10.5005/jp-journals-10024-1819

ORIGINAL RESEARCH

Effect of Different Surface Treatments and Thermocycling on Bond Strength of a Silicone-based Denture Liner to a Denture Base Resin

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ABSTRACT

Aim: The aim of this study is to evaluate the effects of three different surface treatments and thermocycling on the tensile strength of a silicone lining material to denture resin.

Materials and methods: A total of 96 cube-shaped specimens were fabricated using heat-cured polymethyl methacrylate (PMMA) denture base resin. Three millimeters of the material was cut from the midsection. The specimens were divided into four groups. The bonding surfaces of the specimens in each group received one of the following surface treatments: no surface treatment (control group), airborne particle abrasion with 110 μm alumina particles (air abrasion group), Er:yttrium aluminum garnet laser irradiation (laser group), and air abrasion + laser. After the lining materials were processed between the two PMMA blocks, each group was divided into two subgroups (n = 12), either stored in distilled water at 37ºC for 24 hours or thermocycled between 5 and 55ºC for 5,000 cycles. The specimens were tested in tensile and shear strength in a universal testing machine. Data were analyzed with two-way analysis of variance and Tamhane's *post hoc* tests (α = 0.05). The mode of failure was determined, and one specimen in each group was examined by scanning electron microscopy.

Results: Surface-treated groups demonstrated significantly higher tensile strengths compared to the control group ($p < 0.001$). Nonetheless, no significant differences were found between surface-treated groups ($p > 0.05$). The tensile strength was significantly different between thermocycled and water-stored specimens ($p = 0.021$).

Conclusion: Altering the surface of the acrylic denture base resin with air abrasion, laser, and air abrasion + laser increased the tensile strength. Thermocycling resulted in decrease in bond strength of silicone-based liner to surface-treated acrylic resin.

Clinical significance: Pretreatment of denture base resins before applying the soft liner materials improves the bond strength. However, thermocycling results in decrease in bond strength of soft denture liner to surface-treated acrylic resin.

Keywords: Bond strength, Er:YAG laser, Resilient denture liner, Thermocycling.

How to cite this article: Nakhaei M, Dashti H, Ahrari F, Vasigh S, Mushtaq S, Shetty RM. Effect of Different Surface Treatments and Thermocycling on Bond Strength of a Silicone-based Denture Liner to a Denture Base Resin. J Contemp Dent Pract 2016;17(2):154-159.

Source of support: This study was supported by a grant (No. 922456) from the Vice Chancellor for Research of Mashhad University of Medical Sciences. The results presented here are based on an undergraduate thesis (No. 2722) submitted to Mashhad Faculty of Dentistry and Dental Research Center.

Conflict of interest: None

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INTRODUCTION

Denture lining materials, applied as a cushion on the tissue surfaces of the removable dentures and maxillofacial prostheses to achieve more equal force distribution, reduce localized pressure and improve retention by engaging undercuts.[1,2] Patients who have alveolar ridge resorption, bruxism, thin and nonresilient mucosa, and areas of severe undercuts may benefit from the use of soft lining materials in their prostheses.[3,4] There are two types of resilient soft lining materials: Plasticized acrylic resins and silicone rubber. The most important problem with the acrylic product is leaching out of plasticizers and other soluble materials into water, resulting in loss of softness over time.[5,6] Silicone-based resilient lining materials have the advantage of being inherently soft over a long time. Nevertheless, the Achilles heel of these products is inadequate bonding to the denture base.[7,8]

Resilient lining materials have several important problems, including loss of softness, colonization by *Candida albicans*, and low tear strength and porosity.[9,10] One of the most common problems with these materials is deboning from the denture base. To solve this perplexing problem, investigators have focused on methods to alter the denture base resin surface. These methods include airborne particle abrasion,[11-15] tribochemical coating,[16] chemical etching,[14] and laser treatment.[14,15,17,18] A study showed that roughening the acrylic surface results in almost twice the adhesive bond strength of resilient lining materials in comparison to smooth surfaces.[19] Traditionally, airborne particle abrasion with aluminum oxide particles has been used to alter the surface of acrylic resin in order to provide mechanical locks. However, there is conflicting information regarding the efficacy of airborne particle abrasion in enhancing bond strength of the soft lining material to acrylic resin denture base.[12-15]

Technological developments during the last decade have resulted in increased use of lasers in dentistry. Recently, laser has been proposed as an alternative method for surface treatment to obtain higher bond strength between two materials.[20] The laser might be a reasonable choice for treating denture base resin because of its depth of optical penetration depending on the laser type and its parameters. Nevertheless, limited and inconsistent findings are available regarding the effectiveness of laser treatment in improving bond strength between soft lining materials and denture resin.[11,14,17,21]

In the oral cavity, liner denture base resin interface is frequently subjected to thermal stresses. It has been found that the bonding between resilient liner materials and denture resin is affected by aging in water and thermocycling.[22-25] However, no investigation was found in relation to comparing the bond strength of resilient liners to surface-treated denture base resin before and after thermocycling.

The aim of this study was to evaluate the effects of three different surface treatments and thermocycling on the tensile strength of a silicone lining material to denture resin. The first hypothesis was that surface treatments affect the bond strength of resilient denture liner. The second hypothesis was that the bond strength between resilient liner and surface-treated denture base resin changes after thermocycling.

MATERIALS AND METHODS

The resilient liner in this study was a silicone-based material (Detax Gmbh & Co KG, Ettlingen, Germany) and the denture base material was a heat-polymerized acrylic resin (Triplex, Ivoclar Vivadent, Schaan, Liechtenstein). A total of 96 cube-shaped acrylic resin specimens were fabricated according to the manufacturer's instructions. The specimens were prepared by investing brass cube-shaped patterns, 25 mm in height, 10 mm in length, and 10 mm in width. Putty impression material was placed around the brass patterns to facilitate the removal of processed specimens from the flask. Once the specimens were polymerized, 3 mm of the material was cut from the midsection of the specimens using a water-cooled low-speed diamond saw (IsoMet, Buehler, Illinois, USA). The prepared specimen was then randomly divided into four groups (n = 24) according to surface treatments. The bonding surfaces of the specimens in each group received one of the following surface treatments:

Untreated (control): The bonding surface of the specimens received no treatment.

Airborne particle abrasion (air abrasion): The bonding surfaces of the specimens were airborne particle abraded using 110-μm aluminum oxide particles at 2 bars of pressure for 10 seconds at a distance of 10 mm in a sandblasting unit (Basic Classic; Renfert, Hilzingen, Germany).

Laser irradiation (laser): The bonding surfaces of the specimens were irradiated using Er: yttrium aluminum garnet (YAG) laser beams (Smart 2940D Plus; Deka Laser, Firenze, Italy) in noncontact focused mode from 5 mm above the surface. The laser beam with the following parameters was used: 300 mJ, 10 Hz, 3 W, long pulse duration for 20 seconds.

Airborne particle abrasion + laser irradiation (air abrasion + laser): The bonding surfaces of the specimens were airborne particle abraded similar to the air abrasion group. The surface was then irradiated with Er:YAG laser beams in the same manner described for the laser group.

The acrylic blocks were placed back in the molds, and the Molloplast-B bonding agent was applied on the bonding surfaces. The resilient liner materials were then packed into the space between the two blocks, trial-packed, and polymerized according to the manufacturer's instructions. Before the specimens were retrieved from the denture flasks, they were left to cool at room temperature for 20 minutes. The specimens in each group were divided into two subgroups (n = 12), either stored in distilled water at 37ºC for 24 hours or thermocycled between 5 and 55ºC for 5,000 cycles. The dwell time at each temperature was 20 seconds and transfer time was 10 seconds. All the specimens were subjected to a tensile force using a universal testing machine (STM20; Santam, Tehran, Islamic Republic of Iran) at a crosshead speed of 5 mm/min. The force on the failure point was recorded, and the tensile strength values were calculated using this formula: $S = F/A$, where S is the tensile stress (in MPa), F is the maximum tensile force (in N), and A is the bonded surface area (in mm^2). The failure modes were visually determined and classified as adhesive (total separation at the liner resin interface), cohesive (tearing within the liner), or mixed (a combination of adhesive and cohesive). In addition, four other specimens (one specimen for each group) were prepared. The bonding surfaces of these specimens were gold-sputtered and used for surface analysis using scanning electron microscopy (SEM; XL 30; Philips, Eindhoven, the Netherlands). Two-way analysis of variance (ANOVA) was used to evaluate the effect of the surface treatments, thermocycling, and their interaction on tensile strength. The means were then compared using Tamhane's *post hoc* tests ($\alpha = 0.05$).

RESULTS

Mean tensile strength values and standard deviations of all the groups are presented in Table 1. Two-way ANOVA revealed significant differences for surface treatments ($p < 0.001$) and thermocycling ($p = 0.021$). However, their interaction was not significant ($p = 0.768$) (Table 2). According to Tamhane's *post hoc* test, the surface-treated groups (air abrasion, laser, and air abrasion + laser) demonstrated significantly higher tensile strength compared to the control group ($p < 0.001$). Nonetheless, no significant differences were found between surface-treated groups ($p > 0.05$).

Different modes of failure were observed in the experimental groups (Table 3). The control group exhibited 25% adhesive failure and 75% mixed failure, while in the thermocycled group, the results changed to 41.67% adhesive, 8.33% cohesive, and 50% mixed modes. Before thermocycling, the laser group exhibited 8.33% cohesive and 91.67% mixed failure. The air abrasion + laser group exhibited 33.33% cohesive and 66.67% mixed failure, while following thermocycling, the failure mode of laser and air abrasion + laser groups changed to completely mixed.

The SEM images of the treated surfaces of experimental groups are presented in Figures 1A to D, which shows surface treatment resulted in irregularities and many pits and depressions on the denture base resin. In the laser group, holes and cavities with trabecular pattern were noticeable (Fig. 1C).

Table 1: Mean ± (SD) tensile bond strength values (MPa) of experimental groups

Groups	*Water storage*	*Thermocycling*	*Tamhane's post hoc test*
Control	0.9 ± (0.21)	0.75 ± (0.36)	Control: air abrasion, laser, and air abrasion + laser, p < 0.001
Air abrasion	1.29 ± (0.17)	1.13 ± (0.14)	Air abrasion: laser, p = 1
Laser	1.24 ± (0.22)	1.22 ± (0.45)	Air abrasion: air abrasion + laser, p = 0.48
Air abrasion + laser	1.36 ± (0.12)	1.21 ± (0.1)	Laser: air abrasion + laser, p = 0.97

p < 0.05 indicates significant difference; SD: standard deviation

Table 2: Two-way analysis of variance results for comparison of bond strength values

Source	*Sum of squares*	*df*	*Mean square*	*F*	*p-value*
Group	3.239	3	1.080	17.458	< 0.001
Thermocycling	0.342	1	0.342	5.532	0.021
Group × thermocycling	0.071	3	0.024	0.380	0.768
Error	5.442	88	0.062	Error	5.442
Total	133.397	96			

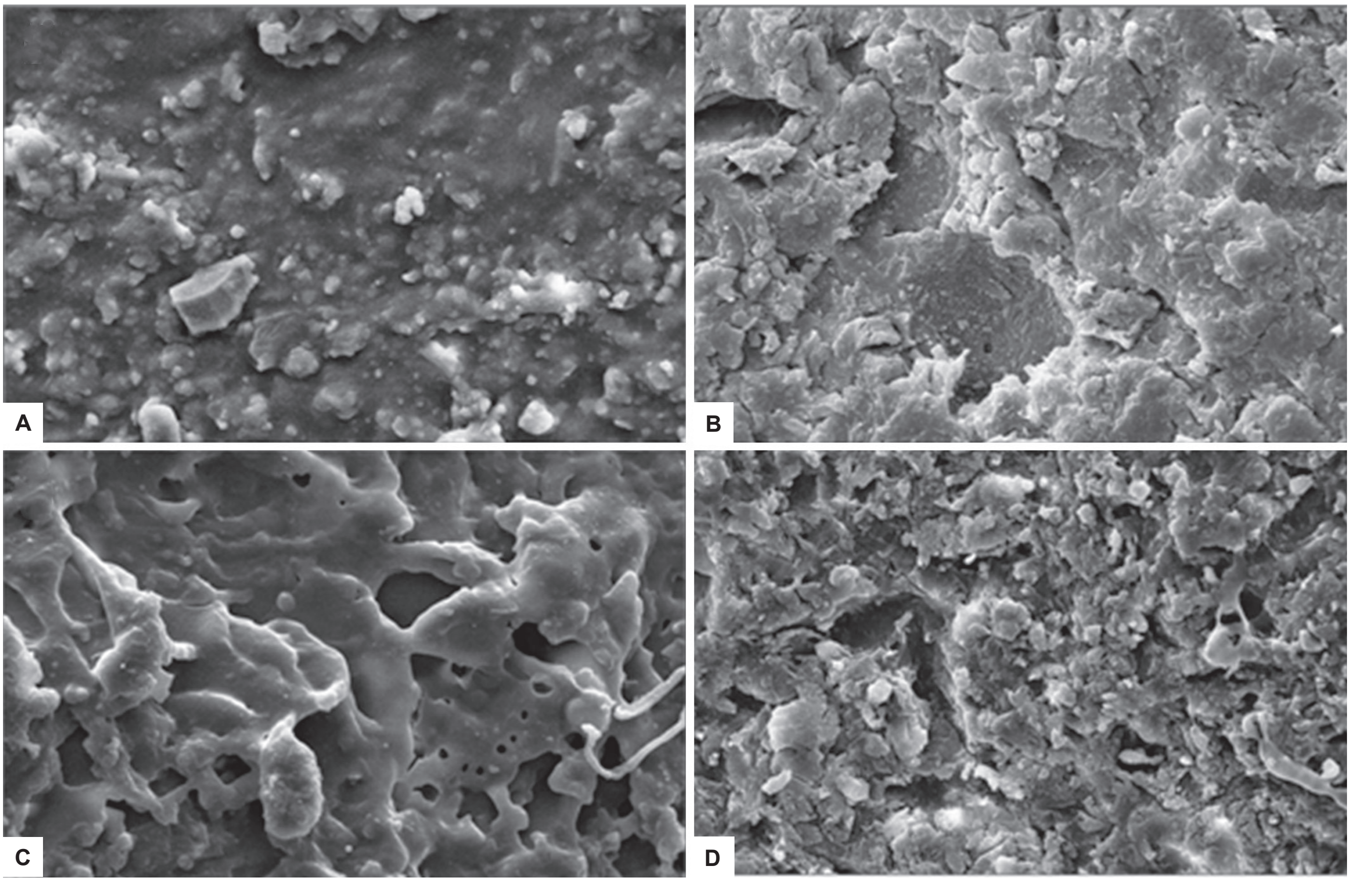
Table 3: Percentage of mode of failure of all groups after tensile bonding test

		Mode of failures		
Groups		*Adhesive*	*Cohesive*	*Mixed*
Control	Water storage	3 (25%)	0	9 (75%)
	Thermocycling	5 (41.67%)	1 (8.33%)	6 (50%)
Air abrasion	Water storage	12 (100%)	0	0
	Thermocycling	12 (100%)	0	0
Laser	Water storage	0	1 (8.33%)	11 (91.67%)
	Thermocycling	0	0	12 (100%)
Air abrasion + laser	Water storage	0	4 (33.33%)	8 (66.67%)
	Thermocycling	0	0	12 (100%)

DISCUSSION

According to the results of this study, pretreatment with airborne abrasion, laser, and airborne abrasion + laser increased the bond strength of silicone lining material to the acrylic resin denture base. Thus, the first hypothesis that surface treatments affect bond strength was accepted.

It is assumed that airborne particle abrasion of acrylic resin improves the bond strength of resilient lining material to denture base, through production of irregularities that can facilitate mechanical interlocking. Nevertheless, the results of investigations are controversial.[11-15] Gundogdu et al[14] and Akin et al[11] reported that roughening the acrylic resin with airborne particle abrasion with 50-μm alumina



Figs 1A to D: Scanning electron microscope image (2000× magnification) of surface-treated acrylic resins before bonding: (A) Control, (B) airborne particle abraded, (C) treated with laser, and (D) treated with air abrasion+ laser

particles resulted in lower bond strength compared to control specimens. Similar findings were reported by Atsü and Keskın,[16] who found that airborne abrasion with 50-µm alumina and 30-µm silica-coated alumina particles did not improve the bond strength of resilient lining material to denture base resin. It has been proposed that the weakening effect of airborne abrasion on the bond strength might be due to stresses that are produced at the acrylic resin resilient liner interface or to insufficient size of irregularities created by airborne abrasion to allow penetration of material into them. In contrast, Storer[12] reported that airborne particle abrasion of the acrylic resin denture surface improved the bond strength of the resilient lining materials. In addition, Usumez et al[15] reported that airborne particle abrasion of the acrylic resin with 250-µm alumina resulted in higher bond strength compared with the control group, although this increase was not statistically significant.

According to the results of this study, the airborne-abraded group exhibited significantly higher bond strength than the control group. This finding contradicted the results of Gundogdu et al[14] and Akin et al,[11] but was consistent with the results of Storer[12] and Usumez et al.[15] The enhanced bond strength achieved in this study could be attributed to larger size of alumina particles (110 µm) that created larger pits and depressions, thereby the resilient lining material could penetrate into them more easily.

The presence of definite cavities on surfaces hit by aluminum oxide particles indicated this. On the contrary, these larger particles are more easily removed from the surface of the liner and the acrylic resin, leaving fewer residual particles that exhibit less interference with the bonding procedure compared with smaller particles.

Recently, laser beams have attracted attention as an alternative technique for the preparation of the surface of the acrylic resin before placement of the soft liner. High-energy laser beams give rise to instant evaporation of water along with widespread volumetric expansion, ablating the surrounding materials and increasing the surface area.[11] Therefore, the elastic liner can penetrate into the created irregularities or spaces, increasing the bond strength. This is confirmed by the presence of trabecular pattern on SEM photomicrographs.

Usumez et al[15] found that Nd:YAG laser treatment of polymethyl methacrylate (PMMA) increased the surface roughness, and irradiated specimens exhibited higher bond strength to resilient lining material, although the difference was not statistically significant. Korkmaz et al[21] compared the effect of erbium, chromium-doped yttrium, scandium, gallium and garnet (Er, Cr:YSGG) laser treatment with different parameters and concluded that laser pretreatment at 3 W, 20 Hz increased the peel bond strength of a silicone-based liner (Molloplast B) to the acrylic denture base resin.

In the present study, altering the surface of the PMMA resin by Er:YAG laser irradiation before application of resilient material resulted in higher tensile strength values than those of the control group. This finding is consistent with the results of Akin et al,[11] who found that Er:YAG laser treatment at 200 mJ, 10 Hz, and 2 W for 20 seconds increased the tensile strength between the resilient liner and denture base resin. However, Nd:YAG and potassium titanyl phosphate lasers were ineffective. In another study, Akin et al[18] reported that surface treatment of light-polymerized urethane dimethacrylate base resin by Er:YAG laser irradiation at 300 mJ, 3 W and pulse duration of 700 µm significantly increased the bond strength to silicone-based soft liner. However, Gundogdu et al[14] reported that surface treatment with Er:YAG laser at 150 mJ and 100 µm was ineffective in increasing the bond strength of PMMA to autopolymerized and heat-polymerized silicone-based resilient liners.

Tugut et al showed that preparation of the acrylic resin surface with laser beams at 3 W, 10 Hz, and 300 mJ created small pits on the surface of the acrylic resin the liner can penetrate into, increasing the bond strength. However, Er:YAG laser at 4 W and 400 mJ produced cavities instead of pits, decreasing the bond strength.[17]

In the present study, Er:YAG laser beams were used with the same parameter as given by Tugut et al.[17] However, higher bond strength values were achieved compared with those reported by Tugut et al (1.23 *vs* 0.98 MPa). One of the factors that might affect the outcomes in the laser group in different studies is the rate of scanning of the laser tip and the distance of the tip to the surface. The scan rate can result in different cavities on surface of acrylic resin. Use of laser in the focus or defocus mode can also affect the ability to create pits by the laser beams.

In the present study, there were no significant differences in mean tensile strength values among surface-treated groups, either before or after thermocycling. However, following thermocycling, the least adhesive failure was observed in the laser treatment groups (laser and air abrasion + laser). These findings indicate that surface treatment with laser can be an effective technique in increasing the bond strength of liner to acrylic resin.

The results of this study indicated that the tensile strength of studied groups significantly decreased after 5,000 thermocycles. Thus, the second hypothesis that the bond strength between resilient liner and surface-treated denture base resin changes after thermocycling was also accepted. This finding is consistent with those of a study by Elias et al,[24] demonstrating a reduction in bond strength values of silicone-based liners after 3000 thermocycles, whereas all the materials tested had higher bond strength than those considered acceptable for clinical use. Kulak-Ozkan et al evaluated the bond strength of six silicone-based soft denture liners after 5,000 thermocycles and reported a significant decrease in bond strength values for all the materials tested expect Ufigel C and Mollosil. However, all the materials tested still exhibited sufficient bond strength for clinical application after thermocycling.[24] In contrast, Pinto et al[26] reported that thermocycling had no effect on bond strength of silicone-based resilient lining material to denture base resin after 4,000 cycles, but affected the bond strength of acrylic resin-based resilient liner.

Craig and Gibbons[19] claimed that an adequate bond strength value for a resilient liner is 0.44 MPa. However, Kawano et al[27] suggested that the bond strength value should be at least 96 MPa to achieve acceptable clinical results. In this study, the bond strength values for all the groups significantly decreased after thermocycling, but they were still higher than 96 MPa, which is the clinically acceptable bond strength level.

One of the advantages of the present study, compared with similar studies, was the concomitant evaluation of the effects of different surface treatments and thermocycling on the bond strength of soft liner to acrylic resin. One of the limitations of the present study was the fact that only one type of resilient lining materials (silicone-based) and one type of denture base material (heat-polymerized) were tested. Although such *in vitro* study could be helpful to predict the outcomes of clinical application, further *in vivo* longitudinal investigations are recommended to demonstrate the effects of the tested pretreatments on bond strength of resilient lining materials to acrylic resin denture base.

CONCLUSION

Within the limitations of this study, the following conclusions were drawn:

- Altering the surface of the acrylic denture base resin with air abrasion, laser, and air abrasion + laser increased the tensile bond strength between silicone-based resilient liner and acrylic denture base resin.
- Thermocycling resulted in a decrease in bond strength of silicone-based liner to surface-treated acrylic denture base resin.

CLINICAL SIGNIFICANCE

Pretreatment of denture base resins before applying the soft liner materials improved the bond strength. However, thermocycling results in decrease in bond strength of soft denture liner to surface-treated acrylic resin.

REFERENCES

1. Dayrell A, Takahashi J, Valverde G, Consani R, Ambrosano G, Mesquita M. Effect of sealer coating on mechanical and physical properties of permanent soft lining materials. Gerodontology 2012 Jun;29(2):e401-e407.
2. Polyzois GL, Frangou MJ. Influence of curing method, sealer, and water storage on the hardness of a soft lining material over time. J Prosthodont 2001 Mar;10(1):42-45.
3. Botega DM, Sanchez JL, Mesquita MF, Henriques GE, Consani RL. Effects of thermocycling on the tensile bond strength of three permanent soft denture liners. J Prosthodont 2008 Oct;17(7):550-554.
4. Machado AL, Breeding LC, Puckett AD. Effect of microwave disinfection on the hardness and adhesion of two resilient liners. J Prosthet Dent 2005 Aug;94(2):183-189.
5. Wagner WC, Kawano F, Dootz ER, Koran A 3rd. Dynamic viscoelastic properties of processed soft denture liners: Part I—initial properties. J Prosthet Dent 1995 May;73(5):471-477.
6. Jepson NJ, McCabe JF, Storer R. Evaluation of the viscoelastic properties of denture soft lining materials. J Dent 1993 Jun;21(3):163-170.
7. McCabe JF, Carrick TE, Kamohara H. Adhesive bond strength and compliance for denture soft lining materials. Biomaterials 2002 Mar;23(5):1347-1352.
8. Braden M, Wright PS, Parker S. Soft lining materials—a review. Eur J Prosthodont Restor Dent 1995 Jun;3(4):163-174.
9. Skupien JA, Valentini F, Boscato N, Pereira-Cenci T. Prevention and treatment of Candida colonization on denture liners: a systematic review. J Prosthet Dent 2013 Nov;110(5):356-362.
10. 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 Feb;99(2):153-159.
11. Akin H, Tugut F, Mutaf B, Akin G, Ozdemir AK. Effect of different surface treatments on tensile bond strength of silicone-based soft denture liner. Lasers Med Sci 2011 Nov;26(6):783-788.
12. Storer R. Resilient denture base materials. Part 1, introduction and laboratory evaluation. Br Dent J 1962;113:195-203.
13. Amin WM, Fletcher AM, Ritchie GM. The nature of the interface between polymethyl methacrylate denture base materials and soft lining materials. J Dent 1981 Dec;9(4):336-346.
14. Gundogdu M, Yesil Duymus Z, Alkurt M. Effect of surface treatments on the bond strength of soft denture lining materials to an acrylic resin denture base. J Prosthet Dent 2014 Oct;112(4):964-971.
15. Usumez A, Inan O, Aykent F. Bond strength of a silicone lining material to alumina-abraded and lased denture resin. J Biomed Mater Res B Appl Biomater 2004 Oct;71(1):196-200.
16. Atsü S, Keskın Y. Effect of silica coating and silane surface treatment on the bond strength of soft denture liner to denture base material. J Appl Oral Sci 2013 Jul-Aug;21(4):300-306.
17. Tugut F, Akin H, Mutaf B, Akin GE, Ozdemir AK. Strength of the bond between a silicone lining material and denture resin after Er:YAG laser treatments with different pulse durations and levels of energy. Lasers Med Sci 2012 Mar;27(2):281-285.
18. Akin H, Tugut F, Guney U, Kirmali O, Akar T. Tensile bond strength of silicone-based soft denture liner to two chemically different denture base resins after various surface treatments. Lasers Med Sci 201 Jan 3;28(1):119-123.
19. Craig RG, Gibbons P. Properties of resilient denture liners. J Am Dent Assoc 1961 Sep;63:382-390.
20. Madani AS, Astaneh PA, Nakhaei M, Bagheri HG, Moosavi H, Alavi S, Najjaran NT. Effectiveness of silica-lasing method on the bond strength of composite resin repair to Ni-Cr alloy. J Prosthodont 2015 Apr;24(3):225-232.
21. Korkmaz FM, Bagis B, Ozcan M, Durkan R, Turgut S, Ates SM. Peel strength of denture liner to PMMA and polyamide: laser versus air-abrasion. J Adv Prosthodont 2013 Aug;5(3):287-295.
22. 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 Mar;89(3):303-310.
23. 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 Feb;99(2):153-159.
24. Elias CN, Henriques FQ. Effect of thermocycling on the tensile and shear bond strengths of three soft liners to a denture base resin. J Appl Oral Sci 2007 Feb;15(1):18-23.
25. Sertgöz A, Kulak Y, Gedik H, Taskonak B. The effect of thermocycling on peel strength of six soft lining materials. J Oral Rehabil 2002 Jun;29(6):583-587.
26. Pinto JR, Mesquita MF, Henriques GE, de Arruda Nóbilo MA. Effect of thermocycling on bond strength and elasticity of 4 long-term soft denture liners. J Prosthet Dent 2002 Nov;88(5):516-521.
27. Kawano F, Dootz ER, Koran A 3rd, Craig RG. Comparison of bond strength of six soft denture liners to denture base resin. J Prosthet Dent 1992 Aug;68(2):368-371.