J Indian Prosthodont Soc (December 2014) 14(Suppl. 1):S155–S160
DOI 10.1007/s13191-014-0389-4

ORIGINAL ARTICLE

Effect of Aging on Bond Strength of Two Soft Lining Materials to a Denture Base Polymer

Alaa'a M. Salloum

Received: 11 November 2013 / Accepted: 22 August 2014 / Published online: 10 September 2014

Abstract The purpose of this study was evaluation the effect of immersion in distilled water and inorganic artificial saliva on the shear bond strength of a heat-polymerized and an auto-polymerized silicone-based denture lining materials. The denture liners investigated were Molloplast-B (heat-polymerized), and Mollosil plus (auto-polymerized). The soft liner specimens were 10 × 10 × 2.5 mm and were processed between two poly(methylmethacrylate) plates. Thirty shear specimens for each type of test lining material were prepared. Specimens were divided equally into three groups for each test lining material: first group, specimens were tested after 48 h of preparation without immersion; second group, specimens were tested following immersion in distilled water at 37 °C for 12 months; and third group, specimens were tested following immersion in inorganic artificial saliva at 37 °C for 12 months. Shear bond strength was measured using an universal testing machine at a crosshead speed of 40 mm/min and failure mode (adhesive, cohesive and mixed) after debonding was assessed. Data were statistically analyzed with one-way analysis of variance (ANOVA) ($\alpha = 0.05$). ANOVA was followed by Bonferroni post hoc tests for pairwise comparisons. A significant difference in shear bond strength was detected between Molloplast-B and Mollosil plus following immersion in distilled water and artificial saliva. Molloplast-B demonstrated considerably higher shear strength than Mollosil plus after immersion. Shear strengths of the lining materials investigated reduced significantly after immersion in both solutions. Visual examination after separation revealed that the soft materials tested exhibited mostly adhesive failure. The effect of immersion in distilled water and inorganic artificial saliva on bond strength of test lining materials was perceivable; however, both of them had acceptable bond strength and might be proper for long-term use.

Keywords Artificial saliva · Bond strength · Distilled water · Soft lining material

A. M. Salloum (✉)
Department of Removable Prosthodontics, Faculty of Dental Medicine, Damascus University, Damascus, Syria
e-mail: drsalloum74@hotmail.com

Introduction

Soft lining materials have introduced in dentistry as a solution for certain clinical problems. These materials may provide an even distribution of functional load on the denture-bearing area and avoid load stress concentrations [1–4]. They are widely used as a cushion on the intaglio surface of dentures in the management of traumatized oral mucosa, ridge atrophy, bony undercuts, bruxism, xerostomia, edentulous arches opposing natural dentition, congenital oral defects requiring obturation, and for improving the retention of the dentures by engaging undercuts [5–7]. The earliest soft liner was soft natural rubber and it was applied by Twichell in 1869 [6]. Since then, many compositions have been provided [8, 9]. One of the first synthetic resins developed in 1945 as a soft liner was a plasticized polyvinyl resin [10], followed by the introduction of silicones in 1958 [11]. On the other hand, these materials have several problems related to their use. One of the more severe problems with soft denture linings is separation of these linings from the denture base [8, 12, 13]. Moreover, bond failure generates a prospective surface for fungal and bacterial growth, as well as plaque and calculus formation [14, 15]. The colonization of denture soft lining material by oral bacteria and fungi can result in infections, stomatitis of oral tissues and deterioration of the material [16, 17].

Thus, it could be concluded that adhesion characteristics of soft lining materials to denture base acrylic resins may contribute to its long-term service. The most commonly used methods to measure the bond strength of soft lining materials to denture base materials have been peel, tensile, and shear tests [18]. Bonding of soft lining materials to Poly(methylmethacrylate) (PMMA) denture base material has been estimated by several investigators [15, 19, 20]. Al-Athel et al. [21] evaluated the bond strength of a heat-cured silicone denture soft lining material (Molloplast-B) using tensile and shearing tests. They concluded that longer immersion of specimens in water at 37 ± 1 °C led to a significant reduction in the measured tensile and shear bond strengths. In 2011, Demir et al. [22] assessed the peel bond strength of two different soft liners (Molloplast B and Permaflex) to PMMA denture base resin before and after thermocycling. They concluded that thermocycling led to significant decreases in the peel strength of both Permaflex liner specimens packed against cured/uncured PMMA resin surfaces, whereas this process did not affect the strength of Molloplast B specimens. Takahashi et al. [23] evaluated the effect of different accelerated aging times on permanent deformation and tensile bond strength of two soft chairside liners (acrylic and silicone based). They concluded that the both soft denture liners investigated had satisfactory bond strength and might be appropriate for long-term use.

Mese et al. [24] tested 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. They reported that use of silicone-based, heat-cured soft liners may provide better clinical success over a long period.

In the last few decades, a large number of experimental or commercially available resilient lining materials have been developed [25, 26], but no products are available that will remain serviceable for extended periods of time [27, 28].

The purpose of this research was to determine the adhesion characteristics of two soft lining materials to a denture base polymer as a function of aging. The null hypothesis was that there was no significant effect of immersing soft lining materials in distilled water and artificial saliva on the adhesion characteristics after one year of observation.

Materials and Methods

The soft denture lining materials involved in this study represented two different curing modes. The first curing mode was a conventional laboratory processing: Molloplast-B (DETAX, Ettligen-Germany), whereas the second was an autopolymerization material: Mollosil plus (DETAX, Ettligen- Germany). The denture base material was heat-curing acrylic resin (Vertex Regular, Vertex dental, Zeist, The Netherland).

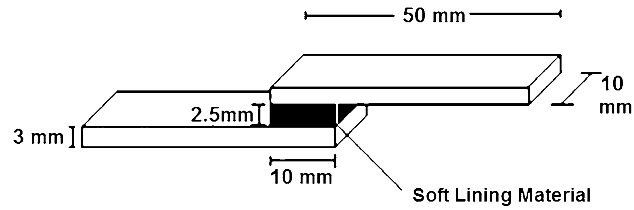

Fig. 1 Diagram of shear specimen

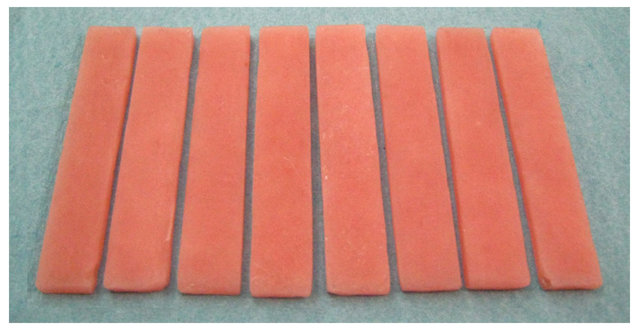

Fig. 2 Acrylic resin strips

Shear bond strength was evaluated using a simple overlap-joint model. Shear specimens consisted of soft denture lining material with dimensions of 10 × 10 × 2.5 mm. The denture lining materials were bonded to two plates of acrylic resin, each 50 × 10 × 3 mm, (Fig. 1). The dimensions of specimen were selected according to previous study [21]. PMMA denture base material was packed into preformed molds 50 × 60 × 3 mm to make the acrylic resin plates. These plates were then cut by a band saw machine into strips with dimensions of 50 × 10 × 3 mm (Fig. 2). The acrylic resin strips were immersed in distilled water at room temperature for 48 h [29]. Every two strips were attached to a glass spacer 10 × 10 × 2.5 mm (Fig. 3) to provide space for the soft lining materials after their removal [30–32]. The strips and spacers were then invested in hard but flexible silicone rubber to allow for easy removal of the spacers as well as the processed specimens from the flask (Fig. 4). Strips were reset inside the mold after spacers removal. Silicone primer was applied to the acrylic bond surface, and the manufacturer's instructions were followed for packing and curing the liners. The number of shearing specimens was thirty for each soft lining material. A power analysis (using G*Power Version 3.1.5) was done to determine the required sample size. Specimens of each soft lining material were equally divided into three groups: In the first group (i.e. the

Fig. 3 Two strips attached to a glass spacer

Fig. 4 Removal of the spacers and the processed specimens from the flask

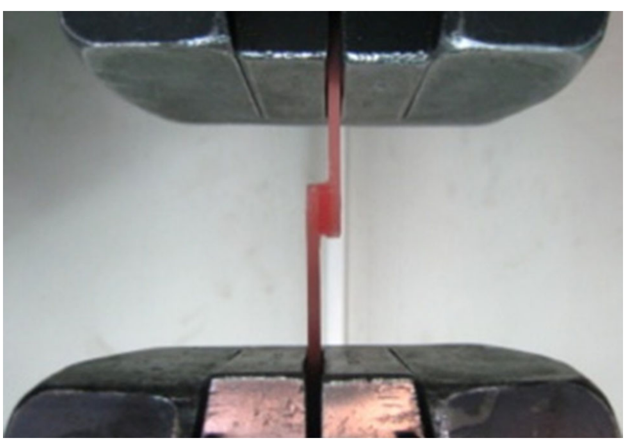

Fig. 5 Shearing test

control group), specimens were tested after 48 h of preparation without immersion. In the second group, specimens were tested after immersion in distilled water at 37 °C for 12 months, whereas in the third group specimens were tested after immersion in an inorganic artificial saliva at 37 °C for 12 months. The artificial saliva was prepared with the following composition [33]: Potassium chloride, (0.400 g/L); Calcium chloride. H2O, (0.795 g/L); Sodium dihydrogen phosphate. H2O, (0.690 g/L); Sodium sulphide. H2O, (0.005 g/L); Distilled water 1,000 ml (pH = 5.25).

Table 1 Shear bond test results (Mean ± SD) in N/mm^2 and type of failure

	Material	N	Mean ± SD	Type of failure
Control	MB	10	1.3810 ± 0.29486	90 % Adh
				10 % Coh
	MP	10	1.1830 ± 0.31066	90 % Adh
				10 % Coh
Distilled water	MB	10	0.9850 ± 0.16112	95 % Adh
				5 % Coh
	MP	10	0.6900 ± 0.18523	95 % Adh
				5 % Coh
Artificial saliva	MB	10	0.8420 ± 0.16484	100 % Adh
				0 % Coh
	MP	10	0.5370 ± 0.13483	97 % Adh
				3 % Coh

MB Molloplast-B, *MP* Mollosil plus, *Adh* adhesive failure, *Coh* cohesive failure

Specimens were tested by using the universal testing machine (DY-34 Adamel Lhomargy, France) (Fig. 5), at a crosshead speed of 40 mm per minute until the liner material was separated from the acrylic plates. The maximum force indicating the point of failure by separation was recorded and the shear bond strengths were calculated by using the following formula [18]:

$$\text{Bond strength} = \text{Maximum load (N)/Cross sectional area}\ (\text{mm}^2)$$

Surfaces of bond failure were evaluated by using an explorer for determining the type of failure (cohesive, adhesive or mixed). Collected data were submitted to one-way analysis of variance (ANOVA) at a significant level of 5 %. ANOVA was followed by Bonferroni post hoc tests to determine significant differences in pairwise comparisons.

Results

Descriptive statistics of the measured variables are given in Table 1. The effect of test solution on shear strengths is presented in Table 2. There were statistically significant difference between shear strengths of Molloplast-B and Mollosil plus when the specimens were immersed in distilled water and artificial saliva (Table 2). Molloplast-B demonstrated considerably higher shear strength than Mollosil plus after immersion (Tables 1, 2). Statistical analysis revealed a significant decrease ($p < 0.05$) in the shear strength of both soft materials when the specimens

Table 2 Mean Difference in the bond strengths between Mollplast-B and Mollosil plus as function of test solutions (Control, Distilled water, Artificial saliva)

Materials		Mean difference (Control)	Mean difference (Distilled water)	Mean difference (Artificial saliva)
MB	MP	0.19800	0.29500*	0.30500*

* Statistically significant difference

Table 3 Multiple comparisons of subsets

Material	Storage solutions		Mean difference
MB	Control	Distilled water	0.39600*
	Control	Artificial saliva	0.53900*
	Distilled water	Artificial saliva	0.14300
MP	Control	distilled water	0.49300*
	Control	Artificial saliva	0.64600*
	Distilled water	Artificial saliva	0.15300

* Statistically significant difference

were immersed in distilled water and artificial saliva (Table 3). Visual examination after separation revealed that the soft materials tested exhibited mostly adhesive failure (Table 1).

Discussion

Debonding of silicone soft denture lining materials is commonly encountered in clinical practice [8, 13]. Failure of adhesion between soft liner and the denture base is considered the most common reason for failure of soft-lined dentures [34]. For this reason adhesive properties of soft denture lining materials has been evaluated by many tests. The most commonly used methods to measure the bond strength of soft lining materials to denture base materials have been tensile, shear and peel tests [18]. The shear testing was adopted in this research work due to the fact that the direction of forces that are encountered with lining material has normally and predominantly a shearing effect [35]. The specimens in this study were based on the simple lap design described by Al-Athel et al. [18]. Thickness of soft denture lining material was chosen according to previous reports [36], which have stated that the soft liner should be 2–3 mm thick to acquire the best benefit in softness.

The results of this study were (1.38 ± 0.29, 0.99 ± 0.16, 0.84 ± 0.16) N/mm2 and (1.18 ± 0.31, 0.69 ± 0.19, 0.54 ± 0.13) N/mm2 for Molloplast-B and Mollosil plus, respectively. These results indicated that the bond strength was higher than 0.5 N/mm2 for two materials investigated. It has been reported that 4.5 kg/cm2 (0.44 N/mm2) would be satisfactory for clinical use of the soft lining materials [14]. Considering this only criterion, the two materials tested were acceptable for clinical use. Bond strengths of Molloplast-B and Mollosil plus were identical when specimens were tested after 48 h of preparation without immersion. However, bond strength of Mollosil plus became significantly less in comparison with Molloplast-B after immersion in distilled water and artificial saliva for 12 months (Table 1). The results of this study revealed that bond strengths of the two test lining materials reduced significantly after immersion in distilled water and artificial saliva (Table 2). The negative effect of the immersion was recorded in previous studies [14, 21, 29, 32, 37]. The reduction in bond strength may be attributed to swelling and stress buildup at the bond interface, or changing the viscoelastic properties of the soft lining materials after immersion [14, 38]. On the other hand, Garcia et al. [39] (at 15 days), Emmer et al. [40] (at 6 months) and Eick et al. [41] (at 1 month) have reported an increase in bond strength after aging. The difference may be the result of the variations in time of immersion, the soft materials tested, the shape of specimens, and the testing procedure [11]. The same negative effect on bond strength was observed after immersion in distilled water and artificial saliva. It may be due to a high content of water in used artificial saliva. This result confirms those of Yanikoglu and Denizoglu [42]. The shear bond strength results of Molloplast-B in this study (1.3810 ± 0.29486 N/mm2 for the control group) were nearly the same of those for Al-Athel and Jagger [18] (1.39 ± 0.07 N/mm2). The mode of failure for soft lining materials was mostly adhesive (Table 1). This can be attributed to the uneven stress distribution in the lap joint and concentration of stresses at or near the edges [18]. Also, it was observed that there was more tendency toward adhesive failure after immersion in distilled water and artificial saliva. It may be due to the complex nature of the bonding phenomenon. This result also indicated that the strengths of soft lining materials were more than their bond strengths.

Limitations of the present in vitro study include that the test specimens do not simulate the real denture design, and in laboratory tests only one type of force is applied. So, it is difficult to interpret the importance of the laboratory bond strength test results.

The findings of this study suggest that immersion in distilled water and inorganic artificial saliva has an effect on bond strength of soft denture lining materials. It also appeared to be a need for further research to understand the nature of the bonding phenomenon.

Conclusions

Within the limitation of the current study, the following conclusions were made:

1. Both soft denture liners tested had acceptable bond strength and might be suited for long-term use.
2. Immersion in distilled water and artificial saliva for 12 months led to reduction in bond strength of soft lining materials tested.
3. Molloplast-B demonstrated better bond strengths after immersion in comparison with Mollosil plus.
4. The negative effects of immersion in distilled water and artificial saliva on bond strength of test lining materials were similar.
5. It was observed that there was more tendency toward adhesive failure after immersion in distilled water and artificial saliva.

Conflict of interest The current research is free of conflict of interest.

References

1. Brown D (1988) Resilient soft liners and tissue conditioners. Br Dent J 164:357–360
2. Demetriou PP, Polyzois GL, Andreopoulos AG (1988) The compressive creep of soft liners. Clin Mater 3:163–170
3. Mack PJ (1989) Denture soft lining: materials available. Aust Dent J 34:517–521
4. Tata S, Nandeeshwar DB (2012) A clinical study to evaluate and compare the masticatory performance in complete denture wearers with and without soft liners. J Contemp Dent Pract 13:787–792
5. Gonzalez JB (1977) Use of tissue conditioners and resilient liners. Dent Clin North Am 21:249–259
6. Qudah S, Harrison A, Huggett R (1990) Soft lining materials in prosthetic dentistry: a review. Int J Prosthodont 3:477–483
7. Jagger DC, Harrison A (1997) Complete dentures—the soft option. Br Dent J 182:313–317
8. Schmidt WF Jr, Smith DE (1983) A six-year retrospective study of Molloplast-B-lined dentures. Part II: liner serviceability. J Prosthet Dent 50:459–465
9. Jin C, Nikawa H, Makihira S, Hamada T, Furukawa M, Murata H (2003) Changes in surface roughness and colour stability of soft denture lining materials caused by denture cleansers. J Oral Rehabil 30:125–130
10. Matthews E (1945) Soft resin lining for dentures. Br Dent J 78:140
11. El-Hadary A, Drummond JL (2000) Comparative study of water sorption, solubility, and tensile bond strength of two soft lining materials. J Prosthet Dent 83:356–361
12. Bates JF, Smith DC (1965) Evaluation of indirect resilient liners for dentures; laboratory and clinical tests. J Am Dent Assoc 70:344–353
13. Wright PS (1986) A three year longitudinal study of denture soft lining materials in clinical use. Clin Mater 1:281–289
14. Khan Z, Martin J, Collard S (1989) Adhesion characteristics of visible light-cured denture base material bonded to resilient lining materials. J Prosthet Dent 62:196–200
15. Kawano F, Dootz ER, Koran A, Craig RG (1992) Comparison of bond strength of six soft denture liners to denture base resin. J Prosthet Dent 68:368–371
16. Bulad K, Taylor RL, Verran J, McCord JF (2004) Colonization and penetration of denture soft lining materials by Candida albicans. Dent Mater 20:167–175
17. Chladek G, Kasperski J, Barszczewska-Rybarek I, Zmudzki J (2012) Sorption, solubility, bond strength and hardness of denture soft lining incorporated with silver nanoparticles. Int J Mol Sci 14:563–574
18. Al-Athel MS, Jagger RG (1996) Effect of test method on the bond strength of a silicone resilient denture lining material. J Prosthet Dent 76:535–540
19. Craig RG, Gippons P (1961) Properties of resilient denture liners. J Am Dent Assoc 63:382–390
20. Wright PS (1982) Characterization of the adhesion of soft lining materials to poly(methylmethacrylate). J Dent Res 61:1002–1005
21. Al-Athel M, Jagger R, Jagger D (2002) Effect of ageing on the bond strength of a permanent denture soft lining material. J Oral Rehabil 29:992–996
22. Demir H, Dogan A, Dogan OM, Keskin S, Bolayir G, Soygun K (2011) Peel bond strength of two silicone soft liners to a heat-cured denture base resin. J Adhes Dent 13:579–584
23. Takahashi JM, Consani RL, Henriques GE, Nobilo MA, Mesquita MF (2011) Effect of accelerated aging on permanent deformation and tensile bond strength of autopolymerizing soft denture liners. J Prosthodont 20:200–204
24. Mese A, Guzel KG, Uysal E (2005) Effect of storage duration on tensile bond strength of acrylic or silicone-based soft denture liners to a processed denture base polymer. Acta Odontol Scand 63:31–35
25. Parker S, Braden M (1982) New soft lining materials. J Dent 10:149–153
26. Hayakawa I, Kawae M, Tsuji Y, Masuhara E (1984) Soft denture liner of fluoroethylene copolymer and its clinical evaluation. J Prosthet Dent 51:310–313
27. Wright PS (1981) Composition and properties of soft lining materials for acrylic dentures. J Dent 9:210–223
28. Craig RG (ed) (1989) Restorative dental materials, 8th edn. CV Mosby, St Louis
29. Polyzois GL (1992) Adhesion properties of resilient lining materials bonded to light cured denture resins. J Prosthet Dent 68:854–858
30. Pinto JRR, Mesquita MF, Henriques GEP, Nobilo MAA (2002) Effect of thermo cycling on bond strength and elasticity of 4 long-term soft denture liners. J Prosthet Dent 88:516–521
31. Sarac D, Sarac YS, Basoglu T, Yapici O, Yuzbasioglu E (2006) The evaluation of microleakage and bond strength of a silicone-based resilient liner following denture base surface pretreatment. J Prosthet Dent 95:143–151
32. Mese A, Guzel KG (2008) 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 99:153–159
33. Williams JA, Billington RW, Pearson GJ (2001) A long term study of fluoride release from metal-containing conventional and resin-modified glass ionomer cements. J Oral Rehabil 28:41–47
34. Wright PS (1984) The success and failure of denture soft-lining materials in clinical use. J Dent 12:319–327
35. McMordie R, King GE (1989) Evaluation of primers used for bonding silicone to denture base material. J Prosthet Dent 61:636–639
36. Wright PS (1976) Soft lining materials: their status and prospects. J Dent 4:247–256

37. Sinobad D, Murphy WM, Hugget R, Brooks S (1992) Bond strength and rupture properties of some soft denture liners. J Oral Rehabil 19:151–160
38. Amin WM, Fletcher AM, Ritchie GM (1981) The nature of the interface between polymethylmethacrylate denture base materials and soft lining materials. J Dent 9:336–346
39. Garcia RCMR, Leon BLT, Oliveira VMB, Cury AAB (2003) Effect of a denture cleanser on weight, surface roughness and tensile bond strength of two resilient denture liners. J Prosthet Dent 89:489–494
40. Emmer TJ Jr, Emmer TJ Sr, Vaidynathan J, Vaidynathan TK (1995) Bond strength of permanent soft denture liners bonded to the denture base. J Prosthet Dent 74:595–601
41. Eick JD, Craig RG, Payton FA (1962) Properties of resilient denture liners in simulated mouth conditions. J Prosthet Dent 12:1043–1052
42. Yanikoglu N, Denizoglu S (2006) The effect of different solutions on the bond strength of soft lining materials to acrylic resin. Dent Mater J 25:39–44