&Co.KG Germany
Auto-cured Silicon-based soft liner	001003	Mollosil plus	Detax, GmbH&Co.KG Germany

Consequently, the physical and mechanical properties of the materials change with time in the patient's mouth [1].

There are several problems associated with the use of soft denture liners: the loss of softness, colonization by Candida albicans, porosity, poor tear strength, and various degrees of softness [2]. One of the most serious problems with these materials is the adhesion failure between the soft denture liner and the denture base [7]. Bond failure also creates a surface for bacterial growth, plaque, and calculus formation [2]. The favorable properties of a denture liner, in the absence of good adhesion to denture base materials, are considered to be useless. A variety of parameters affect the bond between the resilient lining materials and the denture base: water sorption, surface primer use, and denture base composition [8].

Several tests have been used to assess the bond strength of soft denture liners [2,3,9–15]. Craig & Gibbons [14] estimated the bond strength of 10 soft denture liners using a peeling test and concluded that an adhesion value of 10 pounds per inch was satisfactory for their clinical use. Sertgöz & Kulak [16] also used a peeling test for six soft lining materials. Bates & Smith [17] assessed the bond strength of 12 soft denture liners using a tensile test similar to that used in this study. They concluded that the soft denture liners investigated had satisfactory bond strength and showed that the heat-cured soft denture liners have intimate contact with a diffuse boundary when the materials are cured against an acrylic dough. El-Hadary & Drummond [4] also used a tensile test to investigate the bond strengths of two different soft lining materials. They concluded on the basis of lower sorption and solubility and higher tensile bond strength that silicone-based soft liners provide a better clinical result.

The purpose of this study was to assess the bond strength of differently based and cured types of soft denture liners to a polymerized polymethyl methacrylate (PMMA) denture base polymer by a tensile test. The ranking of materials will help clinicians select soft denture liners for their patients and the data will provide a comparative database when new materials are introduced.

Material and methods

The soft liners used, their classification and curing modes, are listed in Table I. Ten specimens with a cross-sectional area of 10×10 mm were prepared for each group using a heat-cured PMMA denture base material (Table I). Two PMMA plates were made by investing brass dies with a 3-mm-thick spacer in a denture flask. All the dies and spacers were machined to the same dimensions to standardize the shape of the denture base blocks and the thickness of the soft denture liners.

The dies and spacer were invested in hard but flexible silicone rubber to allow for easy removal of the processed samples from the flask. Specimens were made by processing the soft denture liners against polymerized PMMA blocks. Denture base polymer was mixed in accordance with the manufacturer's instructions, packed into the mold while the single brass spacer was present, and processed in a water bath at a temperature of 100°C for 30 min. After polymerization, two cured PMMA polymer samples were removed from the flask, trimmed, and the surfaces to be bonded smoothed using 240 grit silicone carbide paper. The prepared surfaces were then treated for the silicone-based soft lining materials used. For Molloplast-B, Primo adhesive was applied and allowed to dry for 60 min. For Mollosil plus, alcohol was applied to the surfaces and after drying the samples Primer was applied and allowed to dry for 1 min. Brass spacers were than removed from the flask.

The PMMA blocks were replaced in the mold and the soft denture liners were packed into the space left by the brass spacer, trial packed, and cured in accordance with the manufacturer's instructions.

After polymerization, the specimen was removed from the flask and trimmed with a sharp blade. Each group ($n = 10$) of samples was stored in water at 37°C for 1 day, 1 week, and 1, 3, and 6 months. Tensile bond strength was determined using a universal testing machine (Testometric Micro 500, Type U4000; Maywood Instruments Ltd., Basingstoke Hants, UK) at a crosshead speed of 20 mm/min. The changes in bond strength of each soft lining material were determined for the five test durations and were

Table II. Mean and standard deviation values of tensile bond strengths of soft lining materials for five time intervals (mean and SD)

	1 day	1 week	1 month	3 months	6 months
Vertex soft	3.50 (0.44)	3.07 (0.46)	2.57 (0.29)	1.91 (0.71)	1.70 (0.46)
	A1	A2	A3	A4	A5
Coe soft	0.45 (0.18)	0.39 (0.04)	0.23 (0.05)	0.22 (0.04)	0.11 (0.01)
	B1	B2	B3	B4	B5
Molloplast-B	1.58 (0.19)	1.42 (0.31)	1.16 (0.12)	1.10 (0.53)	1.03 (0.44)
	C1	C2	C3	C4	C5
Mollosil plus	1.20 (0.14)	1.12 (0.19)	1.07 (0.58)	0.77 (0.15)	0.50 (0.22)
	D1	D2	D3	D4	D5

$n=10$ specimens per experimental group and means are MPa units. Pa = N/m^2 Tensile load/area cross section.

evaluated statistically using two-way and three-way ANOVA and the Tukey HSD post-hoc test. All statistical testing was performed at a pre-set alpha of 0.05.

Results

Bond strength to PMMA ranged from 0.45 MPa (0.18) for Coe soft to 3.50 MPa (0.44) for Vertex soft after immersion for 1 day (Table II). After 1 week, bond strengths ranged from 0.39 MPa (0.04) for Coe soft to 3.07 MPa (0.46) for Vertex soft. Bond strength after 1 month storage ranged from 0.23 MPa (0.05) for Coe soft to 2.57 MPa (0.29) for Vertex soft. At 3 months' immersion, bond strength ranged from 0.22 MPa (0.04) for Coe soft to 1.91 MPa (0.71) for Vertex soft. Bond strengths after 6 months ranged from 0.11 MPa (0.01) for Coe soft to 1.70 MPa (0.46) for Vertex soft. It was evident that the bond strength of acrylic-based soft liners [3.50 (0.44)] was greater than that of silicon-based liners [1.58 (0.19)] and that bond strength of heat-cured soft liners [3.50 (0.44), 1.58 (0.19)] was greater than that of auto-cured liners [0.45 (0.18), 1.20 (0.14)] in both the silicone-based and acrylic-based groups. There was a significant difference between heat-cured acrylic-based soft lining material (Vertex soft) and auto-cured acrylic-based soft lining material (Coe soft), 3.05 ($p<0.001$), and also between heat-cured silicone-based soft lining material (Molloplas-B) and auto-cured silicone-based soft lining material (Mollosil plus), 0.37 ($p<0.001$) (Table III).

The changes in bond strength values are: from 1.70 MPa (0.46) to 3.50 MPa (0.44) for Vertex soft; from 0.11 MPa (0.01) to 0.45 MPa (0.18) for Coe soft; from 1.03 MPa (0.44) to 1.58 MPa (0.19) for Molloplast-B; and from 0.50 MPa (0.22) to 1.20 MPa (0.14) for Mollosil plus. The poorest bond strength was seen in the 6th month, and the greatest at the 24th hour for four types of soft lining materials. It was determined that the bond strength of soft lining materials decreased with time, and that the decrease was higher in the acrylic-based soft lining materials than in the silicone-based soft lining materials (0.67); however, the decrease in the soft lining materials auto-cured was higher compared to the heat-cured ones (1.59) (Table III).

Failure mode was adhesive for Vertex soft and Coe soft and cohesive for Molloplast-B. Mollosil plus was seen as a mixed mode of failure.

Discussion

Sufficient bond strength (4.5 kg/cm^2) between the soft denture lining and the acrylic resin denture base material is required if interfacial separation at the denture borders is to be avoided [15]. The bond strength of soft denture liners to PMMA denture base resin is weak, and when the separation takes place the

Table III. Mean difference values of tensile bond strengths of soft lining material groups

1st Group	2nd Group	Mean difference (1st Group–2nd Group)	Sig.
A1	B1	3.051	<0.001
	C1	1.921	<0.001
	D1	2.293	<0.001
C1	B1	1.130	<0.001
	D1	0.372	0.019
D1	B1	0.748	<0.001
A2	B2	2.676	<0.001
	C2	1.650	<0.001
	D2	1.946	<0.001
C2	B2	1.026	<0.001
	D2	0.296	0.140
D2	B2	0.730	<0.001
A3	B3	2.342	<0.001
	C3	1.410	<0.001
	D3	1.500	<0.001
C3	B3	0.932	<0.001
	D3	0.090	0.932
D3	B3	0.842	<0.001
A4	B4	1.691	<0.001
	C4	0.811	0.002
	D4	1.139	<0.001
C4	B4	0.880	0.001
	D4	0.328	0.378
D4	B4	0.552	0.046
A5	B5	1.592	<0.001
	C5	0.671	0.001
	D5	1.207	<0.001
C5	B5	0.921	<0.001
	D5	0.536	0.006
D5	B5	0.385	0.073

localized area may become unhygienic and non-functional. Ideally, the soft denture liners should bond sufficiently well to PMMA denture base resin to prevent failure of the interface during the service life of the prosthesis [2].

Tensile test differs from the forces that soft denture lining materials are subjected to clinically. Clinically, the stress exerted on the interface of two materials is more closely related to shear and tear; however, this *in vitro* tensile test was effective in evaluating bond strength and in ranking the materials [17,18].

There are different types of polymerization for PMMA denture base materials; however, dentures are normally constructed from heat-cured PMMA. A standard heat-cured polymer was used in this investigation.

One heat-cured acrylic-based Vertex soft showed the highest bond strength of all other materials at the 24th hour, because the chemical composition of Vertex soft is similar to the PMMA denture base polymer. PMMA denture base polymer and acrylic-based soft lining material are supplied in powder/liquid format with the powder consisting of a higher methacrylate polymer and a liquid consisting of a higher methacrylate monomer. According to similar chemical compositions, a chemical bond forms between the acrylic-based liners and PMMA denture base polymer [3]. Bonding agents are not therefore required to achieve a bond with PMMA denture base polymer. The results of the current study concur with those of others [3,7,11,12,19] suggesting that heat-cured acrylic-based soft lining materials show the highest bond strengths to acrylic-based dentures. The present results contradict others reporting that a silicone-based soft liner has a greater bond strength than acrylic-based liners [4].

Coe soft (an acrylic-based, auto-cured material) has a similar chemical composition to PMMA, but it had the lowest bond strength at day 1. This may have been due to the curing mode of this soft lining material. The present results confirm those of others [13,16] who reported that heat-cured liners have a greater bond strength than auto-cured products.

The heat-cured silicone, Molloplast-B, showed a lower bond strength than heat-cured acrylic (Vertex soft) at day 1. For silicone-based soft denture liners, an adhesive is supplied to aid in bonding to the cured denture base because silicone liners have little or no chemical adhesion to PMMA. The bond strength of silicone denture base liners therefore depends on the tensile strength of the liner materials as well as that of the adhesive used [16]. The heat-cured silicone liner had greater bond strength than the auto-cured silicone product.

The bond strength of all soft lining materials decreased with increased immersion duration. The present results are in agreement with those of others [7,9,20] who suggested that water storage reduced soft liner bond strength. A decrease in bond strength may result from swelling and stress built up at the bond interface, or of a change in the viscoelastic properties of the liner, rendering the material stiffer and thus better able to transmit external loads to the bond site. The current study produced results differing from others [10,12,14] who reported that bond strength of soft lining materials increased after water storage. However, a direct comparison of studies cannot be made because of the different research protocols used.

The bonding strength values of acrylic-based liners decreased more than those of the silicone products during the 6-month immersion test. This finding agrees with that of others [21] who reported that water storage reduced acrylic-based liner strength more than that of silicone-based products. Moreover, the bonding strength values of auto-cured products decreased more than those of heat-cured materials over the duration of this experiment. This finding is in agreement with others [22] who have reported that water storage reduces the bond strength of auto-cured liners more so than that of the heat-cured materials.

The results of the present investigation support a common trend reported by others, namely that heat-cured silicone soft liners have optimal properties, that heat-cured acrylic-based soft liners have good properties initially, but deteriorate during use, and that auto-cured soft liners have a useful but limited role.

The present work tested all material combinations in a laboratory environment. *In vivo* testing should be performed to establish whether the trends observed in the present work are applicable in the clinical situation.

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