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Evaluation of Different Improvement Methods of Bonding Between The Denture Base and Silicone-Based Liner

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ABSTRACT

STATEMENT OF PROBLEM: Failure of the bond between the acrylic resin and silicone based liner material is commonly encountered in clinical practice.

PURPOSE: Examine effect of different treatment methods on the tensile bond strength between a silicone –based liner and denture base before and after the thermocycling.

MATERIAL AND METHODS: 140 test samples were fabricated. The samples were divided into 14 groups (n=10), according to the treatments applied. To enhance the bonding capacity between these materials, acrylic resin surface was modified using acetone, methyl methacrylate(MMA),isobutylmethacrylate(IBMA), 2-hydroxyethylmethacrylate (2-HEMA), sandblasted with110 µm aluminum oxide particles (110 µmAL$_2$O$_3$) and combination between sandblasting and each of these chemical material individually while in the group 11 ,silicone based liner was immersed in IBMA but in the group 12, acrylic resin surface was modified using sandblasting and a silicone based liner was immersed in IBMA .in addition ,in the group 13; silicone based liner was immersed in 2-HEMA and Group 14, acrylic resin surface was modified using Sandblasting and silicone based liner was immersed in2-HEMA. Silicone based liner was processed between 2 PMMA blocks. In each group, five samples were thermo cycled in water bath (5-55˚C) 500 cycles before tensile testing, whereas the other five were directly tested without thermocycling using Instron testing machine with speed rate (1 mm/minute) to measure tensile bond strength by MPa. All data were statistically analyzed by One way ANOVA, Tukey post hoc test and Paired sample t-test.

RESULTS: There was no statistically significant difference between all tested groups where (p=0.154) before thermocycling while after the thermocycling, there was a statistically significant difference between all tested groups where (p=0.001) but there was no a statistically significant difference between control and all other tested groups. Furthermore, there was no statistically significant difference between before and after thermocycling in each group except group 9.

CONCLUSIONS: The different treatment methods had poor effect on the tensile bond strength. Thermocycling had poor effect on the tensile bond strength between a silicone –based liner and denture base except group9 (acrylic resin surface was modified using sandblasting followed by IBMA application).

KEYWORDS

Bonding, Denture Base, Silicone -Based Liner,

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INTRODUCTION

Denture relining is defined as the procedures used to resurface the intaglio of a removable dental prosthesis with new base material thus producing an accurate to the denture foundation area [1] .

The reline materials are classified into three groups: Hard reline materials, soft lining materials and tissue conditioning materials[2] .

Soft liner have wide application due to curing effect on inflamed mucosa, functional force distribution on denture base, further retention, denture's compliance improvement and helping patients tolerate hard denture bases[3].

There are 2 types of resilient lining materials: plasticized acrylic resins and silicone elastomers. Acrylic resin-based liners contain plasticizers which are responsible for material softness; leaching of these plasticizers results in hardening of the liner with time. Silicone-based soft denture liners do not require an external plasticizer and inherently soft over a long period. Furthermore, both autopolymerizing and heat-polymerizing forms of liners is available. Silicone-based soft denture liners are dimethylsiloxane polymers. Polymethyl methacrylate (PMMA) denture base resins and silicone-based lining materials have different molecular structures and they cannot be chemically bonded [4].

The chemical etching of the surface of PMMA with MMA[5-9] and acetone[5, 8] are used to increase the bond strength .roughing of the surface of PMMA with aluminum abrasion are used to improve the bond strength[9-12]. 2- Hydroxyl ethyle methacrylate (HEMA) and isobutyle methacrylate (iBMA) improve strength of the bond between Silicone-based denture liners and PMMA[4].

In the oral cavity, liner denture base resin interface subjected to thermal stress. It has been found that the bonding between resilient liner and denture liner were affected by thermo cycling[3,13,14].

Tensile bond strength tests are widely accepted to determine the bond strength of the lining to the acrylic base [15, 16].

So, in this study the tensile bond strength was used to evaluate bond strength of the silicone based liner to PMMA denture base resin after different treatment methods before and after thermocycling.

MATERIAL AND METHODS

For tensile bond strength testing of specimens, gypsum molds were prepared with dumbbell-shaped metal patterns, 75 mm in length, 12 mm in diameter at the thickest section and 7 mm at the thinnest section. The heat-cured specimens were prepared in the molds in denture flasks and were cured in a manner similar to that used in conventional denture construction according to the manufacturer's instructions. The specimens were deflasked, trimmed and polished; (140 tests specimens were prepared). Then, 3 mm of the specimen were cut from the thin midsection of each specimen. The three millimeter was marked on the specimen .after that the acrylic specimens were cut in middle of 3mm (center of the specimens) by hard metal disk. The periphery of both side of the fracture surface was reduced until the marked lines by using acrylic burs.

Group 1 — untreated (control): No treatment was applied to bonding surfaces of the acrylic resin specimen, this group served as a control group.

Group 2: bonding surfaces of the acrylic resin specimens were treated with acetone by scrubbing the testing area with a cotton tipped applicator saturated with pure acetone and then by dipping it in acetone for 30 seconds and it was left to dry for 2 minutes after surface pretreatment. Soft liner was then applied.

Group 3: bonding surfaces of the acrylic resin specimens were treated with methyl methacrylate by scrubbing the testing area with cotton tipped applicator saturated with liquid methyl methacrylat monomer and then the testing surface was dipped in methyl methacrylat solution for 180 seconds and specimens were left to dry for 2 minutes after surface pretreatment . Soft liner was then applied.

Group 4: bonding surfaces of the acrylic resin specimens were treated with isobutyl methacrylate by scrubbing the testing area with a cotton tipped applicator saturated with liquid isobutyl methacrylat monomer and then the testing surface was dipped in isobutyl methacrylate solution for 180 seconds and specimens were left to dry for 2 minutes after surface pretreatment for 180sec.

Group 5: bonding surfaces of the acrylic resin specimens were treated with 2- hydroxyethyl methacrylate by scrubbing the testing area with a cotton tipped applicator saturated with 2- hydroxyethyl methacrylate monomer and then the testing surface was dipped in 2-hydroxyethyl methacrylate solution for 180 seconds and specimens were left to dry for 2 minutes after surface pretreatment.

Group 6: Bonding surfaces of specimens were sandblasted with aluminum oxide particles (110 µm Al_2O_3) at 2 bars for 10s. Specimens were mounted in a special holder at a distance of 10 mm between the surface of the specimen and the blasting tip. After being sandblasted, the specimens were washed with ultrasonic cleaner and dried to remove any remaining on the prepared surface then dried to remove the remnants**.**

Group 7: Specimens were treated by sandblasting as group 6 then acetone treatment as group 2.

Group8: Specimens were treated by sandblasting as group6 then MMA monomer as group 3.

Group9: Specimens were treated by sandblasting as group 6 then IBMA monomer as group 4.

Group10: Specimens were treated by-sandblasting as group 6 then 2- HEMA as group 5.

After the treatments, a silicone based liner packed into the 3mm space between two parts of acrylic specimen then the liner was polymerized according to manufacturer's instructions.

In each group, half of the specimens were tested after 500 thermocycles in water bath (5°C-55°C) before testing of tensile strength and the other half were tested without thermo cycling.

All samples were individually mounted on a computer controlled materials testing machine (Model 3345; Instron Industrial Products, Norwood, A, USA) with a load cell of 5 kN and data were recorded using computer software (Instron® Bluehill Lite Software). Bond test was done by tensile mode of load applied at cross-head speed of 1mm/min via testing machine. The load at failure manifested by a sharp drop at load-deflection curve recorded using computer software (Bluehill Lite Software Instron® Instruments) the load required to fracture was recorded in (Newton). In order to calculate the bond strength in MPa the load at failure was divided by interfacial bonding area. The mean and standard deviation values were calculated for each group in each test. Paired sample (t-test) was used to compare between two groups in related samples. One way (ANOVA) followed by (Tukey post hoc) test was used to compare between more than two groups in non-related samples. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

RESULTS

Results of this study were shown in table (1).

Table (1) *Comparison of tensile bond strength results (Mean values±SD) for control and tested groups:*

Variable	Without thermocycling		thermocycling		t-test
	Mean Value	SD	Mean Value	SD	p-value
GR-1	1.427	0.178	1.67	0.359	0.263 ns
GR-2	1.394	0.339	1.387	0.1	0.965 ns
GR-3	1.639	0.248	2.166	0.449	0.094 ns
GR-4	1.65	0.429	1.805	0.428	0.598 ns
GR-5	1.857	0.308	1.874	0.213	0.905 ns
GR-6	1.807	0.624	1.789	0.54	0.962 ns
GR-7	1.405	0 .318	1.514	0.44	0.722 ns
GR-8	1.737	0.378	2.139	0.3	0.084 ns
GR-9	2.016	0.503	1.068	0.232	0.023*
GR-10	1.951	0.487	1.77	0.297	0.516 ns
GR-11	1.497	0.421	1.879	0.409	0.249 ns
GR-12	1.389	0.324	1.673	0.373	0.280 ns
GR-13	1.564	0.338	1.675	0.204	0.653 ns
GR-14	1.671	0.267	1.651	0.184	0.871 ns
ANOVA	0.154 ns		0.001*		

**; significant (p<0.05) ns; non-significant (p>0.05).*

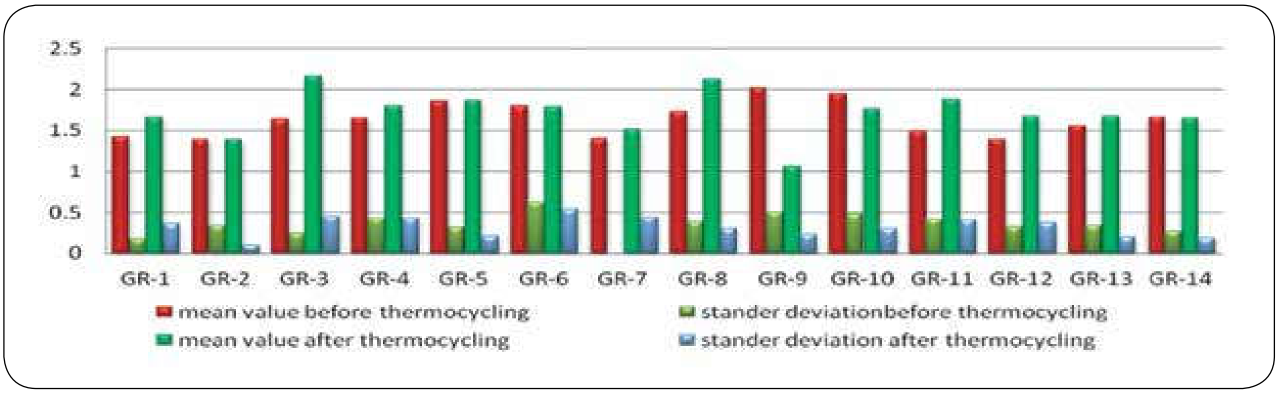

Fig. (1) Tensile bond strength mean value (MPa)and stander deviation of tested groups before and after thermocycling.

DISCUSSION

Failure of adhesion between soft liner and the denture base is considered the most common reason of failure of soft-liner dentures(17). The specimens in this study were based on design described by Akın, Hakan, et al.(18, 19) and Bolayir, G., et al.(20) Thickness of soft denture lining material should be 2–3 mm thick to acquire the best benefit in softness(21, 22).

In the present study, surface treatment by acetone decreased tensile bond strength. This is due to surface treatment with acetone which produce smooth and clear surface with few fissure(23).this decrease in tensile bond strength was statistically insignificant . Acetone is a good solvent for PMMA (24)and the reduction in bond strength may be due to residual acetone trapped between PMMA chains(25). results from surface treatment by acetone is in agreement with the study of Maheshwari R et al (26). In addition, this results is disagreement with the studies of Zhang Y et al. (8), Philip JM etal (27) and Surapaneni H et al (28) .

In the present study, surface treatment by MMA increase the bond strength between silicone liner and PMMA. This increase in tensile bond strength was statistically insignificant. This increase in tensile bond strength may be due to monomer provided additional etching and increased the surface area by creating micro voids, thus increasing the surface area available for the liner to bond with the resin(27); this result is in agreement with the studies of Kulkarni RS et al.(7), Zhang Y et al. (8), Kaur H et al.(6), Khanna A et al.(9), Surapaneni H et al(28)and Jaffer NT et al.(29). In addition , this result is in disagreement with the study of Maheshwari R et al.(26).

In the present study, surface treatment by IBMA increasing the bond strength between silicone liner and PMMA. This increase in tensile bond strength was statistically insignificant. So, this result of the present study were consistent with that of Akin H et al.(4) and Leles C et al. (25). In addition, this result is disagreement with the study of Bolayir G et al. (20).

In the present study, surface treatment by2-HEMA increasing bond strength between silicone liner and PMMA. This improvement in tensile bond strength was statistically insignificant. Akin H et al. reported that immersion of resilient lining materials into 2-HEMA is an effective method to improve strength of the bond between silicone based liners and PMMA(4). In addition, several studies used 2-Hydroxyethyl methacrylate. Vargün E et al. researched on PMMA copolymerized with 2-HEMA and reported that glass transition temperatures of copolymers were decreased from 119°C to 100°C with an increasing amount of 2- HEMA and The Tg of PMMA is lowered by copolymerization with HEMA, which may ease the processing conditions(30). Keyf F et al. reported that surface treatment process of glass fiber with 2-HEMA monomer and air atmosphere increased the transverse strength and the maximal deflection of provisional fixed partial denture resin[31]. The results of the present study were consistent with that of Akin H et al. [4], Vargün E et al. [30] and Keyf F et al. [31]. This increase in tensile bond strength after surface treatment with2- HEMA and iso-butyl methacrylate due to that, the molecules in the PMMA and chemical materials interacted with each other. Methacrylate substances with high numbers of alkyl groups could interact with C-H groups and form hydrogen bonds. Moreover, application of chemical agents possessing solvent effects on the acrylic resin can cause the formation of roughened surfaces, and this in turn, positively affects the strength of the bond [4].

In the present study, surface treatment specimens pre-treated with air-borne particle abrasion (110μ alumina particles), exhibited insignificant increase in the bond strength compared to the control group. Sandblasting has been used to alter the surface of the PMMA with the intention of providing increased surface area and mechanical locks[19].

The results of the present study were coincided with that of Usumez A et al. [10] and Khanna A et al.[9], Philip JM etal.[27]. In addition, this result is disagreement with the studies of Akin H et al.[19], Kulkarni RS et al.[7] , Atsu S et al.[32], Surapaneni H et al.[28] and Maheshwari R et al. [26].

In the present study, surface treatment by sandblasting of acrylic specimens followed by acetone surface treatment recorded 1.41MPa. In addition, sandblasting of acrylic specimens only recorded 1.81 MPa. The combination is lower tensile bond strength than sandblasting surface treatment only .this is due to surface treatment with acetone produce smooth and clear surface[23].

In the present study, surface treatment by MMA only recorded1.64 MPa but sandblasting of acrylic specimens followed by MMA surface treatment 1.74 MPa. This increase in tensile bond strength is due to that, the Sandblasting caused micro voids and monomer acted as a superficial solvent of the PMMA resin, which enhanced bond strength[27]. This is in accordance with a study conducted by Philip JM etal. [27] on the polyvinyl acetate denture liner.

In the present study, surface treatment by IBMA recorded 1.65 MPa but sandblasting of acrylic specimens followed by Isobutyl methacrylate surface treatment recorded 2.02 MPa. This increase in tensile bond strength is statistically insignificant. In addition, sandblasting of acrylic specimens only 1.80 MPa. So, the combination between the two treatment methods is better than treatment individually.

In the present study, surface treatment by 2-HEMA recorded 1.86MPa but sandblasting of acrylic specimens followed by 2-HEMA surface treatment recorded 1.95 MPa. This increase in tensile bond strength is statistically insignificant. In addition, sandblasting of acrylic specimen only recorded 1.81 MPa. So, the combination between the two treatment methods is better than treatment individually.

In this study, it was found that immersion of silicone based liner into IBMA recorded 1.50 MPa. So, immersion of resilient lining materials into IBMA increase tensile bond strength. While the combination between immersion of resilient lining materials into IBMA and sandblasting of acrylic specimens recorded 1.39 MPa. So, the combination decreases tensile bond strength. Sandblasting only is better than that immersion of silicone based liner into IBMA and the combination between the methods.This decrease in tensile bond strength is statistically insignificant. This decrease is due to stresses that occurred at the interface of the PMMA/resilient liner junction[33] or the size of the irregularities created by airborne-particle abrasion medium not be sufficient to allow the resilient lining material to flow into it[34] due to exaggerated solvent effects of IBMA on the acrylic resin [4]. Akin H et al. reported that immersion of resilient lining materials into IBMA for 3minute is an effective method to improve strength of the bond between silicone based liners and PMMA(4). So, This result is in agreement with the studies of Akin H et al. (4). But Akin H et al(4) did not carried out the combination between immersion of resilient lining materials into IBMA and sandblasting of acrylic specimens in the study.

From the present study, it is observed that immersion of silicone based liner into IBMA affect the color and resilience of silicone based liner.

In this study, it was found that immersion of silicone liner materials into 2-HEMA recorded 1.56MPa while the combination between immersion of resilient lining materials into2- HEMA and sandblasting of acrylic specimens recorded 1.67 MPa, so the combination is better than immersion of resilient lining materials into 2-HEMA only. Moreover sandblasting (1.81 MPa) only is better than that immersion of silicone based liner into2-HEMA and the combination between the methods. In addition , 2-HEMA surface treatment(1.86MPa) is better than the combination between immersion of resilient lining materials into2- HEMA and sandblasting of acrylic specimens (1.67 MPa) and the combination between 2-HEMA surface treatment and sandblasting of acrylic specimens(1.95 MPa) is better than 2-HEMA surface treatment only. Akin H et al. reported that immersion of resilient lining materials into 2-HEMA for 3 minutes is an effective method to improve strength of the bond between silicone based liners and PMMA(4). So, This result is in agreement with the study of Akin H et al.(4) But Akin H et al.(4)did not carried out the combination between immersion of resilient lining materials into 2-HEMA and sandblasting of acrylic specimens in the study.

Thermocycling is a common way to more closely simulate the oral condition(32). During eating and drinking the dentures are exposed to thermal cycles ;so measuring the bond strength after thermocycling can provide more information about the aging process(3).

In the present study, the samples prepared for thermo cycling were thermocycled for 500 cycles with temperatures from 5˚C to 55˚C and as the previous study conducted by Khanna A et al(9) .

There is a lot of controversy over the effect of thermocycling on the bond strength of soft liners; therefore, the bond strength may (increase, decrease or not affected). In several studies about the effect of accelerated aging by thermocycling on the bond strength of soft liners, the results were different. This could be due to the bond strength between the acrylic resin and the soft lining material type, sample shape, number of cycles, thermocycling temperature, type of test and/or speed of force application(3).

Results of the present study showed that the tensile bond strength increase after thermo cycling in groups 1, 3, 4, 5, 7, 8, 11, 12 and 13but this result was statistically insignificant. Moreover, tensile bond strength decrease after thermo cycling in groups 2, 6, 9, 10 and 14. This decrease was statistically insignificant except in group 9. The increase in bond strengths may be due to the continued cross-linking process and the decrease in bond strengths may be due to the swelling and altered stiffness of the lining material and the formation of fissures and internal stress at the lining-denture interface(15).

The tensile bond strength increase after thermo cycling in some groups and decrease after thermo cycling in other groups. This may be due to different treatment methods although silicone was used in all experimental groups.

Kulak-Ozkan Y et al. reported that the bond strength of the Permaflex decreased significantly after thermocycling (5000 cycles) between baths of 5˚C and 55˚C (35). This coming with disagreement of the present study which shows increasing of the tensile bond strength of permaflex after thermocycling (500 cycles) between baths of 5˚C and 55˚C . This increase of the bond strength was statistically insignificant. In addition, the difference between result of Kulak et al. (35) on permaflex and the present study may be due to number of cycle, sample shape and force of speed.

CONCLUSIONS

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

1. Before the thermo cycling, all experimental groups are increased in the tensile bond strength except group (2), group (7) and group (12) that recorded lower tensile bond strength as compared to control. The decrease or increase in the tensile bond strength was statistically insignificant.
2. After the thermo cycling, the tensile bond strength increased in groups 1, 3, 4, 5, 7, 8, 11, 12 and 13but this result was statistically insignificant. Moreover, tensile bond strength decrease after thermo cycling in groups 2, 6, 9,10and 14. This decrease was statistically insignificant except group (9).
3. The silicone-based liner had acceptable bond strength for clinical application after different treatment methods before and after the thermocycling.
4. Thermocycling is considered as aging process. So; MMA surface treatment is the best treatment method.

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