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RESEARCH ARTICLE – DENTISTRY (MISCELLANEOUS)

Peel Bond Strength of Soft Liner Using Dental CAD/CAM and Conventional Acrylic Denture Base Materials Treated by Sandblast Technique

Ali Radhi Neamah [1], Firas Abd Kati [1]*, Ihtesham Ur Rehman[2]

[1] College of Health & Medical Technology - Baghdad, Middle Technical University, Baghdad, Iraq

[2] Head of Translational Research, University of Central Lancashire, Preston, United Kingdom

* Corresponding author E-mail: firasalshammari80@gmail.com

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Abstract

Background: One of the most serious problems with silicone soft liners is that they cannot cling to the acrylic denture foundation. The peel test is an appropriate method for assessing the binding strength of soft liners to denture base resin because the forces that the lining material is clinically exposed to are closely linked to the peel and tear test.

Objective of study: Analyzing the impact of sandblasting on the soft liners' ability to adhere to denture base resins' peel bonds.

Materials and Methods: Forty samples 64 x 10x 3 mm (length, width, and thickness), respectively of heat-cured acrylic soft denture liner materials. According to the types of material used, 20 specimens for CAD/ CAM and other 20 for traditional acrylic denture base material were constructed. The specimens were subdivided into two main groups (control group and sandblasting group). CAD/CAM specimens were created by cutting Pre-polymerized PMMA blocks with an In Lab MC X5-miller for PMMA plastic burs.

Results: The results showed that the sandblast treatment produced a higher mean value of Peel strength for conventional acrylic specimens in comparison to control. An Independent t-test reveals no significant difference (P>0.05) between groups. For the CAD/CAM approach, the sandblast group produced the lowest mean value of peel bond strength. Additionally, significant differences (P<0.05) for the CAD /CAM were found between control groups.

Conclusion: Particularly in terms of their mechanical properties, CAD/CAM polymers outperform conventional resins. It should be noted that variations in the features may be caused by differences in the resins' composition as well as the production processes. Also, the results of this study show that sandblasting increased the Peel bond strength of resilient lining materials to denture base resins and that the Peel bond strength was considerably higher in the surface-treated groups than in the control groups.

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Keywords: Sandblast; Peel Bond; Surface Treatment; Soft Denture Liners; Conventional Acrylic Denture Base.

1. Introduction

The tissue surfaces of the denture base can be coated with viscoelastic polymers known as soft lining materials to help distribute functional loads equally over the denture-bearing mucosa [1, 2]. One of the main advantages of soft denture lining materials is their viscoelastic qualities, which act as a cushion and enhance oral comfort, masticatory effectiveness, and denture retention [3]. Soft denture linings were typically made of one of two types of materials: silicone- or acrylic-based. Soft liners made of acrylic contain plasticizers, which stiffen the material. Soft liners made of silicone do not contain plasticizers, which enables them to stay soft for a longer period [4]. Many of the clinical problems caused by the use of acrylic resin denture bases have been alleviated by the use of soft lining treatments. These materials can prevent load stress concentration by distributing the functional load uniformly across the denture-bearing region. Additionally, they increase the complete denture's flexibility and retention during bone resorption [5].

Soft-lined dentures are more comfortable to wear and provide important advantages in terms of articulation, masticatory effectiveness, denture retention, and stability, decreased pain sensitivity and oral ulcers beneath the dentures, increased denture usage time, and comfort [6]. Various soft liners were required for many prosthetic applications. Both silicone and acrylic resin were used to make soft liners. Both auto-polymerized and heat-polymerized versions of these groups are available [7]. Dimethyl siloxane polymers were used to create cross-linked rubber to create silicone-based soft-liner materials, which have a respectable elastic characteristic [8]. Clinical issues that soft liners experience include tearing, a lack of resilience, a failure to adhere to the denture foundation, and color change. Bond failure was one of the key issues that left the liner surface open to bacterial and fungal growth. Bond failure causes the development of plaque and calculus, oral tissue infection, and material degradation [9]. Infections of the oropharynx, esophagus, and respiratory tract are just a few of the systemic disorders that plaque buildup could lead to systemic illnesses brought on by plaque accumulation including infections of the respiratory tract, esophagus, and oropharynx. Contamination of implant overdentures' soft liners may lead to peri-implantitis and bone loss. Insufficient adhesion to the denture foundation components will undermine the soft liner's ability to perform as planned.

The chemistry of the denture base, liner, and primer as well as water absorption affect the bond's tensile strength [10]. Acrylic-resin soft liners connected to the acrylic-resin denture foundation with larger values than silicone-based soft liners. The bonding strength between the lining material and denture foundation needs to be improved to prevent the localized area from degenerating into an unsanitary and dysfunctional state [11]. This study aimed to determine the impact of sandblasting on the soft liners' ability to adhere to denture base resins' peel bonds.

• Group A: Untreated (Control): The acrylic resin specimen surfaces (PMMA, CAD/CAM) received no treatment; this group acted as a control.

• Group B: Sandblasted: Using 110 m aluminum oxide particles at a pressure of 2 bar for 10 seconds, specimen bonding surfaces were (sandblasted, mestra). When the specimens were put in a specialized holder, the distance between the surface and the blasting point was 10 mm. After being sandblasted, the specimens were dried by air to create a clean bonding interface [12, 13].

2. Materials and Methods

2.1. Preparation of conventional PMMA samples

By ISO standard 20795-1:2013) Fig. 1, the dimensions of twenty samples were (64, 10, and 3.3mm) in length, width, and thickness, respectively to standardize the wax pattern size of the samples, a metallic mold was created. The wax design was cut to the correct size, covered with a separating material, and then glued inside the flask. The wax was then removed from the mold by immersing it in hot water for 4 minutes. Acrylic resin denture foundation that has been heat-cured (measured by volume by the manufacturer's specifications). A 3:1 ratio of polymers to monomers was chosen. Before being poured into the mold, the mixture was mixed until it reached the dough stage. The flask was then pressure-sealed after that. The flasks were submerged in a water bath set at 75 o C for two hours, then another set at 100 o C for an hour and a half to cure the material. The samples were removed from the mold [14].

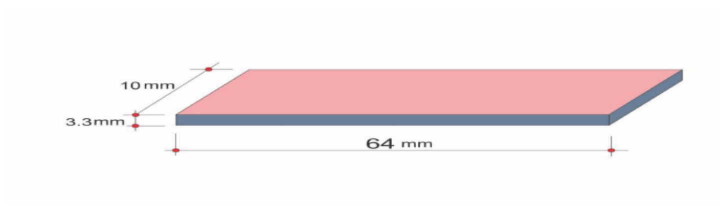

Fig. 1. Sample design of conventional PMMA

2.2.Preparation of CAD/ CAM acrylic resin denture base

Twenty sample's dimension was (64×10×3.3mm) (length, width, and thickness respectively) according to ISO standard number 20795-1:2013) Fig. 2. Subtractive CAD/CAM denture base samples were constructed using pre-polymerized PMMA blocks (CAD/CAM specimens were prepared by cutting blocks using an In Lab MC X5-miller for PMMA plastic burs). After sectioning, the outermost two layers from either side of the block were eliminated to ensure that all test samples had a consistent surface roughness formed by the bur before surface preparation for testing [14].

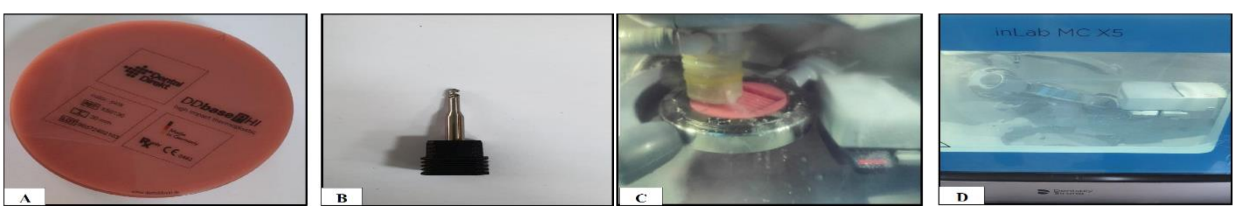

Fig. 2. (A) CAD/CAM block, (B) In Lab MC X5- miller for PMMA plastics, and (C, D) Dental milling machine MC X5 in lab

Vernier calipers were used to measure each specimen accurately for dimensions as depicted in Fig. 3. For this investigation, a total of 40 specimens were made from acrylic denture base resin (Traditional and CAD/CAM PMMA). According to the method of surface treatment, each group will be separated into two groups with twenty specimens each. The material group contains ten specimens: Both the control group's (10) specimens and the sandblasting group's (10) specimens underwent the Peel bond test.

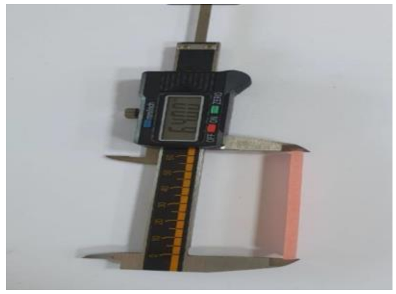

Fig. 3. Vernier caliper used for measuring sample diameter

2.3. Fabrication of the soft liner

After applying a separating agent to the acrylic resin samples, a wax pattern was applied as in Fig. 4, with a thickness of 3 mm was applied. To make place for the flexible lining materials, plaster was utilized to "invest" the flask-containing acrylic resin specimens with a wax covering. The leftover wax was then removed by washing the acrylic resin. The acrylic resin has been painted with the liner adhesive. Once the acrylic resin had cured and hardened, the silicone elastomer denture lining (Molloplast B, Germany) was heated through polymerization. The flask was put back together, clamped, and then placed in a press to make metal-on-metal contact before being cured in a water bath for two hours. The samples were withdrawn from the flask, and any traces of soft-liner flashes were cleaned away [15].

Fig. 4. The flask-containing acrylic resin specimens with wax patterns covering

2.4. *Surface* modification

The bonding surfaces of specimens were (sandblasted, mestra) using 110 μm aluminum oxide particles with 2 bar pressure for 10 s. 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 Fig. 5. The specimens were rinsed under running water and were air-dried to establish a remnant-free bonding interface [16].

Fig. 5. Sandblasting machine

2.5. Peel bond strength measurement

Using a universal testing device with a load cell of 5 KN, the Peel bond strength test was performed to evaluate the bond strength at a 90° angle. Each sample was placed horizontally on the machine's lowest fixed compartment using screws that were tightened through a base with moveable jaws. A piece of the soft liner was raised upward and fastened to the Jackob chuck of the testing device's upper moveable compartment at a distance of 20 mm from the test specimen's adhesive bond position. While the acrylic resin substrate was curing under heat at a rate of 5 mm per minute, the test specimen was dragged under stress to encourage the robust liner to separate from it until failure occurred. Newton made use of software to keep track of failures. By dividing the load at failure by the bonding area, the bond strength was calculated in MPa. The bond strength was expressed in MPa by the formula P/A [12] where P was the load at failure and A was the region between the liner and the acrylic base. The failure mechanisms were categorized as cohesive, adhesive, or mixed depending on whether the fracture surface was in the soft liner only, at the denture base-soft liner contact, or in both [17] as illustrated in Fig. 6.

Fig. 6. Peel bond test by universal testing machine

3. Results

3.1. Results of the peel bond strength test performed using common (acrylic) denture base materials

The descriptive statistics of the values of Peel strength, including the lowest, maximum, averages, and standard deviation for conventional (acrylic) denture base materials, were measured for all specimens in (N/mm^2). According to the findings, as shown in Table 1 and Figure (7), the group treated with sandpaper obtained the highest mean value of peel strength (0.8855), while the control groups obtained the lowest mean value (0.8205). Furthermore, the independent t-test showed no significant difference (P>0.05) between all groups.

Table 1. Descriptive statistics and independent t-test of peel bond strength test for conventional acrylic surface treatment groups

Studied Groups	No.	Mean	SD	SE	Min.	Max.	t-test P value	t-test Sig.
Control	10	0.8205	0.33720	0.10663	0.48	1.30	0.802	NS*
Sandblast	10	0.8855	0.30605	0.09678	0.53	1.29		

* P>0.05 non-significant

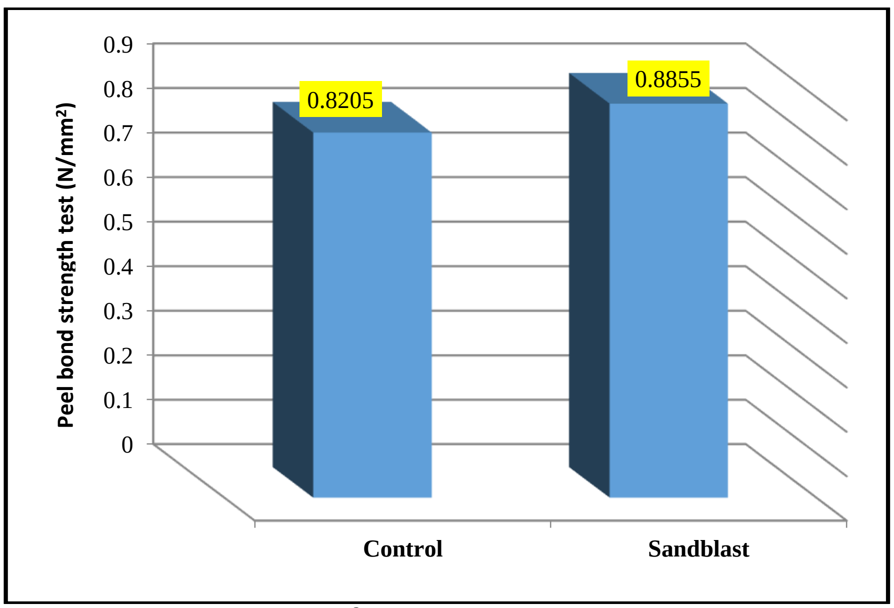

Fig.7. Bar chart represents the mean value N/mm^2 of peel bond strength of the studied groups for conventional acrylics

3.2. Results *of peel bond strength test of CAD/CAM (acrylic) denture base materials.*

Statistical analysis of the values and means for the acrylic (CAD/CAM) denture foundation materials. As stated in Table 2, and Figure (8), the results showed that the mean value of the control groups was the greatest (1.3161), while the mean value of the sandblast group had the lowest mean value (0.7379). Furthermore, the independent t-test showed a significant difference (P<0.05) between groups.

Table 2. Descriptive statistics and an ANOVA test of peel bond strength test for various groups of CAD/CAM acrylic surface treatments

Studied Groups	No.	Mean	SD	SE	Min.	Max.	t-test P value	t-test Sig
Control	10	1.3161	0.57983	0.18336	0.44	1.82	0.006	S* (P<0.05)
Sandblast	10	0.7379	0.45479	0.14382	0.43	1.53		

* P<0.05 Significant

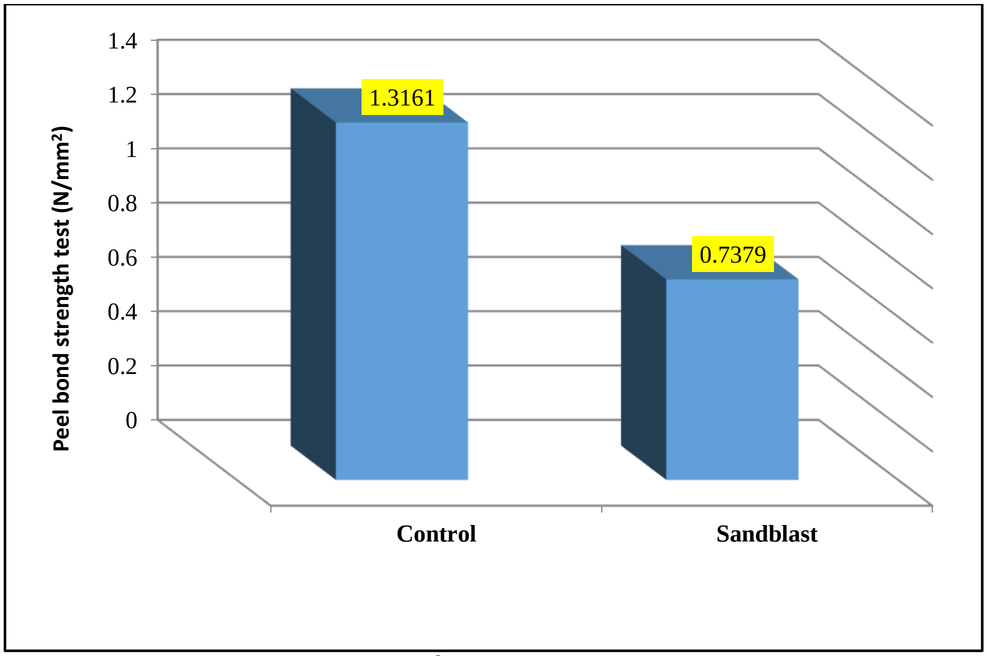

Fig. 8. Bar chart represents the mean value N/mm^2 of peel strength of the studied groups for CAD/CAM acrylics

4. Discussion

Polymethyl methacrylate (PMMA) was a commonly utilized plastic material for denture applications due to its remarkable properties, which included ease of production, lightweight, low cost, aesthetic attributes, and oral durability. In terms of biomaterials, dependability, and the absence of taste, odor, and tissue irritation, PMMA was still superior. Color, ease of manipulation, and a nice visual appearance all affect one's sense of security [18]. For the majority of edentulous individuals, complete dentures (CDs) are still the only option. Polymethylmethacrylate (PMMA) resin is used to create CDs largely utilizing a traditional technique. Any inaccuracy lowers CD retention and occlusal precision and has a direct impact on the quality of the resin prosthetic base during the PMMA polymerization process. Furthermore, when using the standard procedure, the remaining monomer changes the mechanical properties of the resin and may cause mucosal reactions. It has become more and more common to process resin discs that were made under high pressure and temperature using computer-aided design and computer-aided manufacturing (CAD/CAM) methods. It was agreed with [19].

Various methods have been proposed to enhance the bond between denture base resins and soft liners. The three major groups of improvement tactics are (1) increasing surface roughness to expand the area available for bonding; and (2) improving the chemical behavior of the substrate to strengthen the binding between soft liners and denture base resins, many techniques have been devised. To increase the surface area available for bonding, the surface roughness must be improved. Additionally, the substrate's chemical behavior must be improved to increase wettability. Finally, a hydrogen bond must be formed between the acrylic group of PMMA and adhesive primers. Bond strength is impacted by sandblasting because it makes the surface more abrasive. By applying great pressure to a stream of Al2O3 particles, it was possible to sandblast a substance's surface that is a prospective bonding candidate [20]. Adhesive primers and the acrylic group of PMMA are eventually connected by a hydrogen molecule. Bond strength is impacted by sandblasting because it makes the surface more abrasive. By applying great pressure to a stream of Al2O3 particles, it was possible to sandblast the surface of a substance that may be a candidate for bonding [20]. However, this data runs counter to the findings of other research that indicated enhanced peel bond strength following sandblasting [21, 22]. Due to the use of a variety of materials and methods during sandblasting, it might be challenging to determine the exact effect of the procedure on the bond strength. The variables that could affect the peel bond strength values between the liner materials and denture base resin include the type of lining materials, particle size of the sands, blasting pressure and time, test procedures, thermocycling, speed of the testing machine's head, and thickness of the lining material. By considering sandblasting variables such as particle size, blasting pressure, and liner type, this work tried to determine the function of this pretreatment in improving bond strength. It was agreed with [23] that the peel test is a special technique in which failure manifests gradually, and the Peel force is a precise indicator of the detachment process. Additionally, it is thought that a Peel test will reflect the nature of the forces exerted on the union's edges more accurately. The soft materials used were more likely to break cohesively; hence the results from Peel testing were insufficient. The compliance and thickness of the materials have an impact on the results. In this inquiry, the Peel Bond Strength Test Method was used [24].

The sandpaper group had the highest mean value of Peel strength (0.8855), while the control groups had the lowest mean value (0.8205), according to the results of the current study's Peel bond strength test of conventional (acrylic) denture base materials. Considering the results of the peel bond strength test for CAD/CAM acrylic denture base materials the findings showed that the control groups obtained the lowest mean values of peel strength (0.8205), whereas the group treated with sandpaper obtained the greatest mean value of peel strength (0.8855). This was because sandblasting enhances the bonding surface, results in mechanical locking at the bond point, clears impurities and generally strengthens bonds. The [25] result demonstrates that surfaces that have been sandblasted are also rougher and debris-free [26]. The soft lining material's ability to pass through acrylic resin's defects has a major impact on the adhesive properties. Though the size of the faults may prevent the resilient lining material from entering them this was unlikely to considerably increase the peel bond strength [25]. The viscosity of liners determines how easily they can flow into resin faults, while the pliability of elastic materials at a particular contact angle and surface energy determines how far they can penetrate. [26] PC = cos /2, three factors surface tension, contact angle, and viscosity are included in the calculation for the penetration coefficient (PC) of liquids into cavities. This can be utilized to demonstrate that the tensile strengths of the sandblasted specimens used in the reviewed research were lower. The development of microcracks, vacancies, and gaps, however, when the resilient lining material was packed onto the resin surface, may trap air bubbles, make up for the effect of flaws by widening the contact surface, and weaken the binding [19]. The third argument for the loss of strength involves strain that was focused due to surface defects or stress that is generated at the interface between the soft liner and PMMA.

5. Conclusion

In terms of their mechanical qualities, CAD/CAM resins are superior to traditional resins. It should be noted that changes in the features may result from both the composition of the acrylic resins and the production techniques. Sandblasting increased the peel bonding strength of durable lining materials to denture base resins. Peel bond strength in groups with surface treatment was significantly higher than in groups without surface treatment.

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Nomenclature & Symbols

CAD /CAM	Computer-Aided Design/Computer-Aided Manufacture	mm	Millimeter
ASTM	American Society for Testing and Materials	P/L	Powder /liquid ratio
G	Gram	UM	Micrometer
%	Percentage	PMMA	Polymethyl methacrylate
ML	Milliliter	NS	Non-significant
S	second		
LSD	Less Significant Difference		

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