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ORIGINAL RESEARCH

Shear Bond Strength of Acrylic Teeth to Acrylic Denture Base after Different Surface Conditioning Methods

Gajula Venu Madhav, Soundar Raj, Naveen Yadav, Ishitha Mudgal, Nidhi Mehta, Riddhi Tatwadiya

ABSTRACT

Background and Objectives: Acrylic resin ruled the dental profession for 60 years, and this success is attributed to its aesthetics, handling properties, physical and biological compatibility, its stability in oral environment and its cost effectiveness. The objective of this study is to evaluate and compare the bond strength of acrylic resin teeth treated with various conditioning materials like monomer and silane coupling agent.

Methdology: A study was carried out in which 96 samples were grouped into 3 groups with a sample size of 32 each (16 premolars, 16 molars). They were conditioned with different conditioning materials i,e monomer and silane coupling agent. Monomer, Silane coupling agent are coated on the ridge lap area before thermocycling and cured according to the manufacturer recommendations. The samples are retained from the flask; trimmed and polished. The samples are then subjected to shear bond strength using the Insteron Universal Testing Machine.

Results: In the present study it was found that application of monomer increased the bond strength between acrylic teeth and denture base, when compared to the conventionally processed samples. However it was found that application of silane coupling agent further increased the shear bond strength between acrylic teeth and denture base.

Interprations and conclusions: Within the confines of this study it is found that there was a significant improvement in the bond strength between the acrylic teeth and denture base when silane coupling agent and monomer were used as surface conditioning material. The order of shear strength of samples is control > monomer > silane coupling agent.

Keywords: Silane coupling agents, Shearbond strength, Universal testing machine, Acrylic denture teeth, Denture base resin, Bonding strength, Acrylin resin, Monomer.

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INTRODUCTION

Dental materials[30,31] have been evolving with time, One such prominent and most commonly used material in today's dentistry is acrylic resin. Previously materials such as vulcanite, nitrocellulose, phenol formaldehyde, vinyl plastics and porcelain[18,19] were used for denture base construction. Acrylic resin teeth were introduced in 1940's.[1,2,27]

The invention of heat cured acrylic resin revolutionized the discipline of dental prosthesis to a great extent, since then the material has maintained its superiority over other materials in meeting the ideal requirements. Acrylic resin still remains the most preferred choice and the reason for the continual use is the simple processing equipment required and relatively low cost.[3]

In early years of what might be referred to as plastic age in dentistry researchers and experimenters used acrylic resin to fabricate denture teeth, bridges and inlays. Acrylic teeth[9] are the most widely used artificial teeth for denture construction. Unlike porcelain teeth, they are suitable for a chemical adhesion between teeth and denture base resin for enhanced bonding.[4]

The failure of acrylic resin dentures due to fracture[28] has been reported to be high and the most common type of failure encountered was the debonding or failure in adhesion of teeth to the denture base.[3] A survey showed that 33% of denture repairs were to restore debonded teeth.[6]

The aim of this study is to evaluate the shear bond strength[5] between acrylic resin[20] teeth to denture base, after surface treatment with silane[7] coupling agent as surface conditioning material.

The objective of this study is to improve the shear bond strength between acrylic teeth and denture base there by increasing the success rate of acrylic dentures.

Table 1: Comparison of bond strength (Newtons) in premolar, molar and premolar + molar in control group

Control groups	*Bond strength (Newtons)*	
	Min-max	*Mean ± SD*
Premolar	63.50-143.50	110.02 ± 19.77
Molar	171.20-350.00	235.54 ± 42.35
Premolar + molar	63.50-350.00	172.77 ± 71.57
p-value (premolar *vs* molar)	t = 10.743; p < 0.001**	

Table 2: Comparison of bond strength (Newtons) in premolar, molar and premolar + molar in monomer

Monomer	*Bond strength (Newtons)*	
	Min-max	*Mean ± SD*
Premolar	142.70-205.30	173.51 ± 17.42
Molar	109.20-440.50	345.25 ± 100.15
Premolar + molar	109.20-440.50	259.38 ± 112.30
p-value (premolar *vs* molar)	t = 6.757; p < 0.001**	

MATERIALS AND METHODS

The study evaluates and compares the shear bond strength between two types of surface conditioning methods-monomer and silane coupling agent bonded[8] to acrylic resin denture base and crosslinked acrylic resin teeth.

Making of Wax Models

Plastic polyvinyl chloride (PVC) rings of 10 cm height and 0.5 inch width were cut from a long pipe. The 10 cm PVC pipes were adhered to a steel base using sticky wax and sheets of modeling wax was melted and poured till the brim of the PVC pipes, care was taken to fill up all defective areas formed due to shrinking of wax.

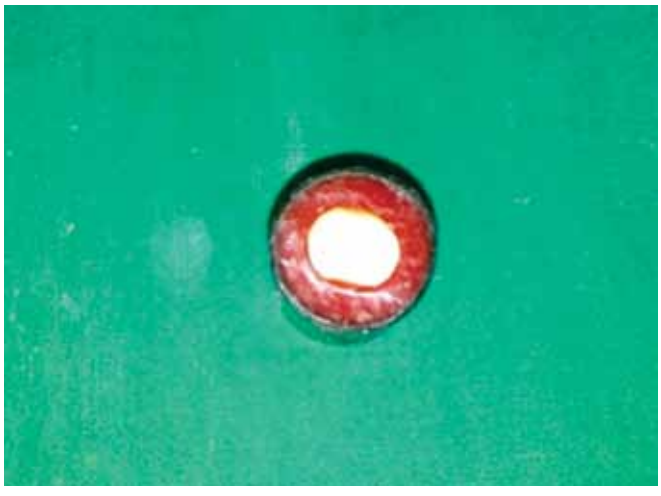


Fig. 1: Prepared models

Fig. 2: Cured models

Preparing the Acrylic Denture Teeth

Premadent crosslinked acrylic molar and premolar teeth of were ground till the ridge lap area with a tungsten carbide bur and they were polished with a buff to obtain smooth surface.

Production of Specimens

The prepared teeth fixed in the PVC rings were filled with wax and the teeth were sealed with a hot wax spatula (Fig. 1).

The wax-tooth assemblies were positioned in the flask and dental plaster was poured up to the border of the PVC rings. The plaster was allowed to set and then a layer of cold mould seal was applied and left to dry. The remaining part of the flask was filled with a mixture of dental plaster and stone and the lid was closed and the flask was pressed (1,250 kgf) for 30 minutes.

After the plaster had set , the flask was placed in boiling water for 15 minutes for dewaxing. Next, the wax was eliminated by running hot water, complete elimination of wax was important from the PVC rings and the teeth ridge lap area as wax causes a detrimental effect in bonding and processing was done conventionally and models were retrieved (Fig. 2).

SURFACE CONDITIONING METHODS

The 2 sets of 96 teeth were dived into three groups based on the method of surface conditioning.

1. SM1 (control) : no surface conditioning

Fig. 3: Silane coupling

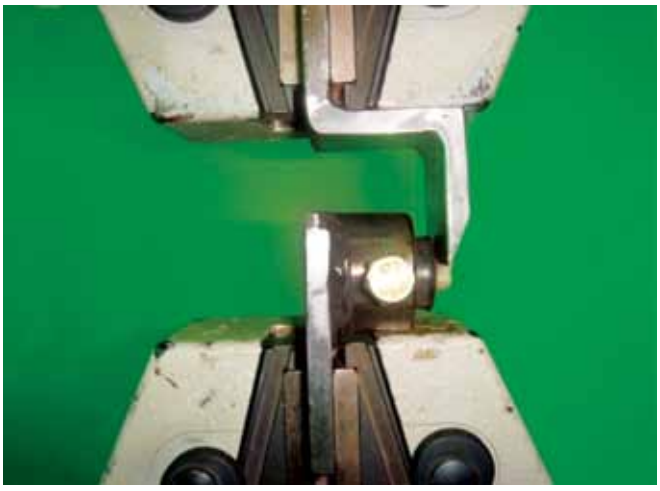


Fig. 4: Cured models subjected to shear failure loads on universal testing machine with the help of custom made jigs

Table 3: Comparison of bond strength (Newtons) in premolar, molar and premolar + molar in silane

Silane	*Bond strength (Newtons)*	
	Min-max	*Mean ± SD*
Premolar	176.00-298.40	230.81 ± 35.91
Molar	396.20-582.30	518.39 ± 57.96
Premolar + molar	176.00-582.00	374.61 ± 153.60
p-value (premolar *vs* molar)	t = 16.869; p < 0.001**	

2. SM2 (monomer) : Two coats of heat cured monomer is applied over the ridge lap area and they were left to evaporate for 5 minutes.
3. SM3 (silane) : Two coats of silane coupling agent (Fig. 3) was applied over the ridge lap area and they were left to evaporate for 5 minutes.

A heat polymerized acrylic resin (DPI) was mixed according to manufacturer's instructions and packed between the denture teeth and the PVC rings. The flasks were bench pressed in a hydraulic press (1,250 kgf).

Curing Procedure

A short curing cycle was employed to cure the specimens. The Acrylizer was filled with water. The clamped flask was submerged in water at room temperature (23 ± 2°C). First the temperature of the water was raised to 74°C for one and half hour. Later the temperature of the water bath was maintained at boiling/100°C for an additional 1 hour.

On cooling the specimens were deflasked. Excess acrylic resin enveloping the necks of teeth was removed.

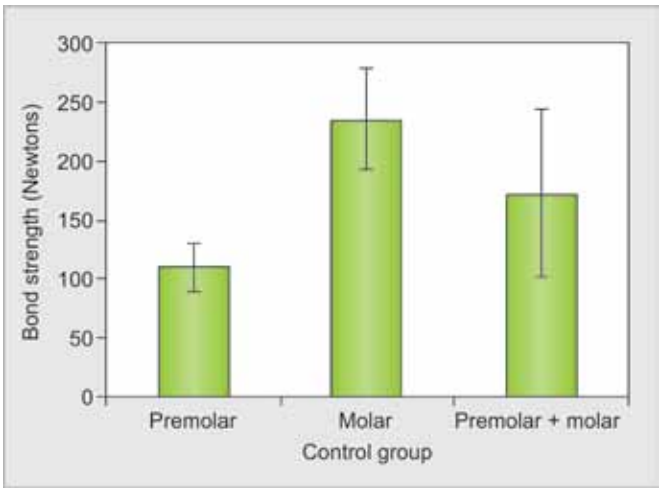
Failure Load Test

The prepared specimens were loaded on to Utm-instron universal testing machine facility at Tifac Composite Park, Kengeri, Bengaluru (Fig. 4). Samples were mounted on a customized JIG. Force was applied by a stainless JIG until fracture occurred. UTM cross head speed was maintained at 5mm/min. The fracture load was measured and recorded by a digital monitor in Newton for all specimens.

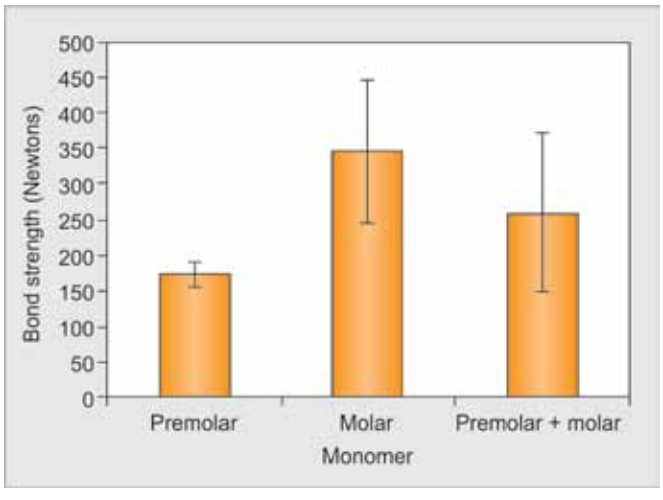
STATISTICAL ANALYSIS

A one-way analysis of variance (ANOVA) was used to find the significance of breaking strengths between different samples which were coated with different surface conditioning materials. Student 't' test was used to find the significance of breaking strengths between sample types.

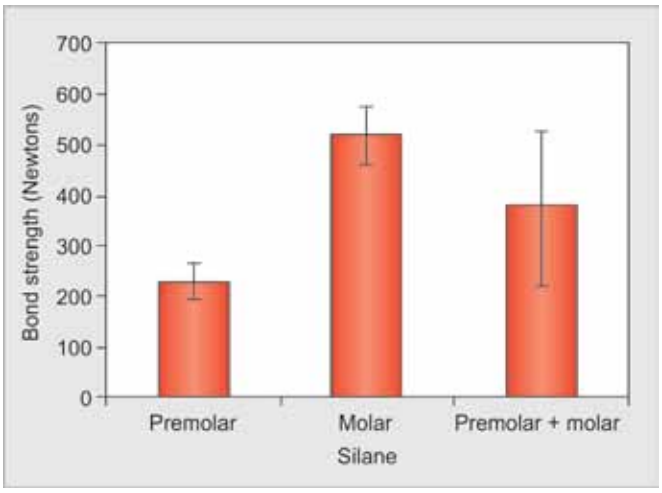
Table 1 and Graph 1 show comparative failure load values (Newton) of premolar and molar in control group, prepared with DPI heat cure denture base resin, and found to be statistically significant with $p < 0.001$, premolar showed a mean failure load value of 110.02 ± 19.77. Molar showed a mean failure load value of 235.54 ± 42.35, and premolar and molar showed a combined mean failure load of 172.77 ± 71.57 N.



Graph 1: Comparison of bond strength (Newtons) in premolar, molar and premolar + molar in control group



Graph 2: Comparison of bond strength (Newtons) in premolar, molar and premolar + molar in monomer



Graph 3: Comparison of bond strength (Newtons) in premolar, molar and premolar + molar in silane

Table 2 and Graph 2 show comparative failure load values (Newton) of premolar and molar in control group, prepared with DPI heat cure denture base resin, and found to be statistically significant with $p < 0.001$, premolar showed a mean failure load value of 173.51 ± 17.42. Molar showed a mean failure load value of 345.25 ± 100.15, and premolar and molar showed a combined mean failure load of 259.38 ± 112.30 N.

Table 3 and Graph 3 show comparative failure load values (Newton) of premolar and molar in control group, prepared with DPI heat cure denture base resin was found to be statistically significant with $p < 0.001$, premolar showed a mean failure load value of 230.81 ± 35.91. Molar showed a mean failure load value of 518.39 ± 57.96, and premolar and molar showed a combined mean failure load of 374.61 ± 153.60 N.

Statistical Methods

Descriptive statistical analysis has been carried out in the present study. Results on continuous measurements are presented on mean ± SD (min-max) and results on categorical measurements are presented in number (%). Significance is assessed at 5% level of significance. Analysis of variance (ANOVA) has been used to find the significance of study parameters between three or more groups of patients, posthoc test has been used to find the significance pair wise between control, monomer and silane Student t-test (two tailed, independent) has been used to find the significance of study parameters on continuous scale between two groups.[31-34]

1. Analysis of variance: F test for K population means

Objective: To test the hypothesis that K samples from K population with the same mean.

Limitations: It is assumed that population are normally distributed and have equal variance. It is also assumed that samples are independent of each other.

Method: Let the j^{th} sample contain nj elements (j = 1, 2, … K). Then the total number of elements is:

$$N = \sum nj \sum \frac{xij}{nj}$$

$$S_1^2 \frac{\sum\sum_{i-1}^{n1} (x1 - \overline{x.j})^2}{N - K} \quad S_2^2 = \frac{\sum_{i-1}^{n1} nj(\overline{x.j} - \overline{x..})^2}{K - 1}$$

$F = S_2^2 / S_1^2$ which follows F distribution (K – 1, N – K)

2. Student t-test (two-tailed, independent)

$$t = \frac{(\overline{x}_1 - \overline{x}_2) - (\mu_1 - \mu_2)}{\sqrt{s^2 (1/n_1 + 1/n_2)}}$$

$$\text{Where } s^2 = \frac{(n1 - 1)\sum_{i=1}^{n1}(x1 - \overline{x}1)^2 + (x2 - 1)\sum_{i-1}^{n2}(x2 - \overline{x}2)^2}{n1 + n2 - 2}$$

3. Significant figures

+Suggestive significance (p-value: $0.05 < p < 0.10$)

*Moderately significant (p-value: $0.01 < p \leq 0.05$)

**Strongly significant (p-value : $p \leq 0.01$)

Statistical Software

The statistical software namely SPSS 15.0, Stata 8.0, MedCalc 9.0.1 and Systat 11.0 were used for the analysis of the data and Microsoft word and excel have been used to generate graphs, tables, etc.

DISCUSSION

Harold Vernon first introduced acrylic polymers as denture base materials[10-14] in 1937. Dental materials have since been evolving with time. One such prominent and most commonly used material in today's dentistry is the acrylic resin, this is attributed to its esthetics, handling properties, biological, physical compatibility and its affordability in terms of cost and chemical stability in the mouth.

The failure rate of acrylic resin dentures as a result of fractures has been reported to be high, with the most common type of failure being the debonding of acrylic teeth to denture base resin. Clinically, it has been observed that denture fractures are usually found in areas which are subjected to high stresses which may be at the acrylic tooth/denture base interface or where the denture base material is thin in cross section and in the midline. There is a lack of bond between untreated acrylic teeth and acrylic resin denture base materials.[2,15]

Many methods have been advocated to increase the adhesion between acrylic denture base to acrylic resin teeth A number of precautions can be taken to reduce the incidence of debonding. Debonding may be the result of incompatible surface conditions at the tooth and denture base interface. Two factors are attributed for this is,

contamination of the surfaces and, or difference in structure of the two components due to their different processing routes.[16] Both of these should be investigated because any failure will cause an increase in the cost because of repair of denture.

Studies have proved that strongest bonding to acrylic resin teeth is achieved in heat polymerized[24,25] acrylic resin[17] hence in this study denture base was fabricated using heat polymerization heat cured acrylic denture base was used in conjunction with crosslinked acrylic denture teeth.

Results from this work suggest that shear bond strength of denture teeth bonded to denture base material can be considerably enhanced by the application of suitable bonding agent. It can be postulated that the bonding agent increases the wettability of the tooth surface and may have a solvent effect, which favors a more effective diffusion of the monomers of the denture base[22,26] polymer into the tooth.[26] This is in agreement with our study but this bond strength is less when compared to silane coupling agents.

This study has confirmed the findings of previous research that enhanced bonding can be achieved by the application of suitable bonding agent like monomer.[29] Silane coupling agent also rather than a conventionally cured denture silane coupling agent significantly increases the bond strength between the denture base and ridge lap area of the teeth when compared to monomer samples not treated with any conditioning agents.[3]

Hence, a simple and quick tooth chemical surface treatment could be an effective option in decreasing bonding failures and could avoid repeated denture repairs improving patient satisfaction.[29]

CONCLUSION

- The present study evaluated the bond strength[21,23] of acrylic teeth to the acrylic denture base[22] using different surface conditioning materials like monomer and silane coupling agents.
- There was a significant improvement in the bond strength with surface conditioners.
- The order of shear bond strength of samples is control < monomer < silane coupling agent.

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