ORIGINAL ARTICLE

The Effect of Various Surface Treatment on the New Digitally Manufactured Materials Versus the Conventional Materials – *In Vitro* Study

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Abstract

Background: Clinical benefits of resilient denture liners have been recognized in prosthodontic practice for many years. The elastic behavior of the soft lining materials is designed to distribute functional and non-functional stress on denture-supporting tissues. **Materials and Methods:** A total of 30 dumbbell-shaped test specimens were prepared from two different heat cure denture base materials. They are divided into two groups. Group (A) was prepared from heat cure poly-methylmethacrylate resin (PMMA) and Group (B) was prepared from computer-aided design and computer-aided manufacturing (CAD/CAM) acrylic resin denture base material. A temporary soft-liner type was used. The denture base specimens of (Group A and Group B) were subdivided equally into three subgroups. 3 mm was marked and sectioned on the specimens with fissure burs and removed to create a uniform space for the application of soft liner. The interface surface of each specimen and the denture base resin surface were conditioned by three surface treatment modalities: 1 – specimens were polished using silicone carbide papers of grit size, 2 – using air abrasion by 50 µm aluminum oxide particle, 3 – by application of 3 M Scotchbond dental adhesive. Tensile bond strength (TBS) was tested for the specimens of each subgroup after thermocycling. **Results:** The mean of TBS of subgroup (A3) and subgroup (B3) specimens treated with 3M Scotch bond was significantly higher than the other subgroups. **Conclusion:** The surface treatment of PMMA and CAD/CAM denture base specimens with primer followed using an adhesive bond of 3M Scotch bond had an effective and superior TBS.

Key words: Dental biomaterial, modern denture base resin, prosthetic material, resilient soft-liner material, restorative material, surface treatment, tensile bond strength

INTRODUCTION

The use of removable dentures for a long time causes changes in the supporting structures, such as pain and discomfort, and is subsequently followed by resorption of the edentulous alveolar ridge, which leads to the formation of a sharp and thin alveolar ridge that causes severe problems for the patient. These problems result from the transmission of occlusal forces by denture bases on the denture-bearing area. The clinical benefit of resilient denture liners has been recognized in prosthodontic practice for many years. They act as stress absorbers, enabling uniform distribution of pressure on denture-bearing tissues and reducing the discomfort of sharp severely absorbed alveolar ridges and sensitive mucosa.[1]

Conventional heat-cured poly methyl methacrylate (PMMA) resins are the most commonly used denture bases in removable prostheses as they have fracture toughness and rigidity.[2] Despite the improvement in the physical properties of PMMA over the years, they were subjected to certain criticism such as volumetric shrinkage, the presence of residual methylmethacrylate monomer, and the tendency to absorb water. PMMA denture base takes up saliva and

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water, which move slowly into tiny holes inside the denture prompting a reduction in the mechanical properties of the material.

Recently with the progress of technology; computer-aided design and computer-aided manufacturing (CAD/CAM) was successfully employed broadly in dentistry. CAD/CAM systems have become commercially available for the fabrication of complete dentures and are considered another technique to conventionally process acrylic resin bases. CAD/CAM dentures fabricated by milling of denture base from prepolymerized acrylic resin block. The fabrication of the denture base by CAD/CAM provides superior fit and strength when compared to conventionally processed bases.[3-5]

Elastic behavior of the soft lining materials is designed to distribute functional and non-functional stress to have a dampening effect on denture-supporting tissues which are confined between the hard denture base and the bone and may result in chronic soreness, and pathologic changes.[6,7]

Soft denture liners are classified into two forms acrylic-based soft liners and silicone-based soft liners which are composed of monomers, polymers, and plasticizers that provide softness to the relining material and comfort to the patient. Acrylic-based soft liners are available in autopolymerizing and heat-cured form, they are different in the percentage of plasticizers cross-linking agents, catalysts, and fillers.[6]

The removable denture is relined either by laboratory procedure or at the chairside technique in the dental clinic. The chairside relining procedure with a soft denture liner is used extensively in prosthodontics clinics because it is a simple technique and allows a good fit of the prosthesis.[8]

Autopolymerized soft liners are used for a short period (up to several weeks) to improve the comfort and fit of an old denture unit; it can be permanently relined. Laboratory-processed heat-cured soft liners are used with patients who experience chronic soreness with their dentures because of heavy bruxism or poor health. Heat-cured silicone soft liners are expected to be used for extended service periods, and during its service life, need to be exposed to disinfectants several times and this may adversely affect the strength and structure of the denture, as well as the soft liner.[9-12]

When the relined denture is inserted into the oral cavity, plasticizers, and other soluble ingredients are leaching out into the saliva. The relined denture absorbs water and saliva that results in swelling of the denture base and also changes the viscoelastic properties of the resilient liners.[7]

Loss of adhesion between the resilient liners and the denture base as well as water sorption, growth of bacteria, color change, and the decrease of the bond strength are considered a problem observed during clinical use.[13,14] Which requires the replacement of the soft-liner material. This procedure is time-consuming and costly for the dentist and the patient.[6,13-15]

Several authors tried to improve the adhesion bond or the bond strength between the liner and denture base. The authors advised roughing the acrylic denture surface, while others used sandblasting on the acrylic resin surface to provide a slightly irregular surface for mechanical locking of the soft material. Other investigators used other means such as airborne particle abrasion, or laser treatment of the denture base.[16-19]

Therefore, effective bonding is important for the longevity of resilient-lined dentures, by preventing leakage of fluids between the liner and denture base.

Although several studies have assessed the effects of different condition methods on the tensile bond strength (TBS) between autopolymerizing relining resins and PMMA denture base resin but still now limited research has reported about the bond strength between CAD/CAM denture base and resilient liner, there for the purpose of the present study was to investigate the TBS between the relining resin material and polymeric denture base of PMMA and CAD/CAM resin.

MATERIALS AND METHODS

A total number of 30 dumbbell-shaped test specimens with a rectangular area of (10 × 10 × 2.5 mm) were prepared from two different heat cure denture base materials, 15 specimens in each group (Group A and Group B).

Two different heat cure denture base materials were selected in this study as follows:

A – powder/liquid system (Group A): Heat cure PMMA denture base resin (PMMA, Vertex RS Dentimex Netherlands), and, B – CAD/CAM (Group B) denture base resin (Polident d.o.o. Volčja Draga 42, Sl-5293 Volčja Draga, Slovenia).

The temporary autopolymerizing PMMA soft-liner type (Acrostone relining material England) was used in this study.

The denture base specimens of (Group A and Group B) were subdivided equally into three subgroups (A1, A2, A3 and B1, B2, B3) each of five according to the different surface conditioning methods.

Preparation of test specimens [Figure 1]

Group (A): The specimens were prepared from heat cure PMMA using a conventional compression molding technique according to the manufacturer's instructions. The wax specimens of this group were invested in dental stone

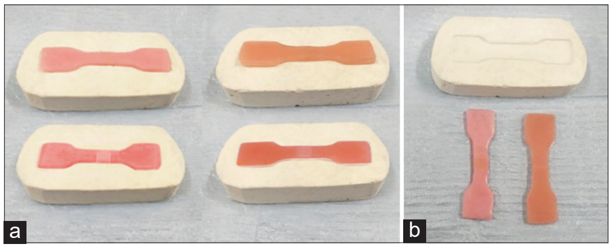

Figure 1: Plaster key for heat cure acrylic resin denture base specimens Group (a) and specimens lined with soft liner and computer-aided design and computer-aided manufacturing denture base resin specimens Group (b) and specimens lined with soft liner

in denture dental processing flask, packing and processing in heat PMMA according to manufacturer's instructions at 75°C for 9 h. After deflasking, the specimens were finished and polished except for the surface that faces the soft-liner material.

Group (B): The specimens were prepared from a pre-polymerized block of CAD/CAM acrylic resin denture base material and cut with a diamond disk (Isomet, Buehler, USA) under water irrigation into quadrilateral samples of dimensions 10 × 10 × 2.5 mm^2.

The denture base specimens of each group were embedded into a plaster key. 3 mm was marked on the specimens and with a fissure burs. Sections of the acrylic resin base specimens were removed to create a uniform space for the application of soft liner.

The interface surface of each specimen and the denture base resin surface to be bonded were conditioned by the following methods:

Subgroup A1, B1: The subgroup specimens were polished with silicone carbide papers of grit sizes of 1000, 1500, and 2000, respectively, for 20 s at 1500 rpm.

Subgroup A2, B2: The subgroup specimens were conditioned with air abrasion by 50 µm aluminum oxide particles (Korox aluminum oxide blasting, Bego Germany) under 0.5 Mpa of pressure for 15 s at 10 mm. Distance away from the outlet of the sandblasting machine (Bego Duostar sandblasting, Germany), then cleaned with water spray and air dried with compressed air.

Subgroup A3, B3: The subgroup specimens were conditioned by the application of one layer of primer (3M Scotchbond Multipurpose plus Dental Adhesive system, 3M Dental Laboratory, USA) using a microbrush on the interface surfaces of each specimen and the denture base resin surface to be bonded and waited for its reaction for 5 min. Then apply the adhesive (3M Scotchbond) to the prepared surfaces and rub it in for 20 s. The adhesive is light-cured for 10 s.

All the specimens of Group A subgroups and Group B subgroups were stored in distilled water at room temperature for 24 h until the application of a soft liner.

Application of soft liner

The auto polymerizing PMMA soft-liner material was mixed and applied into the created space between the conditioned acrylic resin specimens (treated surface) of subgroup (A1, A2, A3, and subgroup B1, B2, B3) using a spatula, and any excess material was removed using a sharp knife and polymerized according to the manufacturer's recommendation.

Thermocycling

The specimens of each subgroup were tested after artificially aged by thermocycling (500 cycles in a water bath (5°c–55°) with a dwell time (immersion time) for 30 s before testing of TBS (20).

Test equipment and procedure

All the specimens of Group (A) subgroups and Group (B) subgroups were subjected to a tensile force at cross-head speed (5 mm/min) using a load cell with maximum load capacity (100 N) until failure in a universal testing machine (Tinius Olsen Ltd, UK) [Figure 2]. Force at failure was recorded in Newton. The value of TBS was calculated and recorded for each test specimen on a computer-controlled software testing machine (Bluehill Instron) [Figure 3] as the force at the de-bonding divided by a cross-section area of interface according to the following formula: S=F/A

Where S (MPa) is the TBS (N/mm^2),

F is the maximum force (N, Newton) and, A is the cross-sectional area (mm^2)

Statistical analysis of the data

The collected data were statistically analyzed using Statistical Packages for the Social Sciences, (version 23.0 software Chicago, IL) to perform the statistical analyses of the data. Descriptive statistics as mean and standard deviation were calculated for each test group. One-way (analysis of variance [ANOVA]) test followed by (Tukey's *post hoc* test) was used to compare the TBS of subgroups. Student's *t*-test was used to compare between Group (A) subgroups and Group (B) subgroups. A significant level was set at $P \leq 0.05$.

RESULTS

Table 1 represents the mean values and standard deviation of the bond strength of the heat cure acrylic resin Group

Table 1: Comparison of the tensile bond strength between different subgroups (A1, A2, and A3)

Tensile bond strength	Subgroup A1 (*n*=5)	Subgroup A2 (*n*=5)	Subgroup A3 (*n*=5)	F	*P*
Mean±SD	0.41±0.02	0.47±0.01	0.67±0.01	579.714*	<0.001*
Sig. bet. groups.	P_1<0.001*	P_3<0.001*	P_2<0.001*		

F: ANOVA test, Pairwise comparison between each two subgroup was done using post hoc test (Tukey's). *P value was considered significant if ≤ 0.05.

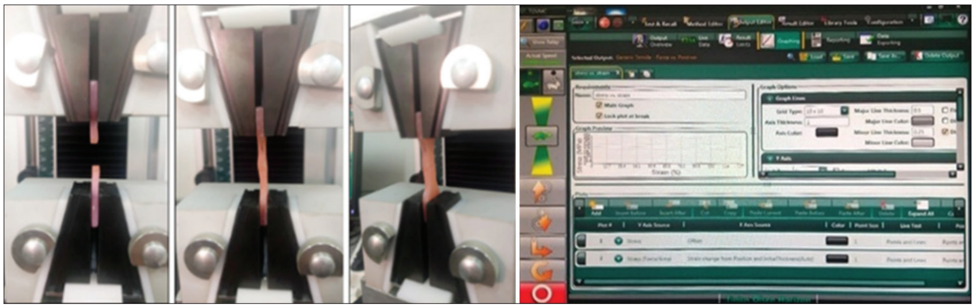

Figure 2: Testing specimens in the universal testing machine with computer software

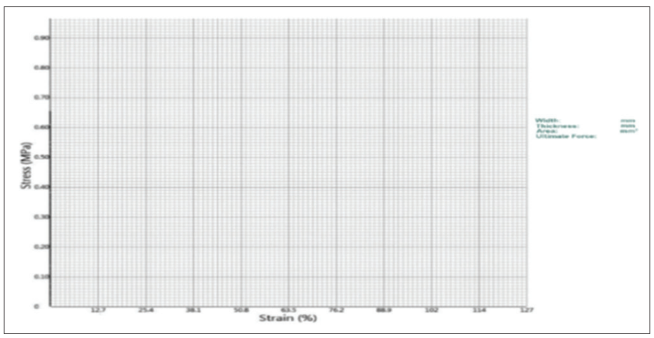

Figure 3: Stress-strain curve showed the value of tensile bond strength

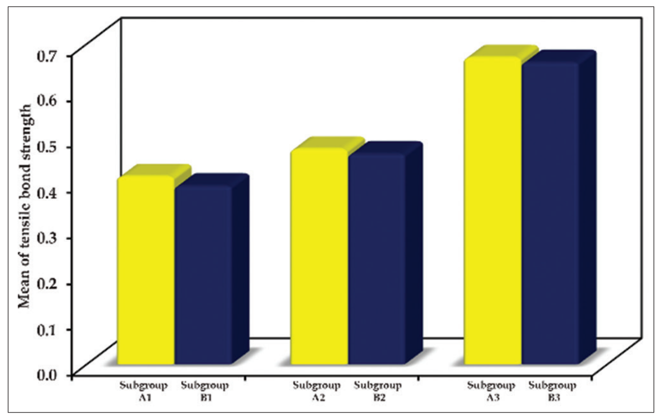

Figure 4: Comparison of tensile bond strength between two different denture base specimens with various surface treatments of subgroup (A) and subgroup (B).

(A) subgroups specimens with soft lining materials. Comparison between the TBS of Group (A) subgroups by one-way ANOVA test revealed a statistically significant difference between (subgroups A1 and A2), (subgroup A2 and A3), and (subgroup A1 and A3) at 5% level ($P < 0.001$, F = 579.714).

Table 2 shows the mean value and standard deviation of CAD/CAM Group (B) subgroups. Comparison between the TBS of CAD/CAM group (B) subgroups with soft lining materials by one-way ANOVA test showed a statistically significant difference between (subgroup B1 and B2), (subgroup B2 and B3), and (subgroup B1 and B3**)** at 5% level ($P < 0.001$, F = 492.862).

Table 3 shows the mean values of the bond strength of the heat cure acrylic resin Group (A) subgroups and CAD/CAM Group (B) subgroups specimens with soft lining materials. Comparisons between each subgroup using Student's *t*-test revealed no statistically significant difference between (subgroup A1 and B1), (subgroup A2 and B2), and (subgroup A3 and B3) [Figure 4].

DISCUSSION

The bond strength between the soft-liner material and denture base is important in the removable prosthesis to avoid the interfacial separation between them. Failure of the adhesion bond between the resilient liner and the denture is considered a clinical problem due to the formation of a gap between them that leads to the accumulation of dental plaque.[20,21]

TBS test is a good measuring method of the bond strength of lining materials because it gives information about the bond strength of the material. Furthermore. It assesses interfacial separation under oral conditions.[14,22]

In the present study, surface treatment of heat cure acrylic resin PMMA (Group A), and CAD/CAM (Group B) specimens were selected to evaluate the adhesion bond between the soft liner and these denture base materials. PMMA is commonly used in removable denture base prostheses in clinical practice

Table 2: Comparison of tensile bond strength between different subgroups (B1, B2, and B3)

Tensile bond strength	Subgroup B1 (*n*=5)	Subgroup B2 (*n*=5)	Subgroup B3 (*n*=5)	F	*P*
Mean±SD	0.39±0.02	0.46±0.01	0.66±0.01	492.862*	<0.001*
Sig. bet. groups.	P_1<0.001* → P_2<0.001*← P_3<0.001*				

F: ANOVA test, Pairwise comparison between each two subgroup was done using *post hoc* Test (Tukey's), *P value was considered significant if ≤ 0.05.

Table 3: Comparison between the tensile bond strength of different subgroups

Statistical parameters	Subgroup A1	Subgroup B1
Mean±SD	0.41±0.02	0.39±0.02
t (P)	1.486 (0.176)	
	Subgroup A2	**Subgroup B2**
Mean±SD	0.47±0.01	0.46±0.01
t (P)	1.549 (0.160)	
	Subgroup A3	**Subgroup B3**
Mean±SD	0.67±0.01	0.66±0.01
t (P)	2.271 (0.053)	

Student *t*-test. *P*: *P*-value for comparing between heat cure acrylic resin Subgroups and CAD/CAM Subgroups

due to its resistance to surface wetting and its low surface energy. Long polymerization of heat cure acrylic denture base (Group A) was used in this study because a lot of residual monomers were lost to the water-immersed mold during the polymerization process.[23] CAD/CAM denture base Group (B) was selected in this study because it is an innovative method for the construction of removable prostheses which are milled from industrially PMMA pucks and considered alternative materials to conventionally processed acrylic resin denture bases. For that reason, CAD/CAM denture base resin was selected to evaluate the bond strength after different surface treatment modalities.[5,24] CAD/CAM is polymerized under high temperature and pressure, so it promotes the formation of longer polymer chains that lead to a higher degree of monomer conversion with lower values of residual monomer.[24]

Acrylic-based auto polymerizing temporary soft denture liners were used in this study due to their better viscoelastic properties which permit improvement to masticatory function and are commonly used in dental clinical practice with the denture base. The thickness of the soft liner was designed as 2.5 mm to obtain the best benefits in the softness which is required for adequately cushioning the hard acrylic base, this temporary soft-liner thickness was consistent with the previous report.[7,25]

The TBS was measured after thermocycling of the specimens since it provides more information about the aging process. Temperatures of 5°C and 55°C were chosen since they are similar to the temperature of food, and drink intake and exposure of the denture to thermal cycles. These temperatures are well tolerated by the oral mucosa without causing any damage to it.[26-28]

Surface treatment of (subgroup A2) and (subgroup B2) with 50 µm aluminum oxide particles with spherical shape for 15 s exhibited a higher bond strength more than subgroup (A1) and subgroup (B1). These results could be due to the method of surface treatment by sandblasting which created a mechanical roughening and irregular porous surface. Furthermore, sandblasting alters the surface of the denture base providing great surface area and mechanical lock as a result of the formation of microvoids on the surface that enhance bond strength, whereas the surface treatment of subgroup A1 and subgroup B1 with silicon carbide paper produced a smooth surface which simulates clinical relief of the denture base for bonding of the reline resins.[6,29-31]

The autopolymerizing soft liners tested in the present study had a satisfactory bond strength to thermocycling heat-cured denture base resin subgroup (A3) and CAD/CAM base resin subgroup (B3), which is significantly higher than the values observed in (A1 and B1) and (A2 and B2). These results may be attributed to the use of a primer of 3M Scotchbond 2-hydroxyethyl methacrylate (HEMA) followed by 3M dental adhesive bonding system. The surface conditioning promoted by the solvent present in the primer composition facilitates the bonding of resin-based soft liner to PMMA acrylic resin as the solvent increases the water wettability and dissolves unattached particles of PMMA acrylic resin. Primer penetrates into tiny irregularities and copolymerizes with other viscous resin to form a strong chemical and micromechanical bond to the denture base.[32] The use of adhesive of 3M Scotch bond (BIS-GMA-HEMA) after using a primer is an effective method to improve the bond strength between the resilient liner and PMMA particles. This result was due to the molecules of PMMA and chemical materials interacting with each other which caused the formation of rough surfaces that affected the bond strength. The adhesive is light-curing for 10 s. Scotchbond adhesive is hydrophilic before light curing. This hydrophilicity allows for the adhesive to properly wet out the surface, while Scotchbond adhesive becomes hydrophobic after light curing. This hydrophobicity decreases water absorption and improves the longevity of bond strength.[6,13,33]

Surface treatment modality of subgroup (A1 and B1), subgroup (A2 and B2), and subgroup (A3 and B3) in the present study revealed no statistically significant difference in TBS between them which may be due to the similar nature between polymeric material of denture base (Group A and Group B) to be bonded to a soft liner. The bonding compatibility of denture base material with soft-liner material is an important factor during studying the strength bond failure. Plasticized PMMA temporary soft liners and PMMA and CAD/CAM denture base materials are similar in chemical structure.[34]

CONCLUSION

Within the limitation of the current study the analysis of the dental biomaterial (acrylic resin of the denture base), it can be concluded that: The surface treatment of the specimens of (subgroup A3) and (subgroup B3) with 3M Scotch bond multipurpose adhesive showed a superior significant bond strength than those obtained by other surface treatment.

The application of primer of 3M Scotch bond followed by the adhesive bond of the dental adhesive system on PMMA and CAD/CAM resin denture base surface specimens was effective and satisfactory in improving the TBS. A better adhesion bond is obtained with the same chemical properties of the soft liner and denture base.

CLINICAL SIGNIFICANCE

It is evident from this study that our results have a clinical significance as it may minimize the time required to make relining of dentures, minimize dentist dependency on laboratory work, and permit chairside relining.

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