

Comparative Evaluation of Shear Bond Strength between Acrylic Teeth and Denture Base Material after Four Different Types of Surface Treatment – An *In Vitro* Study

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Abstract

Background: Acrylic teeth have been in use in dentistry for decades in the fabrication of completed dentures with increased use of implants supported overdentures; the use of acrylic teeth and resin denture bases have further increased de-bonding of acrylic teeth from denture base is the common mode of failure. The following study is undertaken to evaluate the durability of adhesion between acrylic teeth and denture base after surface conditioning methods, which includes a combination of mechanical and chemical treatment. **Materials and Methods:** A sample size of 80 molar acrylic teeth was selected; all the samples were divided into four groups depending on surface conditioning methods before acrylization, that is, each group of 20 samples. Group 1 was the control group; Group 2 was the silage coupling agent used for surface treatment. Group 3 cyanoacrylate was used as surface treatment. Group 4 methyl methacrylate (MMA)-based bonding agent. After acrylization and specified dimensions, the samples were loaded perpendicular at interface of acrylic teeth and denture base, using universal testing machine till catastrophic failure occurred. **Results:** Comparison of fracture resistance of four different groups showed mean value of Group 1 – 368.23 N, Group 2 – 486.09 N, Group 3 – 265.68 N, and Group 4 – 525.05 N. There was statistically significant difference of bond strength between groups as determined by one-way ANOVA ($F [3.76] = 50.98, P < 0.00001$). **Conclusion:** MMA-based bonding agent had the highest bond strength. Silane coupling agent increased the bond strength significantly compared to control group. Cyanoacrylate surface treatment had least bond strength acting as interference instead of bonding agent.

Keywords: Acrylic teeth, Catastrophic, Cyanoacrylate, Methyl methacrylate.

INTRODUCTION

The most common reason for the elderly to seek dental treatment is for the replacement of missing teeth.^[1] The reason for the continued popularity of acrylic resins in dentistry is the simple processing equipment required and the relatively low cost of the fabrication process.^[2] Because of the increase in the number of implant-supported dentures, the use of acrylic denture teeth has also increased markedly.^[3] According to Cunningham *et al.*, approximately 30% of all denture repairs received by commercial dental laboratories involved faults attributed to failed bonding between the teeth and the denture base resin.^[1] Attempts to improve bond strength between denture base and teeth include mechanical preparation, etching or bonding with chemicals, priming with methyl methacrylate (MMA) liquid, and wetting organic solvents of the tooth

surface.^[4] Previous studies have drawn heavily on the methods described in the specifications, and the products evaluated were diverse in nature, ranging from “plain acrylic teeth” to interpenetrating polymer network (IPN) teeth, and from auto polymerizing denture base resin to high-impact polymers. In this work, the products were restricted in range and more emphasis was placed on technique rather than material

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structure.^[5] Many studies have been conducted to evaluate the bonding between the acrylic teeth to denture base resin using different surface treatments. Silane coupling agent as a surface treatment was used in past over porcelain teeth for bonding with denture base material. Role of coupling agent on acrylic teeth is to be more studied. Bonding effect of cyanoacrylate with denture base material too needs to be further evaluated. The following study was undertaken to compare shear bond strength between acrylic teeth and heat cure denture base resin using cyanoacrylate, coupling agent, and MMA based bonding agent.

The null hypothesis considered was that the bond strength of denture base resins to acrylic teeth would not be affected by the surface treatment of ridge lap area.

MATERIALS AND METHODS

A total of 80 mandibular and maxillary first molar acrylic denture teeth were selected. All the samples were divided into four groups depending on surface conditioning methods. That is every group of 20 samples. Tapered metal cylinder was fabricated with openable lid at the base for easy removal of wax tooth assembly (Figure 1).

The ridge lap surface of all molars was modified and made flat using acrylic trimming bur and finished using 220 grit dry and wet sandpaper. Uniformly heated molten modeling wax was then poured into the metal mold. The wax was allowed to cool to the room temperature. The prepared acrylic molar was properly positioned and sealed (Figure 2).

The lid of the base was opened and the assembly was gently pushed to withdraw from the metal mold. All 80 wax assemblies were similarly obtained and stored in water. Wax block patterns were invested in the flask and dewaxing was done. Base and counter of the flask were then separated and the residual wax was removed by flushing boiling water into the mold.

Surface conditioning method, Group-1 ($n = 20$): This group acted as a control group with only surface treatment using 220

grit dry and wet sandpaper on the bonding surface, done before flasking and dewaxing procedure (Figure 3).

Group-2 ($n = 20$): The bonding surface was etched using 37% phosphoric acid for 15 s. Further, the surface was washed thoroughly using distilled water for 15 s. Surface was air dried and the coupling agent was applied on the surface using applicator tip with uniform coating (Figure 4).

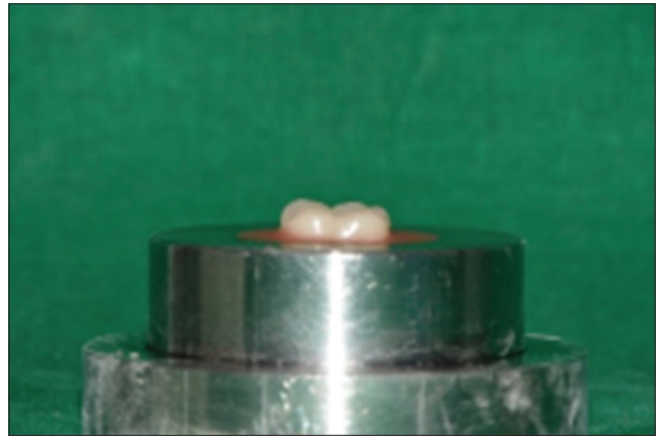


Figure 2: Prepared acrylic molar sealed with wax assembly



Figure 3: Group 1 surface treatment using 220 grit dry and wet sand paper on bonding surface

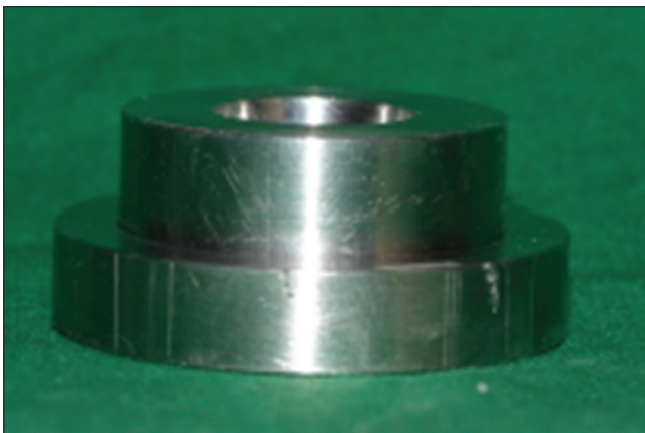


Figure 1: Tapered metal cylinder for easy removal of wax tooth assembly

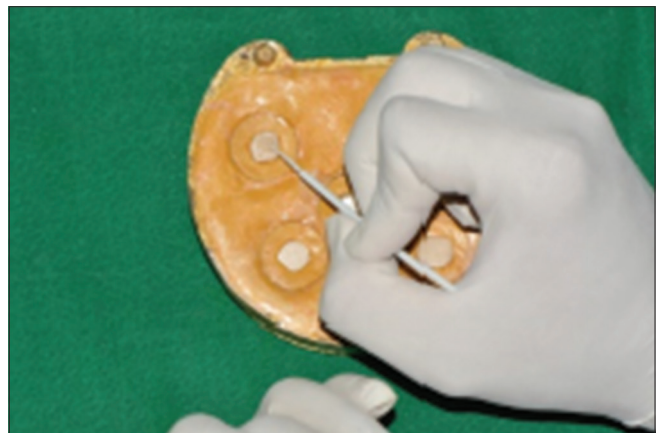


Figure 4: Group silage coupling agent application using applicator tip

Group-3 ($n = 20$): The cyanoacrylate was applied directly on the bonding surface with the help of tip of the dispensing bottle and allowed to dry for next 5 min (Figure 5).

Group-4 ($n = 20$): The MMA-based bonding agent (super bond) used was a Brush-dip kit. The surface preparation included application of etchant directly from the syringe for 30 s provided with kit followed by rinsing with water and air drying (Figure 6).

The polymer was dispensed in the dispensing cup; activated liquid was prepared by dispensing the monomer and catalyst V according to the manufacturer instructions and applied on the bonding surface with the brush provided. Another tip of brush dipped in the activated liquid was used for picking and applying the polymer ball on to the bonding surface (Figure 7).

Heat-cured denture base resin (Probase, ivoclar Co.) was manipulated according to manufacturer's instructions and packed into the mold space in dough consistency. Bench curing was done for 8 h and the flask and clamp together were placed into the thermostatic acrylization unit at room temperature. The temperature was gradually raised and resin was polymerized by long curing cycle at 74°C for 9 h and at 100°C for 1 h in

thermostatic acrylizing unit. Bench cooling was allowed and deflasking was done to obtain the acrylized specimens and was stored in water before finishing and polishing.

The final finishing and polishing was performed using acrylic trimming burs, sandpaper of grit 100, 220, 320, followed by buffing using pumice powder and polishing cake (Figure 8).

The specimens were trimmed to a final dimension of 7-mm mesiodistally and 5-mm buccolingually on the polishing machine incorporated with sandpaper of grit 100. The dimensions of every block were evaluated using the digital caliper.

Shear bond strength testing and measurements: The samples were loaded from buccal surface perpendicular at the interface of acrylic teeth and denture base, using universal testing machine with chisel at a crosshead speed of 5 mm/min. The specimens were loaded till catastrophic failure occurred and ultimate load was recorded.

RESULTS

Our observation revealed that Table 1 compares the fracture resistance of four different groups.

The mean value of bond strength for Group 1, that is, the control group, was 368.23N with a standard deviation of



Figure 5: Group 3 cyanoacrylate application directly on bonding surface with help of dispensing bottle

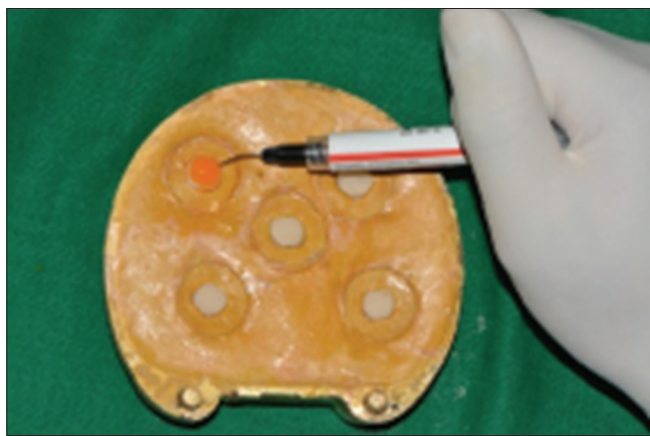


Figure 6: Group 4 methyl methacrylate based bonding agent (super bond) used as brush dip kit



Figure 7: Application of polymer ball on bonding surface



Figure 8: Final finished acrylic assembly

72.93. The mean value of bond strength for Group 2, that is, coupling agent group was 486.09 N with a standard deviation of 89.37. The mean value of bond strength for Group 3, that is, cyanoacrylate adhesive group was 265.68 N with a standard deviation of 71.95. The mean value of bond strength for Group 4, that is, (MMA-based) bonding agent group was 525.05 N with a standard deviation of 57.34.

Table 2 displayed a comparison of shear bond strength between groups – ANOVA test.

The F-value for comparison between the groups and within groups obtained was 50.95. *P*-value obtained was <0.0001.

There was a statistically significant difference of shear bond strength between groups as determined by one-way ANOVA ($F [3.76] = 50.98, P \leq 0.00001$).

Table 3 highlights multiple comparisons using *post hoc* Dunnett Multiple Comparisons Test with control group. When Group-1 was compared to Group-2, a mean difference obtained was -117.86 and $P < 0.01$, making it statistically significant. When Group-1 was compared to Group-3, a mean difference obtained was 102.55 and $P < 0.01$, making it statistically significant. When Group-1 was compared to group-4, a mean difference obtained was -156.82 and $P < 0.01$, making it statistically significant.

Graph-1 provides a comparison of shear bond strength between four groups indicate that Group-4 showed the highest mean for shear bond strength with the value of 525.05. Group-2 showed the second highest mean for shear bond strength with the value of 486.09. Group-1 that is control group showed mean for shear

bond strength with the value of 368.23 which was better than Group-3 with the value of 265.68.

DISCUSSION

Although complete dentures cannot be considered a substitute for natural teeth, they have been and would probably remain, the staple treatment for edentulous patients.^[6] Debonding of acrylic teeth from denture base remains a major concern in prosthodontics practice. It has been estimated that between 22% and 30% of denture repairs involve tooth debonding.^[7,8]

Chung *et al.* tested in his study that acrylic teeth polymerized with either heat or microwave-polymerization bonded satisfactorily. Nevertheless, the microwave-polymerized subgroups exhibited lower bond strengths, indicating that the method of polymerization influenced tooth-to-base bond strength, microwave polymerization was reported to have uncontrolled temperature rise, causing the denture base components to heat above the boiling point of monomer and resulting in the formation of pores. Thus causing increased porosity, which reduces denture base strength.^[8,9]

Cunningham compared the shear bond strength of acrylic teeth with heat and light-cured denture base resins.^[10] The VLC resin was processed in a light curing unit for 10 min and load was applied at a crosshead speed of 2.5 mm/min and bond strength recorded in Newtons. The VLC resin failed to achieve the same degree of tooth attachment as heat-cured resin.^[9]

Hence, in the present study, the heat cure denture base resin (Probase, Ivoclar) was preferred over microwave-polymerized and light-polymerized denture base resins.^[11]

Three important criteria required for the structure and function of durable denture teeth are as follows: Hardness/wear resistance, bond strength to the denture base resin, and esthetics.^[10,12]

In the present study, the cross-linked Acryrock acrylic teeth are been used, cross-linking improved the physical properties of acrylic teeth but simultaneously decreased the bonding efficiency between the acrylic teeth and heat cure denture base material.^[13,14] Hence, the present study was undertaken

Table 1: Descriptive statistics of the groups

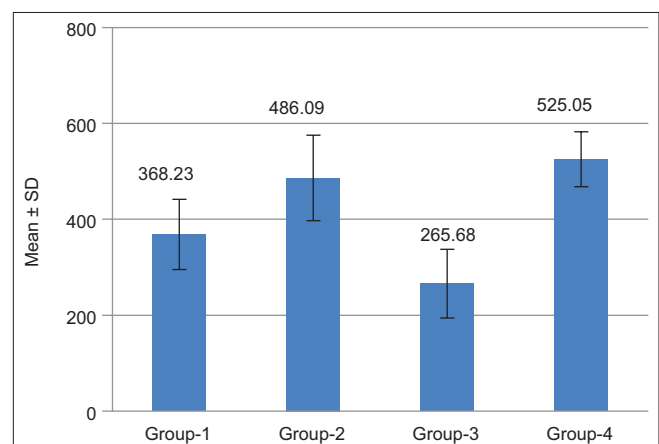
Group	Minimum	Maximum	Mean	SD
1	102.19	449.59	368.23	72.93
2	363.22	613.03	486.09	89.37
3	166.59	394.15	265.68	71.95
4	411.53	609.47	525.05	57.34

Table 2: Comparison of shear bond strength between groups – ANOVA test

Source	Df	SS	MS	F-value	P-value
Between groups	3	831852	277284	50.95	<0.0001
Within groups	76	413646	5442.7		
Total	79	1245498	8354.5		

Table 3: Multiple comparisons using *post hoc* Dunnett multiple comparisons test with control group

Group (I)	Group (J)	Mean difference (I-J)	P-value	Remarks
Group-1	Group-2	-117.86	<0.01	Significant
	Group-3	102.55	<0.01	Significant
	Group-4	-156.82	<0.01	Significant



Graph 1: Comparison of shear bond strength between four groups

to evaluate the shear bond strength after four different types of surface treatment were done on ridge lap surface of cross-linked acrylic teeth (Acryrock).^[15]

Lang *et al.* in his study evaluated that the failure load of bonding highly cross-linked denture teeth to acrylic resin can be significantly influenced by modifications to the base surfaces of teeth before processing.^[16,17] The highest bond values were observed for the heat-curing resin in combination with surface conditioning by sand-blasting and bonding agent. Tribochemical silica coating and silanization method revealed significantly higher bond on each tested denture base material and was recommended for pre-treatment application on teeth either with heat-cured or cold-cured denture base resin.^[11,18] Krishna *et al.* evaluated that chemical surface treatment of cross-linked acrylic teeth with cyanoacrylate gave least bond strength, even less than the control group.^[12,19] Considering the chemical surface treatment of the mentioned studies, the present study was undertaken to evaluate the bond strength using the MMA-based bonding agent, silane coupling agent, and cyanoacrylate as surface treatment.

According to Lang *et al.* tribochemical silica coating and silanization method revealed significantly higher bond on each tested denture base material and can be recommended for pre-treatment of teeth applying either heat-cured or cold-cured denture base resin.^[11,20,21] Accordingly, the Group-2 in which silane coupling agent was used, as a surface treatment, showed significant increase in the bond strength compared to control group.

Bond strength with cyanoacrylate adhesive surface treatment was found to be even less than that of control group. This may be because the set adhesive forms a layer at the interface of tooth and denture base resin which inhibits diffusion of monomer across the interface to form an IPN. Thus, cyanoacrylate interferes with chemical adhesion between the denture base and the tooth.^[3,6,22] The results of the present study using cyanoacrylate as a surface treatment (Group-3) were in accordance with the results of Krishna *et al.*

Meng *et al.* evaluated that the treatment of the denture tooth surface with the MMA-based bonding agent would dissolve the acrylic resin component of the denture tooth and cause the surface to swell, permitting the diffusion of repair acrylic resin to form an IPN with the treated denture tooth surface.^[4,23] Present study undertaken, in accordance with the above studies, showed similar results of a significant increase in bond strength when MMA-based bonding agent super bond is used as bonding agent (group-4).

For all specimens, interface where the failure occurred, were inspected. The failure was classified as adhesive or cohesive in nature. An adhesive failure occurred if there was no trace of denture base resin on the tooth surface or vice versa after fracture. Alternatively, cohesive failure occurred if there was any trace of denture base resin present on the surface of the acrylic tooth or remnants of the acrylic tooth present on the denture base. One of the most common types of failure

in a denture is adhesive type of bond failure between the acrylic resin polymer tooth and the denture base.^[12,24] Failure cohesively can be considered as an evidence to increase in bond strength between the tooth and the denture base so, cohesive and adhesive failures were also taken into consideration in the study. The type of failure simulated the results obtained from universal testing machine. The maximum percentage of cohesive failures was found with Group-4 that is surface treatment with bonding agent followed by the cohesive failures in Group-2 that is surface treatment with coupling agent, then group-1(control group) and the adhesive failures seen were maximum with Group-3 (cyanoacrylate group).

Limitations

It can be considered that the present study method and variables did not simulate all clinical conditions. Despite these limitations, the materials evaluated in this study are expected to perform similarly in oral environment. It is well accepted that *in vivo* performance does indeed differ from an *in vitro* setting. A long-term longitudinal study will help in evaluating the findings observed in the present study. In the present study, the shear bond testing was done within few days after acrylisation. The time gap of months and years after acrylization was not considered, which indeed could be the actual clinical situation/scenario.

In this study, a continually increasing static load was applied on the samples which are not the kind of loads in oral cavity. A study under cyclic loading would provide a better understanding for the findings observed in the present study.

Clinical significance

Surface treatment with MMA-based bonding agent and silane coupling agent can be applied on the ridge lap surface of acrylic teeth after dewaxing, to improve the bonding between acrylic teeth and denture base resin in complete denture prosthesis and implant supported over denture.

CONCLUSION

The shear bond strength after four different types of surface treatment, that is, treating with sandpaper, coupling agent, cyanoacrylate, and MMA -based bonding agent, were evaluated and compared. Within the limitations of this study, the following conclusions were drawn:

1. MMA -based bonding agent had the highest bond strength when used as surface treatment of bonding surface
2. The silane coupling agent increased the bond strength significantly compared to the control group
3. Cyanoacrylate application for surface treatment had the least shear bond strength, lesser than the control group, as it acted as interference instead of acting as a bonding agent at the inter.

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