Effect of sandblasting with different size of aluminum oxide particles on tensile bond strength of resilient liner to denture base

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ABSTRACT

Objectives: The purpose of this study was to investigate the bonding properties of sandblasted with different size of aluminum oxide particles denture base to silicone based soft denture liner. **Methods**: Polymethyl methacrylate (PMMA) test specimens were fabricated and then randomly assigned to 5 groups (*n*=15), according to the treatments applied, untreated (control, group 1), sandblasted with 50 µm Al_2O_3 (group 2), 60 µm Al_2O_3 (group 3), 120 µm Al_2O_3 (group 4), and 250 µm Al_2O_3 (group 5). The resilient liner specimens were processed between 2 PMMA blocks. Bonding strength of the liners to PMMA was compared by tensile test with the use of universal testing machine at a crosshead speed of 5 mm/min. The mean value and standard deviation of the specimens were statistically evaluated by 1-way ANOVA and post hoc Tukey-Kramer multiple comparisons tests (α=0.05). **Results:** The highest mean force value was observed in group 4 specimens, and the lowest mean force value was observed in group 2 specimens. The differences between groups 1 and 4 was found to be statistically significant (*p*=0.001). Nevertheless, there was no statistical difference in tensile bond strength between groups 1 (control) and groups 2, 3, and 5 specimens. **Conclusions:** Different particle sizes of aluminum oxide particles affect the bond strength of PMMA/resilient liner. Furthermore, 120 µm Al_2O_3 particles are the best particle size to improve strength of the bond.

Keywords: Sandblasting, tensile bond strength, soft liner, aluminum oxide.

INTRODUCTION

Soft liners which are intended for relining removable dentures and other oral and maxillofacial prostheses are used to evenly distribute the forces applied to soft tissues during function.[1] They are used to provide comfort for patients who present alveolar ridge resorption, chronic soreness, knife edge ridges,[2] traumatized oral mucosa, bruxism, bony undercuts,[3,4] and congenital or acquired oral defects requiring obturation.[4,5]

A reliable bond between denture base and soft liner is required for the denture to function properly, however, the achilles heel of silicone products is often an inadequate bonding to the denture base.[6] The most common reason for failure of soft-lined dentures is the basic structural difference of the two materials.[7] Silicone-based resilient lining materials are similar in composition to silicone impression materials. Both are dimethylsiloxane polymers.[2] Several studies have been conducted to improve bond strength between liners and acrylics. Craig and Gibbons[8] advocated a roughened surface to improve the adhesive bond. They reported that adhesive values obtained with the roughened surface were

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approximately double those of the smooth surface. Recently, alumina abrading,[4,9-12] lasers,[4,11-13] chemical etching or primers, acrylic burs, and net woven glass fiber[14] have been shown to provide a relatively safe and easy means of roughening the surface of materials. Sandblasting is routinely applied in general industry to provide surface roughening making materials more bondable. It has a variety of applications, such as in ceramic[15-18] and composite repair procedures,[19-21] indirect composite bonding,[22] bonding of glass fiber post,[23] polymethyl methacrylate (PMMA)-soft denture liner bonding,[4,11,12] for pretreatment of metal surface in metal–ceramic restorations,[24] or as a part of a tribochemical silica-coating process.[25]

Sandblasting procedure involves spraying a stream of aluminum oxide particles against the material surface intended for bonding under high pressure.[26] Sandblasting systems rely on particle abrasion with different particle sizes ranging from 30 to 250 µm. The abrasive process removes loose contaminated layers and the roughened surface provides some degree of mechanical interlocking or 'keying' with the adhesive.[27] Such conditioning systems could be applied either at the laboratory or chairside, using large or small size particles. It can be argued that the increased roughness also forms a larger surface area for the bond. Moreover, the information on the effect of sandblasting with large or small particle size on bond strength of acrylic resin denture base and soft lining material is lacking. Therefore, the purpose of this study was to investigate the effect of sandblasting with different size of aluminum oxide particles on tensile bond strength of resilient liner to denture base. The null hypothesis tested was that strength of the bond between liner and denture base is not affected size of aluminum oxide particles.

MATERIALS AND METHODS

The soft liner used in this study was a silicone-based material (Permaflex, Kohler, Neuhausen, Germany) and the denture base material was a heat-cured polymerized acrylic resin (Paladent, Heraeus Kulzer, Hanau, Germany). For tensile bond strength testing of specimens, gypsum (Moldabaster S, Heraeus Kulzer GmBH, Hanau, Germany) molds were prepared with dumbbell-shaped brass 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 cured in a manner similar to that used in conventional denture construction. The heat-polymerized acrylic resin was processed according to the manufacturer's instructions. After the acrylic specimens were removed, finishing was performed. Then, 3 mm of the material was cut from the thin midsection using a water-cooled diamond edge saw (model no. 11-1280-250, Buhler Ltd., Lake Bluff, IL, USA). Eventually, a total of 150 test specimens were prepared. Specimens were then randomly assigned to 5 groups (n=30), according to the surface treatments applied. Bonding surfaces of specimens were sandblasted (Ney, Blastmate II, Yucaipa, CA, USA) with different size of aluminum oxide particles, and the surface treatments performed on each group were as follows:

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

Group 2— 50 µm Al_2O_3 at 2 bar for 10s.

Group 3— 60 µm Al_2O_3 at 2 bar for 10s.

Group 4— 120 µm Al_2O_3 at 2 bar for 10s.

Group 5— 250 µm Al_2O_3 at 2 bar 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 rinsed under running water then dried with oil-free compressed air to remove the remnants.

After surface preparations, the specimens were secured in the gypsum (Moldabaster S; Heraeus Kulzer GmbH) molds, and the specimens and relining material were polymerized. This process was carried out according to manufacturer's instruction (for 2 h in boiling water). The processed molds were left to cool at room temperature for 20 min, and were then placed under running tap water for 10 min. Specimens were then stored in distilled water at 37 ^{0}C for 1 week. All specimens were placed under tension until failure in a universal testing machine (Lloyd LF Plus; Ametek Inc, Lloyd Instruments, Leicester, UK) at a crosshead speed of 5 mm/min. The maximum tensile stress before failure was recorded for each specimen. Failure strength was recorded in newtons and for each specimen, the bond strength (in megapascal) was calculated using the following formula:

$$\text{Bond strength (N/mm}^2\text{)} = \frac{F}{A}$$

Where F is maximum force (N), and A is cross-sectional area (mm^2). Modes of failure were visually determined for every specimen after testing and categorized into one of the following types:

1- *Adhesive failure* refers to total separation at the interface between the resilient liner material and acrylic resin.
2- *Cohesive failure* refers to tear within the resilient liner material.
3- *Mixed failure* refers to both.

The mean value and standard deviation of the specimens were statistically evaluated by 1-way ANOVA and post hoc Tukey-Kramer multiple comparisons tests (α=0.05).

RESULTS

The results of the tensile bond strength test for sandblasting with different size of aluminum oxide particles are shown in Table 1. Silicone resilient lining material applied to the sandblasted PMMA resin surface with 120 µm Al_2O_3 particles recorded the highest mean tensile strength and differences between groups 1 and 4 was found to be statistically significant (*p*=0.001). In addition, lining material applied to the sandblasted PMMA resin surface 50 µm Al_2O_3 particles recorded the lowest mean tensile strength. Moreover, there was no statistical difference in tensile bond strength between groups 1 and group 2 (*p*=0.255), 3 (*p*=0.999), and 5 (*p*=0.073).

Modes of failure are presented in Table 2. Only group 1 specimens (control) predominated in adhesive failures (80%). Nevertheless, 73% of groups 2 and 3, 93% of group 4 and 100% of group 5 specimens presented mixed failures.

Table 1. Mean tensile bond strength and SD of each group.

Groups	Mean (N)	SD
Group 1	0.88^a	0.09
Group 2	0.73^a	0.06
Group 3	0.9^a	0.21
Group 4	1.2^b	0.27
Group 5	1.09^a	0.29

n=15, F=11.682, df=4 and groups with same superscripted letters not significantly different (p>0.05).

Table 2. Mode of failures of groups for each specimen.

Groups	n	Adhesive failure	Cohesive failure	Mixed failure
Group 1	15	12	—	3
Group 2	15	4	—	11
Group 3	15	4	—	11
Group 4	15	—	1	14
Group 5	15	—	—	15

DISCUSSION

The results of the present study support rejection of the hypothesis because altering the PMMA surface by sandblasting with 120 µm Al_2O_3 particles significantly increased the bond strengths in PMMA/silicone specimens. There has been no concensus in the literature regarding sandblasting or the best particle size for optimum bond strength. In the present study, sandblasting with 250 µm Al_2O_3 particles of the PMMA before resilient-material application resulted in higher mean tensile bond strengths than those of control specimens, but these increases were not statistically significant. Our results are in compliance with the earlier report by Usumez et al.[4] who showed that sandblasted with 250 µm Al_2O_3 PMMA resin surface recorded higher tensile bond strength than Nd:YAG lased and control groups, however, there was no statistical difference in tensile bond strength between all groups. Our results are partially in agreement with Jacobsen et al.[11] who advocated that surface treatment with 250 µm Al_2O_3 particle and lasing were found ineffective on the bond strength of the soft liners. Because, they also reported that sandblasting with 250 µm Al_2O_3 particle reduced the bond strength of the PMMA/soft liners. Furthermore, consistent with the present study, Akin et al.[12] reported that sandblasting with 50 µm Al_2O_3 particle before applying a lining material had a weakening effect on the bond. The interfacial stresses introduced can be resulted in this reduction. Another possible cause of the weakened bond strength was an insufficient flow of the soft liner into the irregular cavities created by sandblasting.[28]

Nevertheless, little information is available on the effect of surface treatments with sandblasting on the bonding of PMMA and soft liner. Storer[9] reported that sandblasting the acrylic resin surface before placing a resilient lining material improved the strength of the bond with a slightly irregular surface provided mechanical locking for the soft material. To the contrary, Amin et al.[10] advocated roughened acrylic resin base by alumina abrasion before applying a lining material had a weakening effect on the bond. However, Katsumata et al.[29] showed that sandblasting with 30 µm Al_2O_3 particle of PMMA increases the shear bond strength of an autopolymerizing resin to a nylon denture base polymer. Moreover, Chung et al.[26] researched on the bond strength between acrylic teeth after various surface treatments (control, grinding and grinding plus sandblasting with 250 µm Al_2O_3 particle) and processing with either a heat- or microwave-polymerized denture base material. They found that acrylic tooth surface preprocessed surface treatment with grinding plus sandblasting and processed with a heat-polymerized denture base provided the greatest bond strength between acrylic tooth and denture base.

Wang et al.[30] investigated the method of increasing the bond between titanium and porcelain by the use of sandblasting with different particle sizes (50 and 125 µm Al_2O_3 particles) and steaming treatment on the titanium surface in order to find out the optimal method for improving the bond strength of titanium and porcelain. They found that when the titanium surface was sandblasted with alumina particles, the surface roughness was significantly increased and the bond strength of porcelain to titanium tended to increase. However, no statistically significant differences were detected in bond strength among control and sandblasting (both sizes, 50 and 125 µm Al_2O_3 particles), although the surface roughness increased as the particle size of alumina increased. Contrarily, in our study, sandblasting with 120 µm Al_2O_3 particles significantly increased the bond strengths of PMMA and liner.

Kulak-Ozkan et al.[31] investigated the effect of thermocycling on tensile bond strength of six silicone-based resilient denture liners and reported that the tensile bond strength of Permaflex decreased after thermocycling. However, this decrease was not found to be statistically significant. Therefore, in the present study, aging of the specimens was not performed.

On failure after tensile bond strength testing, different failure types were observed among the groups. According to Usumez et al.,[4] sandblasted (nine adhesive failures, one cohesive failure), and control specimens (10 adhesive failures) were dispersed between adhesive failures. These results are partially in agreement with our study in which adhesive failures in control group and mixed failures in sandblasted groups was found.

CONCLUSIONS

Within the limitations of this study, it was found that different sizes of alumina particles affect strength of the bond. Moreover, the tensile bond strength of PMMA/resilient liner can be improved by application of sandblasting with 120 µm Al_2O_3 particles.

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