EAS Journal of Dentistry and Oral Medicine
Abbreviated Key Title: EAS J Dent Oral Med
ISSN: 2663-1849 (Print) & ISSN: 2663-7324 (Online)
Published By East African Scholars Publisher, Kenya
OPEN ACCESS
Volume-6 | Issue-3 | May-Jun-2024 | DOI:10.36349/easjdom.2024.v06i03.006

Original Research Article

Evaluation of Peel Bond Strength between Heat Cured Acrylic Based Denture Soft Lining Material and Heat Polymerized Acrylic after Different Acrylic Surface Treatment Methods

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Article History
Received: 23.05.2024
Accepted: 30.05.2024
Published: 07.06.2024

Journal homepage:
https://www.easpublisher.com

Quick Response Code

Abstract: ***Background***: In dentures that involve soft liner materials, it is important that the attachment to soft liners is preserved for an extended period to ensure maintenance of prosthetic parts and patient satisfaction. Debonding can be prevented by a variety of acrylic surface treatments to enhance the connection between the different materials. ***Methods***: 30 specimens were fabricated (30 soft-liner specimens bonded to 30 acrylic specimens). All specimens were 75mm x 10mm x 2mm in dimensions. After bonding, 10 specimens were categorized into each group according to each surface treatment. Acrylic bonding surfaces were treated according to each method and a primer was then applied. Soft liner was mixed and poured inside the matrix part of the mold with acrylic specimens. Peel strength test was measured using a universal testing machine. Specimens were categorized according to failure mode into cohesive, adhesive, and mixed failures. ***Results***: homogeneity of variance and One way ANOVA were utilized. Ethyl acetate group with had the highest peel strength values (4.5138) followed by sandblasting group (3.4633) and silicon carbide paper group (2.9082) respectively. ***Conclusions***: Acrylic specimens treated by ethyl acetate solution, sandblasting, and Silicon carbide paper before bonding to soft liners can provide significant increase in peel strength values which can improve the maintenance of prosthetic parts.

Keywords: Peel bond strength, Soft-liners, Ethyl acetate, Sandblasting.

1. INTRODUCTION

Patients who use prostheses with acrylic and soft liner parts may notice debonding which can happen for a number of causes, including saliva, improper use, or the growth of microbes [1]. Additionally, using harsh cleaning methods may damage bonding between the materials thus reducing the lifetime of the denture [2, 3]. Since the soft liner part of the denture prosthesis is attached to the acrylic, it is crucial that the two denture parts have a durable connection to allow the patient in his daily uses of the denture without damaging the adhesion [4]. The soft liner ability to adhere to acrylic resin can lengthen the denture's functional lifespan. This is because different factors affect the soft liner-acrylic interface and the denture's margins. This results in soft liner being torn and separated from the margins.

In order to address the issue of weak bonding strength, the surface of the acrylic resin has been altered before soft liners are applied. The bonding qualities have been examined using a number of criteria. Three widely used methods can be used to check the connection integrity of soft liners to acrylic base resins: tensile, peel, and lap-shear tests [5, 6].

Numerous methods for surface modification have been researched, including chemical agent application, mechanical treatment to roughen the surface, and a combination of chemical and mechanical treatment [7, 8]. The bonding strengths obtained with treated surfaces—whether mechanical or chemical—were found to be almost twice as high as those obtained with smooth surfaces, according Craig and Gibbons' investigation [8]. Sandblasting the acrylic resin surface before adding a soft liner might result in a slightly uneven surface that

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mechanically interlocks with the softer material, strengthening the bond [9].

Pretreating acrylic denture bases with a range of solvents, such as methyl methacrylate, dichloromethane, methylene chloride, and ethyl acetate, has been studied. Using methyl methacrylate monomer for 180 seconds was found to greatly boost the tensile bond strength. However, chemical treatment could lead to a partial dissolution of the denture base resin, which might rupture the material when used in a clinical setting [10]. Sarac (2005) showed that the shear bond of the material was strengthened across all tested denture base resin types by the use of chemical agents such as acetone, methylene chloride, and methyl methacrylate [11].

In 2006, Shimizu came to the conclusion that applying ethyl acetate for 120 seconds resulted in the strongest bond strength because it made the surface expand and allowed the denture base resin to diffuse more easily [12].

2. MATERIALS AND METHODS

2.1 Study Design

Thirty soft liner specimens and thirty acrylic specimens were fabricated. The specimens were divided into three groups, with ten specimens in each. Materials used were Vertex-soft (heat polymerizing acrylic- based soft liner material), A-330 primer (Factor II, USA), and Heat polymerized acrylic resin as listed in (Table 1).

Table 1: Materials employed in the research

Material	Manufacturer
Vertex-soft (heat polymerizing acrylic- based soft liner material)	Vertex, Netherlands
A-330 Primer	Factor II, Inc., Lakeside, Az, USA
Heat polymerized acrylic resin	Meliodent, Kulzer, Germany

The peel test was developed in compliance with previous studies [13, 14]. After treating the surface of acrylic with ethyl acetate (Shyn Industries, India), sandblasting with 50 millimeter aluminum oxide particles, and applying silicon carbide (SiC) paper, 30 soft liner specimens and 30 acrylic specimens were made and connected. Based on the type of surface treatment, three groups of bonded specimens were created.

2.2 Mold Fabrication

The molds for creating soft liner specimens were made from metal sheets, and the test specimen dimensions were designed using computer software (AutoCAD 2019). The mold's pieces were then constructed and cut using a wire cutter. Two rectangular stainless-steel plates were fabricated: one plate has spaces of 100mm length x 10mm width x 2mm height for PMMA, while the second plate has spaces of 150mm x 10mm x 2mm for soft liner [15].

2.3 Specimen Fabrication

A plastic model was used to make spaces inside dental stone. The plastic templates with dimensions of 75 mm in length, 10 mm in width, and 2 mm in thickness were treated with separating medium (Figure 1) and allowed to completely dry. The lower part of the flask was then filled with a mixture of dental stones. After inserting the plastic templates to a depth of about half, the stone was allowed to harden. The flask's lower part is then filled with the separating medium and allowed to dry. The top part is then packed with mixed stone and placed on a dental vibrator to remove air bubbles. The flask lid was then installed and left to solidify. After the setup, the two portions are separated, and the plastic templates are removed to create spaces for the acrylic material to be packed within (Figure 2).

Figure 1: Separating medium

Figure 2: Mold spaces created after plastic Templates being removed

Acrylic was then packed into the mold space and cured inside in the water bath at temperature of 100ºC for 15 minutes. Finally, the flask was carefully opened, and the acrylic specimens were removed. Acrylic specimen's surfaces are divided into nonbonding area and bonding area. The nonbonding (50mm x 10 mm) area was covered with adhesive tape.

Three surface preparation techniques were used to prepare the 25 mm × 10 mm region for attaching the soft liner to the acrylic: sandblasting, treating with 80 grit SiC paper, and ethyl acetate solution. Adhesive tape was used to cover the remaining acrylic specimen (Figure 3). Ethyl acetate solution was put over the acrylic bonding surface and left for 120 seconds to dry. Using high pressure and aluminum oxide particles, the bonding area was sandblasted for ten seconds in the second approach. Lastly, the surface was prepared using 80 grit SiC paper. For the second and third methods, the area was cleaned of any leftover particles using acetone. The stainless-steel mold was filled with treated acrylic specimens (Figure 3).

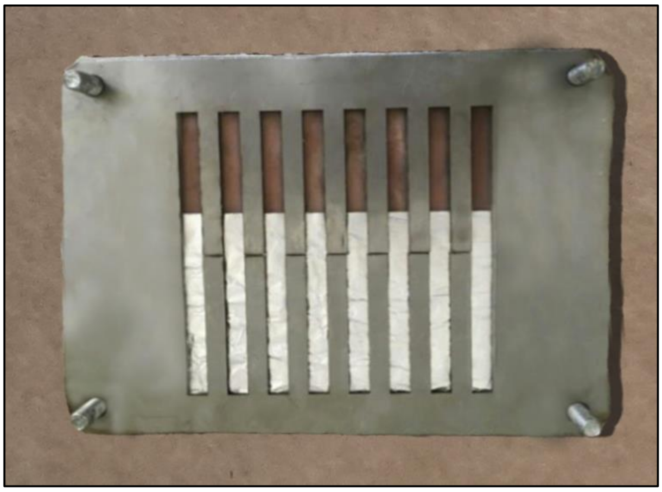

Figure 3: Acrylic specimens positioned inside the stainless-steel mold and the nonbonding area is covered by an adhesive tape

Soft liner material was mixed according to the manufacturer with a powder/liquid ratio of 1.2g/1 ml, and packed into the hollow space inside the stainless-steel mold that was designed for soft liner (Figure 4).

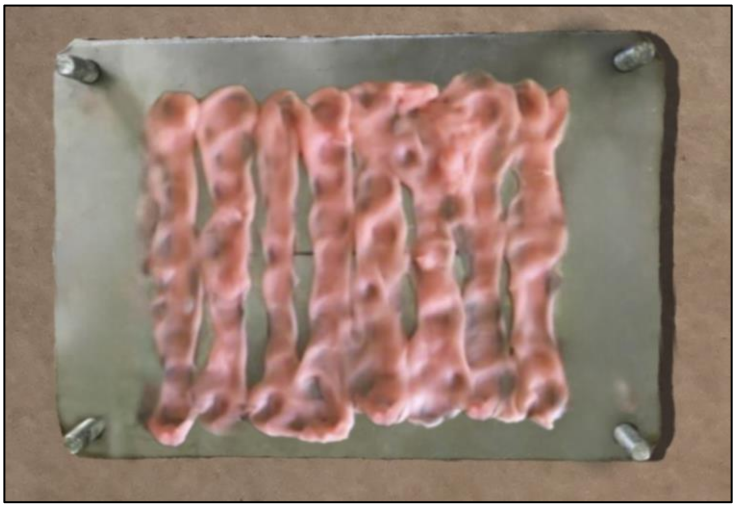

Figure 4: Soft liner packing into the mold spaces

The assembly was covered by another plate and pressed under hydraulic press until (100 MPa) for 5 minutes. The excess material was removed, and the flask was placed in a water bath in a temperature of 20 C followed by 70 C, 90 C, until it reached 100 C for 30 minutes. After complete polymerization, the specimens were removed and finished (Figure 5).

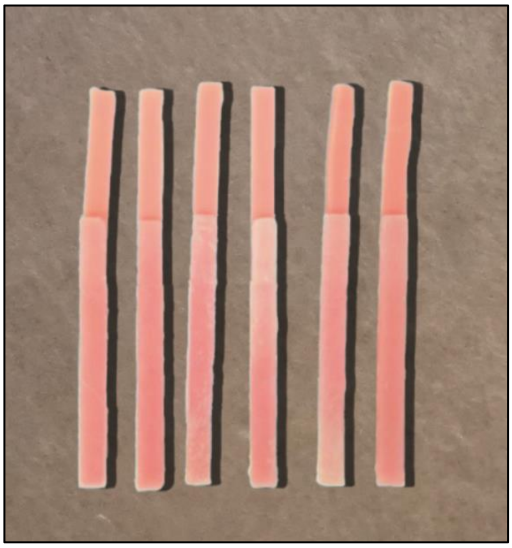

Figure 5: Finished specimens after defalsking

2.4 Specimens Testing

Specimens subjected to ASTM D903-93 testing conditions in a universal testing apparatus at a 180° angle and 152 mm/min. The lower clamp grasps 25mm of the soft liner specimen, while the upper clamp grasps the acrylic specimen. An alignment plate was used to maintain the specimen with the plane of the clamps (Figure 6). Peel strength (PS) (N/mm) was calculated according to Equation [16-17]:

Peel strength= Average load/ Width of the specimen

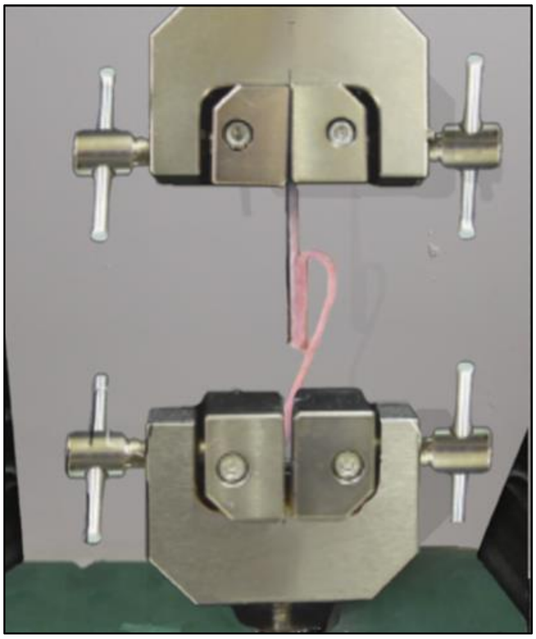

Figure 6: Universal testing machine and an illustration of peel bond strength test

After testing, the nature of the bond failure was examined by naked eye, and decided into cohesive, adhesive, and mixed failures. Cohesive failures are tearing within the material itself, adhesive is complete separation between acrylic and soft liner, while mixed is failure in both.

2.6 Statistical Analysis

A one-way analysis of variance (ANOVA) using release 26 of SPSS Inc. (Chicago, IL) was employed to assess significant variations in peel bond strengths across distinct surface treatment techniques, considering a significance level of $p < 0.05$. To check the assumption of equal variances, Levene's test of homogeneity was performed at $\alpha = 0.05$. With a p-value greater than 0.05, equal variances were assumed. A Tukey post hoc test was subsequently conducted.

3. RESULTS

The specimens treated with ethyl acetate acrylic (Group 1) had the maximum peel strength, followed by those treated with sandblasting (Group 2) and SiC paper (Group 3). A one-way ANOVA (Figure 7) revealed a significant difference (P < 0.05) between the groups. The post-hoc Tukey test revealed a highly significant difference between Groups 1 and 2. Furthermore, there was a significant difference between Groups 1 and 3. As demonstrated in Table 2, there was no significant difference between Group 2 and Group 3.

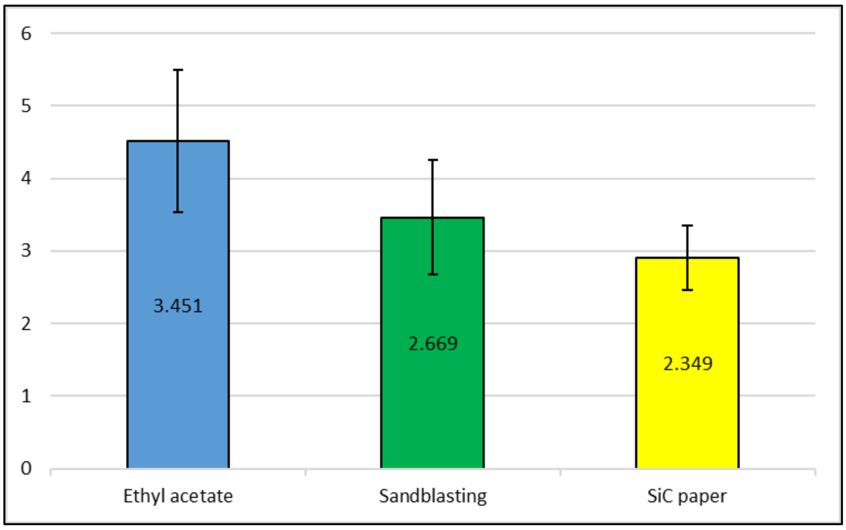

Figure 7: Bar chart representing means and standard deviation for all groups

Table 2: Summary of Descriptive Statistics and Results from One-Way ANOVA Analysis, and Tuckey post-hoc test

Peel bond strength					**ANOVA**		**Tukey HSD**	
Group	**Min**	**Max**	**Mean**	**±SD**	**F**	**P value**	**Groups**	**P value**
Group 1	3.08	5.95	4.5138	.97406	11.318	.000	Group 1 and Group 2	0.013
Group 2	2.61	4.85	3.4633	.78350			Group 1 and Group 3	0.000
Group 3	2.41	3.84	2.9082	.44702			Group 2 and Group 3	0.255
Levene statistics=3.349, p value= 0.050 [NS]								

Table 3 lists the results for the mode of failures. Among the three classes, cohesive failures were more common than adhesive and mixed failures.

Table 3: Types of Failures Recorded

Failure Modes	**Group 1**	**Group 2**	**Group 3**
Cohesive	8	7	5
Adhesive	2	4	2
Mixed	0	1	1

4. DISCUSSION

Soft lining materials are important in denture prosthetic dentistry because of their viscoelastic qualities, which help transfer functional stresses over the denture supporting region. The soft liner's attachment to the acrylic resin greatly extends the functional life of the denture prosthesis. The soft liner element of the prosthesis is connected to the matrix, thus it is very necessary to have appropriate bond strength between the two pieces to allow daily use of the prosthesis without loss of bonding. This is because several forces act on the interface and prosthesis margins, causing soft liner to tear from the margins and acrylic housing to break away from the soft liner prosthesis due to bond failure.

To improve the bond between soft liner and acrylic, a range of bonding agents are available [18]. In this work, the A330-G primer was used to generate hydrogen bonds and covalent coupling with polymers on both sides. Both components can be dissolved by the potent organic solvent in this kind of primer. According to information provided by the manufacturer, Primer A-330 contains a polyac solution in methylethylketone and dichloromethane to provide reactive sites for the soft liner. The primer's hydrophilic and hydrophobic groups can react with the functional groups of soft liner and acrylic. Potential bonding mechanisms between soft liner, acrylic, and primer include physical linkages such as hydrogen bonds, dipole-to-dipole bonds, and van der Waals forces. Primers can raise the surface energy and wetting properties of the resin substrate by starting the covalent coupling and hydrogen bonding processes. This makes it easier for polymeric components to permeate the surface layer, which together activates resin surfaces [19].

Ethyl acetate, an ester formed from ethanol and acetic acid, is manufactured extensively on a notable scale. Its widespread use as a solvent and diluent can be attributed to its cost-effectiveness, low toxicity, and pleasant aroma [20]. Group 1 surface treated specimens showed increased peel strength values compared to the group 2 and group 3 specimens. This can be related to the fact that this solvent can cause the surface to expand, thus allowing diffusion of the primer to the denture base resin thus increasing the resistance to peel [21]. Sandblasting and SiC papers create surface porosities which also increased the diffusion of primer thus increasing the peel strength. There was non-significant difference between group 2 and group 3, while significant differences were found between group 1 and groups 2 and 3.

As such, the energy that is absorbed depends on the hardness and dimensions (width and thickness) of the sample, whereas the energy required to separate the soft liner from the acrylic depends on the adhesive primer's interfacial thickness and the area that is bonded. Therefore, the elastic energy inside the split tab only becomes negligible when the soft, supple liner peels off with little effort [22].

Among the three groups, cohesive failures constituted the majority. This suggests that the strength of the soft liner material was not as strong as the interfacial bond between the acrylic surface and the soft liner. Adhesive failures that only account for a small number of specimens suggest that the soft liner's strength was greater than the interfacial bond. Thus, the surface-treated acrylic specimen showed no signs of soft liner residue. When soft liner residue is left on the acrylic surface, mixed failures occur [23]. For healthy young men and women, biting forces between 847N and 597N were observed in the area of the posterior molars [8]. It was shown that the typical masticatory forces accounted for about 40% of the biting forces. It is crucial to realize that intra-oral forces are much greater than extra-oral forces; hence, primers and adhesives need to have sufficient bond strength to support functional prostheses [24].

5. CONCLUSIONS

From the current study, it was found that the bond strength between soft liner and acrylic specimens had increased significantly after surface treatment of the acrylic specimen surfaces especially those treated by ethyl acetate solution. Specimens treated by sandblasting and SiC paper also revealed an increase in the bonding values. Cohesive failures were predominated among the other types of failures indicating the effectiveness of the surface treatment methods.

A Conflict of Interest: None.

Funding Source: Fully Independent.
Clearance for Ethics: An in vitro investigation.

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Cite This Article: Ali Saad Ahmed, Saif Saad Kamil, Safwan Abdul-Hammed, Rusul Saad Ahmed (2024). Evaluation of Peel Bond Strength between Heat Cured Acrylic Based Denture Soft Lining Material and Heat Polymerized Acrylic after Different Acrylic Surface Treatment Methods. *EAS J Dent Oral Med, 6*(3), 45-51.