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Original Article

Bond Strength Evaluation Between Surface-Treated Denture Teeth and Injection Molded PMMA Denture Bases

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ABSTRACT

This study aimed to investigate the shear bond strength of PMMA teeth treated with ridge lap surfaces and high-impact injection-molded denture foundations. A black line was drawn 1 mm above the ridge lap area on 51 samples. The samples were divided into three groups: diatoric cavity ridge lap samples (group C), sandblasted ridge lap samples (group B), and the control group (group A). The samples were then placed in a 7.5 x 7.5 mm mold. The shear bond strength of the retrieved samples was evaluated using a universal testing machine, and the wax patterns were created using injection molding. Groups A, B, and C had mean shear bond strengths of 991.29, 1038.71, and 1187.41, respectively, with a P-value of 0.010. There was a statistically significant difference between groups C and A (P-value > 0.05). The results obtained were statistically analyzed using SPSS version 17, especially post hoc tests and one-way ANOVA analysis. This analysis revealed that the samples in group C had a higher shear bond strength due to the preparation of the diatoric cavity, increasing the surface area of the ridge lap section.

Keywords: Diatoric cavity, Injection molding technique, High-impact resin, Ridge lap surface, Sandblasting

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Introduction

The two most widely accessible materials for edentulism rehabilitation are acrylic and porcelain teeth. However, as an operational component with an acrylic resin denture foundation, acrylic resin teeth are usually preferred over porcelain teeth since they are chemically linked to produce a stronger one-unit denture [1].

Acrylic resin dentures have an unreasonably high fracture failure rate [2], with tooth fracture or debonding being the most common failure type [3]. At roughly 33%, the most common kind of denture failure happens between an acrylic resin denture base and an acrylic resin tooth [4, 5]. Studies have shown that debonded teeth account for 26-33% of denture repairs, which frequently causes patients to experience financial hardship and grief [6–8]. The direction of the tensions that emerge during the functions and the reduced ridge lap surface area that is available for connections are probably the reasons for this separation. The majority of denture base denture and tooth bond failures were cohesive or adhesive [9–12]. When there was no sign of denture base material on the tooth ridge laps following a fracture, an adhesive failure occurred. Also, when residues of the denture base material were found on the ridge lap of the teeth after the fracture connection, the failure was considered a cohesiveness failure [9]. Changing bond interfaces due to laboratory mistakes, the kind of resin base material used, the existence of impurities on the tooth surface that are in intimate contact with the denture base, and its chemical and physical characteristics can all affect adhesive failure [13–16].

According to studies, altering the surface of the acrylic tooth's ridge lap will significantly improve the tooth's bonding properties. Additionally, numerous research has supported various tooth surface alterations. However, the strength of polymers is always influenced by the sort of polymerization procedure used. According to several studies, the injection molding polymerization approach appears to offer more dimensional stability, precision, and strength than both traditional and microwave polymerization techniques. However, no research has been done to assess the bond strength of acrylic teeth that had been surface-modified and polymerized using the injection molding approach. The objective of the present research was to examine the shear bond strength of PMMA teeth treated with ridge lap surfaces and high-impact injection-molded denture foundations.

Materials and Methods

A total of 51 polymethyl methacrylate (PMMA) maxillary right central incisors (SR IVOSTAR Small-bold 41of Ivoclorvivadent, USA) with measurements of 9.6 mm inciso cervically and 7.7 mm mesiodistally were selected. A black line was scribed around the cervical area, 1 mm above the bottom of the tooth (ridge lap area) using a vernier caliper. Then the samples were grouped as,

Group A – 17 samples - No surface treatment (Control)
Group B – 17 samples – Sandblasting on the ridge lap surface
Group C – 17 samples – Diatoric cavity on the ridge lap surface

Surface treatment

Samples from group A act as the control group and won't have their ridge lap surface treated in any way. A 3 x 3 cm putty index (Aquasil soft putty, Dentsply, India) was made for the samples in groups B and C to secure the tooth while surface care was being performed. 50 µm aluminum oxide particles (Aluminox, Delta, Chennai, India) were applied to the ridge lap region of group B samples at 4 psi of pressure while being kept 1 cm away for 10 seconds. Group C samples were modified to have a diatoric cavity (2.3 mm diameter x 2 mm depth) utilizing round bur no. 8 (Midwest, Dentsply, India) in a milling machine (Amann Girrbachaf 350, Austria) at an acceleration of about 40,000 rpm **(Figure 1)**. To maintain process standardization, eleven samples were surface-treated by a single observer in just one day.

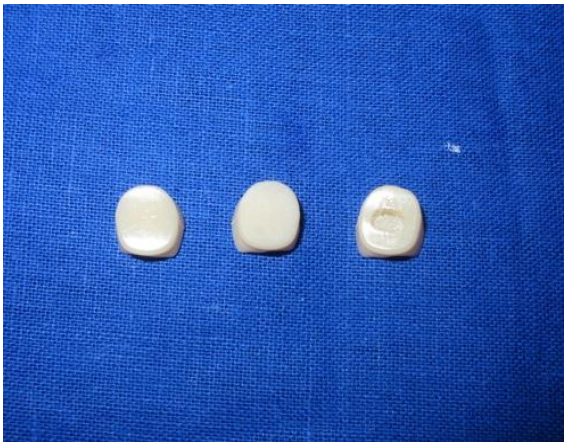

Figure 1. Surface-treated samples of groups A, B, and C

Mold preparation

For the creation of the specimens, a square metal mold with eight holes measuring 7.5 mm in diameter and 7.5 mm in height and a flat base was built **(Figure 2)**.

Figure 2. PMMA tooth attached to the mold

Specimen preparation

The mold was filled to the top with modeling wax (Hindustan modeling wax No. 2, India). Following surface treatment and control, the PMMA teeth were immersed up to the scribed cervical line, which forms a 45° angle with the flat base of the wax. The samples' wax patterns were created utilizing type 2 dental stone (Gyprok, Australia) and placed in a single flask (Ivoclar BPS preparation flask, USA). About eight specimens were created in a day using single flasks under the supervision of a single observer to standardize the process. The polymer substance was injected through wax rollers that connected each of the eight specimens in each flask. The counterpart was then put together.

The flask was dewaxed by submerging it in a water bath set at 100 °C for roughly ten minutes. After that, the flask was taken out and washed to get rid of any leftover wax. The mold was coated with a coating of

splitting media (Ivoclar Vivadent Splitting Fluid, USA). The flask's two elements were reassembled. For the acrylization, pre-measured capsules of heat-cure acrylic resin (SR Ivocap, Ivoclar Vivadent, USA) were used. The flask component was linked to a vibrator (Cap vibrator, Ivoclar Vivadent, USA), which was employed to mix the monomer and polymer capsules. The assembly was fastened to a polymerizing machine, which uses 6 pa of pressure to force the resin substance into the mold cavity. For the polymerization to take place, the assembly was later submerged in a hot water bath that increased from 37 °C to 100 °C in roughly 45 minutes. After retrieving the flask, it was left on the bench to cool for roughly half an hour. After that, the samples were taken out of the mold, and abrasive and polishing agents were used to finish and polish them **(Figure 3)**. The manufactured samples were kept at room temperature in distilled water until testing was completed to avoid any distortion.

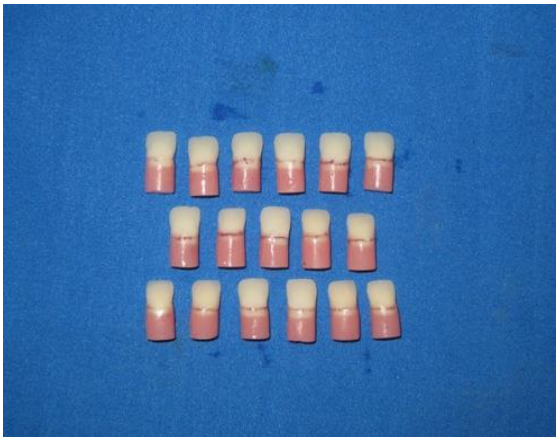

Figure 3. Processed and finished samples

Measuring shear bond strength

To determine the strength of the shear bond, the samples are subsequently placed into a universal testing machine (Autograph-Shimadzu, Japan). The specimen's acrylic cylindrical components were attached to the UTM machine at a 45° angle. A cylindrical pin with a cross-head speed of 0.5 mm/min was used to apply the load to the incisal portion from the lingual aspect. The digital bond strength values were recorded after the load was applied until the tooth fractured. Newton's (N) was used to display the values that were acquired. The usable surface area was not calculated because of the teeth's ridge lap surface's complicated topology. Newton's measured failure load was therefore converted to Kgf. The binding strength was determined using the following formula.

$$B = F/A \quad (1)$$

Where, A – surface area (mm^2)

F – Load at fracture (N)

B – Bond strength (MPa)

The data in Megapascals (MPa) were examined statistically, applying the post hoc test and one-way ANOVA employing SPSS version 17.

Results and Discussion

It was determined that there were notable variations in the shear bonding strength between acrylic resin and PMMA teeth that had been surface-treated and those that had not. The bond strength of each group as evaluated by the Universal testing machine was statistically analyzed using one-way ANOVA and the post hoc test.

Table 1 displays the mean and standard deviation of the shear bond strength of PMMA teeth with acrylic denture bases that have been surface-treated and those that have not. Groups A, B, and C had mean shear bond strengths of 101.03 ± 17.2, 105.88 ± 24.5, and 121.07 ± 13.8 Kgf, respectively, with a p-value of 0.010. It was determined that the mean shear bond strength was within medically acceptable boundaries. Groups C and A and groups C and B differed from one another in a statistically meaningful way.

Table 1. Mean and SD of shear bond strength of groups A, B, and C

Groups	N	Mean	SD	Std. Error	95% CI		Minimum	Maximum
					Lower range	Upper range		
A	17	101.035	17.219	4.176	92.182	109.888	66.500	132.800
B	17	105.882	24.587	5.963	93.241	118.524	57.100	148.400
C	17	121.071	13.854	3.360	113.947	128.194	100.700	146.700

Group C's value was around 121.071 kg, which was substantially higher than groups A and B's values of 101.035 and 105.882 kg, respectively, as indicated in **Table 2**.

Table 2. Oneway ANOVA for groups A, B, and C

Source of variations	Sum of squares	df	Mean square	F value	P- value
Between groups	3715.007	2	1857.504	5.099	0.0098

Within groups	17487.379	48	364.320
Total	21202.386	50	

Table 3 demonstrates a substantial distinction between the group C and group A data, with a mean differential of 20.035 and a P-value of 0.01 for the post-hottest. However, group B samples are not much different from groups A and C samples.

Table 3. Using the post hoc test (Bonferroni test), groups A, B, and C's shear bond strengths are compared between groups.

Group	Comparison	Mean difference	Std. Error	P-value	Interpretation
A	B	-4.847	0.740	> 0.05	NS
	C	-20.035	3.060	< 0.05	S
B	A	4.847	0.740	> 0.05	NS
	C	-15.188	2.320	> 0.05	NS
C	A	20.035	3.060	< 0.05	S
	B	15.188	2.320	> 0.05	NS

The mean and SD for each of the three study groups are plotted in **Figure 4** with the groups on the X-axis and the numbers of measurements on the Y-axis. Group C's mean bond strength was 121.07 ± 13.8 Kgf, greater than group B's and group A's respective means of 105.88 ± 24.5 Kgf and 101.03 ± 17.2 Kgf.

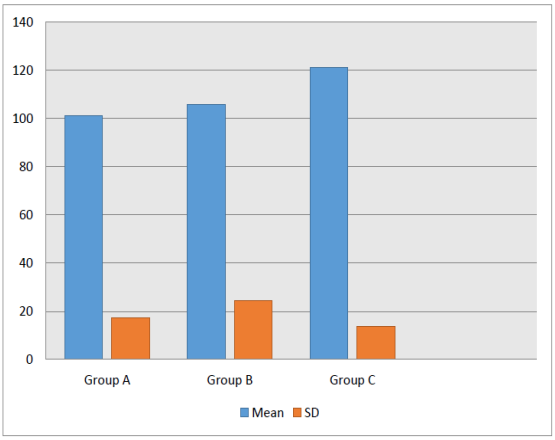

Figure 4. Graphical representation of mean and standard deviation of groups A, B, and C

The primary component of acrylic resin teeth is polymethylmethacrylate, which has undergone extensive mutation to improve its fundamental characteristics by adding other monomer units, cross-linkers, and fillers [17]. In most cases, cross-linking agents increase the prosthesis's physical strength and resistance to crazing. Conversely, cross-linking agents stop monomers from diffusing onto surfaces [18, 19]. To improve bonding with acrylic denture base resin, the ridge lap surface of the acrylic teeth is therefore designed to be minimally cross-linked [19]. The injection molding technique attracted attention among the various denture manufacturing methods because of its ability to prevent polymerization shrinkage by constant pressure injection of acrylic resin [20]. Therefore, when it comes to acrylic resins, the injection molding polymerization approach was thought to be more careful than the traditional compression molding technique [9].

The most frequent cause of failure was either tooth fracture or debonding and acrylic dentures have a very high number of failures because of breakage [21, 22]. However, manufacturers have disclosed little to nothing about the bond strength of acrylic teeth and acrylic denture foundation resin, in addition to studies comparing the shear bond strength of PMMA teeth connected to an injection-molded denture base material. Numerous types of literature have demonstrated that wax residues or other impurities on the acrylic teeth's ridge lap surface would weaken the bonding ability at the denture-tooth interface [23–25]. Additionally, it had been taken into account when the samples were being prepared. To ensure that there were no residues on the ridge lap surface, every sample was meticulously cleaned. This improved the way that the acrylic tooth and denture base resin bonded together. The shear bond strength of group C samples in this investigation, who evaluated the binding strength of acrylic teeth that had been changed with or without mechanical retentive grooves and polymerized using conventional denture base resin and high-impact. The mechanical retentive grooves were positioned across the ridge lap surface in that investigation in a horizontal and vertical orientation. They stated that the binding strength of denture base resin and acrylic teeth will be increased by widening the surface area for physical and

chemical bonding. Furthermore, numerous other experiments have demonstrated that mechanically altering the acrylic teeth's ridge lap part will greatly alter the teeth's ability to bind [27-30].

Acrylic resin teeth with rough inner surfaces had the lowest bond strength values, according to a study that evaluated the surface roughness of modified acrylic teeth using a scanning electron microscope [9, 31]. This finding is contradicted by the current investigation, which found that surface treatment significantly increased the bonding properties of acrylic teeth [32–34]. Numerous investigations have acknowledged a notable increase in bond strength of roughly 250 µ following alumina sandblasting, indicating that this is because of better micromechanical retention [35–37]. Sandblasting group B samples with 50µ of alumina in this investigation produced a similar increase in shear bond strength, which may be because there was more surface area available for bonding.

There are differing findings about how different surface treatments affect the shear bond's strength, which could be because different bond-testing techniques, measurement tools, and study experimental designs were used. The study had certain limitations because it only looked at the mechanical changes made to the acrylic teeth's ridge lap section. Chemical surface treatments or a combination of chemical and mechanical surface treatments may affect the study's findings. A mixture of mechanical and chemical modifications to the ridge lap section of different acrylic tooth strands utilizing denture base resin material that simulates the intraoral surroundings may be part of the research's future scope.

Conclusion

By creating a diatoric cavity on the ridge lap region of denture teeth, the surface area is increased, strengthening the binding between the injection-molded denture base and the acrylic tooth.

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Conflict of Interest: None

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Ethics Statement: The study was approved and completed as per the research protocol approved by the Institutional Review Board with the approval number SRMDC/IRB/2015/MDS/No.208.

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