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Research Article

The effect of sandblasting surface treatment on shear bond strength between acrylic denture teeth and thermoplastic nylon denture base: experimental study

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ABSTRACT

Introduction: Thermoplastic nylon has been introduced in dentistry as a material for denture bases since 1950. It has become a popular alternative for denture fabrication due to its superior aesthetics and several advantages. However, thermoplastic nylon has insufficient shear bond strength with acrylic resin, causing the acrylic denture teeth to often debond from the thermoplastic nylon denture base. Sandblasting is suggested to increase the shear bond strength between artificial teeth and denture bases. This study aims to analyze the effect of sandblasting surface treatment on the shear bond strength between acrylic denture teeth and thermoplastic nylon denture base. **Methods:** Four groups with different aluminum oxide particle sizes (No treatment/control, 50 µm, 110 µm, 250 µm) were used in this study (n=8). A universal testing machine was used to test the specimens. The data were analyzed using a One-way ANOVA test followed by an LSD (Least Significant Difference) post-hoc test. **Results:** The One-way ANOVA test showed a significant difference among groups (P<.001) and LSD (Least Significant Difference) test showed a statistically significant difference between groups (P<.005). **Conclusions:** Sandblasting surface treatment has a significant effect in increasing the shear bond strength between acrylic denture teeth and thermoplastic nylon denture base. Sandblasting with 250 µm aluminum oxide showed the best result compared to the other groups.

KEY WORDS: shear bond strength, sandblasting, acrylic denture teeth, thermoplastic nylon, denture base.

Pengaruh surface treatment *dengan* sandblasting *terhadap kekuatan ikatan geser antara anasir gigi tiruan akrilik dan basis gigi tiruan nilon termoplastik: studi eksperimental*

ABSTRAK

Pendahuluan: *Nilon termoplastik telah diperkenalkan dalam dunia kedokteran gigi sebagai bahan basis gigi tiruan sejak tahun 1950-an. Nilon termoplastik telah menjadi alternatif populer untuk pembuatan gigi tiruan yang memberikan estetika lebih baik dan beberapa kelebihan. Namun, nilon termoplastik memiliki kekuatan ikatan geser yang tidak memadai dengan resin akrilik, menyebabkan anasir gigi tiruan akrilik sering kali terlepas dari basis gigi tiruan.* Sandblasting *disarankan dapat digunakan untuk meningkatkan kekuatan ikatan geser antara anasir gigi tiruan dan basis gigi tiruan. Penelitian ini bertujuan untuk mengevaluasi pengaruh* surface treatment *dengan* sandblasting *terhadap kekuatan ikatan geser antara anasir gigi tiruan akrilik dan basis gigi tiruan nilon termoplastik.* ***Metode:*** *Empat kelompok dengan ukuran partikel aluminium oksida berbeda (Tanpa perlakuan/kontrol, 50 µm, 110 µm, 250 µm) digunakan dalam penelitian ini (n=8). Universal* Testing Machine *digunakan untuk menguji spesimen. Data dianalisis menggunakan uji* One-way ANOVA *diikuti dengan* uji post-hoc LSD (Least Significant Difference)*.* ***Hasil:*** *Uji* One-way ANOVA *menunjukkan perbedaan yang signifikan secara statistik antar kelompok (P<0,001) dan uji* LSD (Least Significant Difference) *menunjukkan perbedaan antar kelompok yang signifikan secara statistik (P<.005).* ***Simpulan:*** *Terdapat pengaruh* surface treatment *dengan* sandblasting *terhadap peningkatan kekuatan ikatan geser antara anasir gigi tiruan akrilik dengan basis gigi tiruan nilon termoplastik.* Sandblasting *dengan aluminium oksida 250 µm menunjukkan hasil paling baik dibandingkan kelompok lainnya.*

KATA KUNCI: *kekuatan ikatan geser, sandblasting, anasir gigi tiruan akrilik, nilon termoplastik, basis gigi tiruan.*

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INTRODUCTION

Thermoplastic nylon dentures, commonly known as flexible dentures, have been marketed for over 70 years.[1,2] Thermoplastic nylon is a class of thermoplastic material that is widely used in prosthetic dentistry to make denture bases.[2] Thermoplastic resins can be categorized into five types: polyesters, acrylics, polyamides, polypropylenes, and polycarbonates.[3] Polyamide, usually referred to as thermoplastic nylon, is synthesized through a condensation reaction of diamine and dibasic acid.[4,5] Compared to conventional poly-methyl-methacrylate (PMMA), thermoplastic nylon offers greater flexibility and sufficient strength to be used as a denture base.[2,6] It is usually used to provide better aesthetics and is suitable for individuals with metal or monomer allergies.[2,4,7] Additionally, it exhibits superior fracture resistance compared to PMMA.[6]

Thermoplastic nylon has some limitations, such as a significant water absorption rate, substantial deformation during loading tests, a rough surface, susceptibility to bacterial contamination, and the potential for discoloration.[6] Fitting and polishing thermoplastic nylon dentures is more complicated than PMMA. Additionally, it has been found to exhibit lower flexural strength and modulus of elasticity.[4,5] Furthermore, the bonding strength between the thermoplastic nylon denture base and the acrylic denture teeth is inadequate, resulting in frequent debonding.[1,4,6]

An adequate bonding between the denture teeth and the denture base is necessary to increase the strength and durability of the denture.[8] Fractures and detachment of denture teeth from denture base often occur in dental practice. Around 30% of denture repairs are caused by the detachment of denture teeth from the denture base, mostly occurring in the anterior region.[1,6,9] Several factors that may impact the bond strength include the presence of wax or contamination from separating materials, artificial tooth and denture base material selection, and the preparation of the ridge lap of the denture teeth.[10–12]

The detachment of denture teeth from the denture base typically occurs due to adhesive or cohesive failure.[13] Adhesive failure is observed when there is a complete absence of denture base material on the ridge laps of the teeth after fracture. Conversely, the bond is deemed to fail due to cohesion failure if there are traces of the denture base material remaining on the ridge laps of the denture teeth after a fracture.[8,13] Several research studies have shown techniques to enhance the bond strength between denture teeth and the denture base, which can be achieved through surface treatments. Those methods can enhance the bonding of materials by creating a modified surface on the ridge lap.[11,14]

Sandblasting is a mechanical method commonly used for treating surfaces. Sandblasting is a process where high-pressure aluminum oxide spray is used to treat the ridge lap surface of the denture teeth.[14] This mechanism induces the ridge lap surface's roughening, irregularity, and porosity. It can facilitate mechanical interlocking that promotes the bonding between the denture tooth and the denture base.[14,15] Aluminum oxide with different particle sizes were frequently used as a material for surface treatment.[14,16] Studies suggest that variations in retention outcomes when using different particle sizes of aluminum oxide.[14,17] Several studies indicated that sandblasting increased the average value of roughness and shear bond strength.[18–21] Several studies have examined the effect of surface treatment on the shear bond strength between acrylic denture teeth and acrylic resin base. However, there is a lack of research evaluating the effect of sandblasting surface treatment on the shear bond strength between acrylic artificial teeth and thermoplastic nylon denture bases using various sandblasting sizes. The null hypothesis in this study would be there was no effect of sandblasting surface treatment on shear bond strength between acrylic denture teeth and thermoplastic nylon denture base. Thus, this study aims to analyze the effect of sandblasting surface treatment on the shear bond strength between acrylic denture teeth and thermoplastic nylon denture base.

METHODS

This research was an experimental laboratory study with a posttest-only control group design. It was conducted for one month and started with sample preparation, followed by specimen preparation, shear bond strength test, data presentation, and statistical analysis.

The samples were made in UJI Dental Laboratory USU. Thirty-two acrylic maxillary central incisor denture teeth (Caiyu Yuying, Cai Yu Dental Materials Co., LTD, China) were selected. Each denture tooth was embedded in a thermoplastic nylon denture base (Bioplast, Scheu Dental GmbH, Germany) (Figure 1).

The samples were divided into four groups (n=8). Group I: Untreated acrylic denture teeth (Control group). Group II: Sandblasted acrylic denture teeth with 50 µm aluminum oxide (Cobra Aluminum Oxide, Renfert, Germany). Group III: Sandblasted acrylic denture teeth with 110 µm aluminum oxide. Group IV: Sandblasted acrylic denture teeth with 250 µm aluminum oxide.

Figure 1. Specimen for the shear bond strength test.

Groups II, III, and IV were treated using a sandblaster (Blasty, FilliManfredi, Italy) at a 10 mm distance at 0.28 MPa for 15 seconds. Specimens were manufactured according to ANSI/ADA specification no. 15 for synthetic resin teeth. Thirty-two cylindrical wax specimens were made using a tube mold (18 mm diameter x 20 mm length) as a denture base specimen. The acrylic denture teeth were attached to the wax model: 1 mm in the mesial, distal, and palatal, while the labial was 2 mm, which formed 45° angulation to ensure that the teeth on the wax model were all in the same position and angulation. The samples which attached the denture tooth were invested with type III dental stone (Moldano, Heraeus Kulzer GmbH & Co. KG, Germany) in the lower half of the injection metal flasks, boiled out for 30 minutes, and placed into the injection molding machine. The remaining wax and sprue were removed using boiling water.

The cartridge was placed into the furnace for 11 minutes at 250°C according to the manufacturer's instructions until the thermoplastic nylon melted. The melted thermoplastic nylon was injected into the flask and allowed to bench cool. After completion of the polymerization, the specimens were removed from the flask, trimmed, and wetly polished using 600 grit sandpaper to remove any irregularities around them. All samples were stored in distilled water at 37°C for 24 hours in the incubator before testing. The shear bond strength was tested in the Mechanical Engineering Laboratory USU using the Universal Testing Machine (Tensilon RTF-1350, A&D Company, Japan). The compressive load was applied at 45^0 at the incisal line of the palatal surface to provide the most precise simulation of the contact angle in class I occlusion between the maxillary and mandibular anterior teeth, using a 0.5 mm/minute crosshead speed (Figure 2). The compressive load was 1000 N until the denture tooth separated from the denture base. The shear bond strengths were determined using the shear bond strength formula (L/A), where L equals the maximum load (N), and A equals the bonded area (mm2).

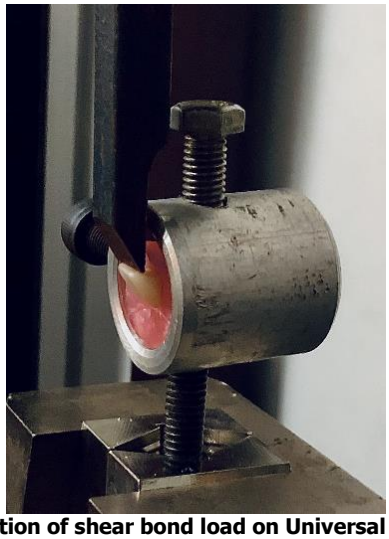

Figure 2. Application of shear bond load on Universal Testing Machine.

The data were analyzed with a statistical software package (IBM SPSS Statistics version 22.0, IBM Japan, Ltd., Tokyo, Japan). All groups' mean and standard deviation of shear bond strength values were obtained. A One-way ANOVA test was used to analyze the significant difference in shear bond strength between the tested groups, followed by an LSD (Least Significant Difference) post-hoc test to compare the intergroup significance (α =0.05).

RESULTS

The results of the shear bond strength values between acrylic denture teeth and thermoplastic nylon denture base showed that the treated group produced higher shear bond strength values than the untreated group. The highest mean shear bond strength was observed in Group IV (2.680 ± 0.254 MPa), followed by Group III (1.688 ± 0.247 MPa), Group II (0.921 ± 0.205 MPa), and the least was seen in Group I (0.572 ± 0.106 MPa).

The Shapiro-Wilk test was used to check the normality of the data, which were found to be normally distributed (p>.05). After that, the data homogeneity was performed using Levene's test to find out that the data was truly homogeneous (p>.05). Data that were normally distributed and homogeneous were analyzed statistically parametric using One-way ANOVA.

Table 1. Mean ± standard deviation (SD) shear bond strength values (MPa) of experimental groups.

Groups	Shear Bond Strength (MPa)		p-value*
	n	Mean±SD	
Group I	8	0.572 ± 0.106	0.001
Group II	8	0.921 ± 0.205	
Group III	8	1.688 ± 0.247	
Group IV	8	2.680 ± 0.254	

*One-way ANOVA

The One-way ANOVA test showed a significant difference among groups (P<.001), which means that there was a significant effect on shear bond strength between acrylic denture teeth and thermoplastic nylon denture base after surface treatment with sandblasting (Table 1).

Least Significant Differences (LSD) was carried out to identify groups with significant differences, and the results showed a statistically significant difference between groups (P<.005) (Table 2). Diagram 1 describes the significant difference between the four groups, where different alphabets indicated significant differences.

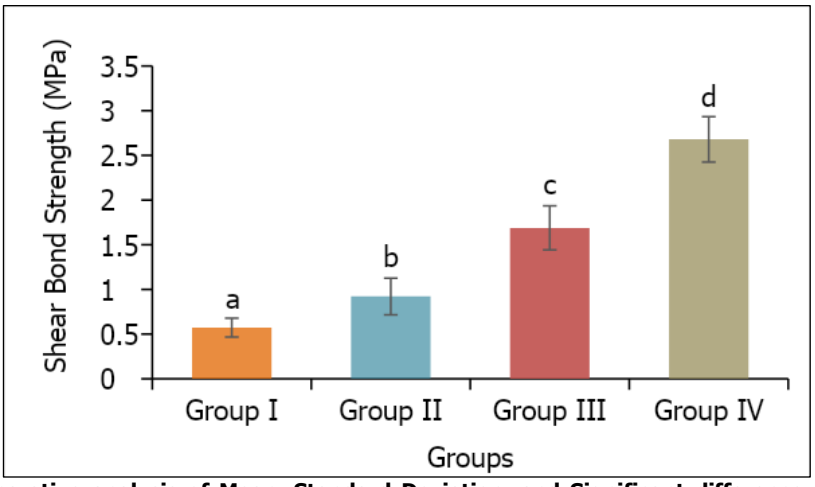

Diagram 1. Comparative analysis of Mean, Standard Deviation, and Significant difference values for al groups.

Table 2. Multiple group comparisons (LSD) between experimental groups

Groups		p-value*
Group II	Group I	0.003*
	Group III	0.001*
	Group IV	0.001*
Group III	Group I	0.001*
	Group IV	0.001*
Group IV	Group I	0.001*

*Significant

DISCUSSION

The current study evaluated the effect of sandblasting surface treatment on the shear bond strength between acrylic denture teeth and thermoplastic nylon denture base. The null hypothesis of this study was rejected as there was a significant difference in the effect of sandblasting surface treatment on the shear bond strength between acrylic denture teeth and thermoplastic nylon denture base.

Shear bond strength refers to the ability of a material or component to resist failure or structural damage when receiving shear forces.[22] Achieving an adequate bond between the denture teeth and the denture base is essential in making dentures to enhance the overall success rate.[8] Denture teeth are expected to withstand significant stress during mastication.[14,23] Hence, an adequate bond between the denture teeth and the denture base is necessary to withstand the stress.[14] Inadequate shear bond strength can result in the detachment of denture teeth from the denture base during the patient's use.[14]

Thermoplastic nylon denture base resin poses a challenge when bonding with acrylic denture teeth because its highly crystalline structure imparts chemical resistance.[1,2,6] The bond strength of acrylic denture teeth and thermoplastic nylon denture base was lower than that of acrylic denture base resin.[3,9] Previous study found that mean shear bond strength values of acrylic denture teeth and thermoplastic nylon denture base was 3.7 ± 0.84 MPa and mean shear bond strength values of acrylic denture teeth and acrylic denture base was 4.52 ± 1.67 MPa.[1] Therefore, additional mechanical bonding, such as surface treatment, are required to enhance the shear bond strength.[2,9,24]

Surface treatments lead to modifications in the surface texture of the substrate material. Variations in the surface topography can impact the ridge lap of denture teeth that can be used for mechanical bonding.[14] Sandblasting is a highly efficient method for achieving micromechanical interlocking and is commonly used for surface treatment in dentistry.[2] The sandblasting process enhanced shear bond strength by adding the newly abraded

surface.[14] Spraying the denture ridge lap surface with aluminum oxide at high pressure causes abrasion, leading to friction and collision. It creates a surface morphology that is rough, irregular, and porous.[11,15,25,26] Previous study also indicated that sandblasting enhanced shear bond strength by producing rough surfaces and forming undercuts on the ridge lap, leading to micromechanical retention.[12] The increase in shear bond strength can be due to the surface roughening achieved during sandblasting, which expands the bonding surface area.[11] Furthermore, abraded aluminum oxide particles facilitate the formation of mechanical interlocking in each area, remove the top layer of the ridge lap surface, and reveal the underlying layer, which has larger free surface energy.[17,19,27]

The results of the current study were in line with the findings of previous studies. Studies discovered that modifying the surface of acrylic denture teeth and making mechanical modifications to the ridge lap surface with sandblasting significantly improved the shear bond strength between the acrylic denture teeth and the heat-cure acrylic denture base resin.[12,27,28] Apart from sandblasting, surface treatment can be carried out using other methods such as applying chemical materials, e.g., silane, ethyl acetate, chemical bonding, and making diatoric holes and laser irradiation.[2,9,14,29] Prior research indicated that the average bond strength between acrylic resin teeth and denture base resin was greatly improved by either adding retentive grooves or using sandblasting compared to the untreated surface.[13] Nevertheless, chemical surface treatment alone had a negligible effect on the shear bond strength values, suggesting that the chemical surface treatment did not effectively improve monomer penetration into the resin surface.[28,30] The shear bond strength values improved when chemicals were applied after mechanical surface treatment, such as sandblasting with aluminum oxide, followed by applying 4-META resin.[2,19]

Based on the average values of shear bond strength, surface treatment with 250 μm sandblasting is the most effective method for increasing the shear bond strength between acrylic denture teeth and thermoplastic nylon denture base, as compared to using lower grits of aluminum oxide (50 μm and 110 μm). Previous study suggested that utilizing various sizes of aluminum oxide particles produced diverse denture base retention outcomes. The retention of denture bases significantly increased by 78.79% after sandblasting with 100 μm aluminum oxide and by 48.06% after sandblasting with 50 μm aluminum oxide, compared to denture bases without sandblasting.[17] Larger grit of aluminum oxide particles will cause larger holes or indentations in the surface of acrylic denture teeth during sandblasting due to their size and greater momentum. The surface roughness increased as particle size increased. Furthermore, the higher roughness resulted in higher bonding strengths due to larger contact areas for bonding.[17,30]

The micro-density in the ridge lap may rise with larger particles, producing more extensive and deeper microroughness and better shear bond strength values. Smaller particles are more likely to create a smoothing effect on the ridge lap and produce smaller micro-retentions than larger particles. Furthermore, compared to flat or smooth surfaces, surfaces with higher surface-free energy offer more potential for retention, increasing the shear bond strength value.[17,31] The thermoplastic nylon material will easily penetrate larger grooves or pits when injected, making a better micromechanical bond.[30]

Another study evaluated the shear bond strength at the resin/bracket interface after sandblasting with different aluminum oxide particle sizes and found that shear bond strength was higher when sandblasting was done with 110 μm aluminum oxide (9.34 ± 4.18 MPa) compared with 50 μm (6.86 ± 1.08 MPa), 25 μm (7.53 ± 3.20 MPa), and the control group (2.40 ± 0.85 MPa).[32] In this current study, the micro-roughness that occurs on the ridge lap of acrylic denture teeth after sandblasting was considered different. The samples in Group IV have a rougher surface than those in Groups I, II, and III since Group IV was sandblasted using a larger particle size, resulting in higher shear bond strength values. The shear bond strength in this study exhibited a direct correlation with the size of the aluminum oxide particles used as sandblasting material.

It is also important to analyze the type of failure, as the denture teeth might fracture before any damage occurs at the interface between the denture teeth and the base. In the current study, the bond failure of all groups was adhesive failure since there was a complete absence of thermoplastic nylon denture base material on the ridge laps of the acrylic teeth after fracture. This was caused by the nature of the bond and the different materials used.[12,14]

The limitation of this study was that the shear bond strength test was conducted using a single vertical loading point, angle, and only one surface treatment. Hence, it is recommended that a future study involve actual occlusal force, different angles, and other surface treatment methods.

CONCLUSION

An improvement in shear bond strength was obtained after sandblasting surface treatment between acrylic denture teeth and thermoplastic nylon denture base compared to the untreated group. The group treated with 250 µm sandblasting exhibited a greater increase in shear bond strength than the groups treated with 50 µm and 110 µm sandblasting. The implication of this study is that using aluminum oxide sandblasting as a surface treatment may minimize the debonding of denture teeth from the removable prosthesis in the future.

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