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Original Research Article

Effect of mechanical and chemical surface treatment on bond strength of acrylic denture teeth to heat cure acrylic resin-an invitro study

Mrinali Maria Viegas^{1,*}, Vidya S Bhat¹, Sanath Kumar Shetty¹¹Dept. of Prosthodontics, Yenepoya Dental College, Mangalore, Karnataka, India

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ABSTRACT

Background and Aim: Debonding of denture teeth from the denture base has posed a great problem to the clinician and patient. Chemical and mechanical treatments have been performed separately, but there are no studies performed using the combination of chemical and mechanical surface treatments. This study aims at evaluating and comparing the bond strength by using chemical and mechanical surface treatments.

Materials and Methods: 60 maxillary right central incisor teeth were used in 5 groups for surface treatment on the ridge lap area: 1 untreated, 2-sandblasting, group 3- Heat cure monomer, 4- sandblasting+ monomer, 5- Dichloromethane. The acrylic teeth were attached to a wax block at an angle of 45°. These were flaked and dewaxed, followed by surface treatment and acrylisation. All cured specimens were loaded under a universal testing machine on the palatal surface at a cross head speed of 1mm/min till fracture occurred. Data obtained was statistically evaluated by one way ANOVA.

Results: Surface treatment with dichloromethane showed the highest bond strength of acrylic teeth to heat cure denture base when compared with sandblasting and monomer application. On visual analysis of the fractured specimens, maximum amount of cohesive failures were noticed in the dichloromethane group.

Conclusion: Dichloromethane can be used as an effective and quick method to improve the bonding of acrylic teeth to denture base.

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1. Introduction

Tooth loss leading to partial or complete edentulous situations is most commonly replaced by removable prosthesis. Previously materials like vulcanite, plastic and metal were widely used in denture fabrication and in recent years, (PMMA) Denture base resins, Polyethyl ether ketone, Valplast are being used. Most common material used for fabrication of denture prosthesis is denture base resins made of polymethyl methacrylate.

Heat cure polymethyl methacrylate is a translucent, aesthetic, light weight and economical material but has a disadvantage of low fracture resistance. It is available as

powder and liquid and the liquid mainly contains methyl methacrylate. These two are mixed together and dentures are processed either by compression moulding or injection moulding technique. A long or short curing cycle can be followed for processing the material.

Acrylic teeth made of cross linked polymethyl methacrylate are most commonly preferred above porcelain teeth as it bonds chemically to acrylic denture base. The acrylic teeth are also easy to trim and adjust. Acrylic teeth are cost effective and require simpler processing equipment for fabrication.

Bonding of acrylic teeth to the denture base is by chemical linking of polymethyl methacrylate. Two processes affect the achievement of a bond between the acrylic teeth and denture base resin: (I) the polymerizing

* Corresponding author.

E-mail address: mrinaliv30@gmail.com (M. M. Viegas).

denture base resin must come into physical contact with the denture tooth resin, (II) the polymer network of denture base resin must react with the acrylic tooth polymer to form interwoven polymer network.¹ However, debonding of denture teeth from the denture base has posed a great problem to the clinician and patient. It is estimated that between 22% and 30% of denture repairs involve tooth debonding, usually in the anterior region of the denture. This detachment may be attributed to a lesser ridge lap surface areas available for bonding and the direction of the stresses encountered during function.¹

Debonded denture teeth are most commonly re bonded to the same denture base by increasing the surface area of the denture tooth by means of chemical and mechanical methods and the use of autopolymerising denture base resin material.

The denture teeth available have their ridge lap area highly polished and glossy, these can be surface treated before processing the denture by various mechanical and chemical treatments or a combination of both. This will increase the surface area for denture base to contact the acrylic teeth and thus enhance the bonding of both.

Increase in bond strength can be obtained by grinding a diatoric recess or removal of the denture tooth glaze. Various chemicals like acetone, chloroform, tetrahydrofuran, dichloromethane can be used to roughen the ridge lap area of denture tooth. Dichloromethane is a volatile organic solvent also known as Methylene Chloride, having the chemical formula CH_2CL_2 and M.W 84.93.

Air abrasion with aluminium oxide can cause roughness and micro porosities on the treated surface.

Various literature is available to prove that surface treatment of teeth before processing the denture increases bond strength. Chemical and mechanical treatments have been performed separately, but there are no studies performed using the combination of chemical and mechanical surface treatments.

2. Aim

This study aims at evaluating and comparing the bond strength by using various organic solvents and air abrasion for chemical and mechanical surface treatments respectively, as well as a combination of both to create surface roughness.

3. Materials and Methods

This experimental study was conducted in the Department of Prosthodontics and Department of Dental Materials, Yenepoya Dental College, Mangalore.

The bond strength between the denture base and acrylic resin teeth were evaluated after the following mechanical and chemical surface treatments on the ridge lap area: sandblasting, heat cure monomer application, sandblasting

and heat cure monomer application, dichloromethane solution.

The results obtained were compared with bond strength of the untreated surface on the ridge lap surface of the acrylic teeth.

3.1. Materials

1. Maxillary right central incisor.
2. Modelling wax.
3. Heat cure acrylic- polymer powder and monomer liquid
4. Poly vinyl siloxane impression material Putty Consistency.
5. Dichloromethane solution (CH_2CL_2), M.W 84.93.
6. Aluminium oxide 250 μ .

3.2. Methodology

3.2.1. Sample size estimation

Based on 5% level of significance, 80% power and effect size of 0.48, the sample size for the study was calculated as 60 i.e. 12 samples for 5 group each.

The sample size was calculated using G*Power software.

3.2.2. Fabrication of test specimen

60 maxillary right central incisors of the same mould shape M1-24 were selected. Test specimens were prepared simulating clinical condition, as described in Japanese Standards Association 6506 (1989).² A wax block of dimension 10mm×10mm×30mm was made (Figure 1) and the acrylic tooth was attached to it at an angle of 45 degrees to the base of the wax block. This was acrylicized and a standard master specimen was obtained (Figure 2). The master specimen was used to make a silicone split mould for fabrication of further test samples. The untreated acrylic teeth were placed in the silicone mould and molten wax was poured to form the base of the specimen (Figure 3). This gave standard angulations' to all the test specimens (Figure 4). The wax specimens were flaked and dewaxed (Figure 5).

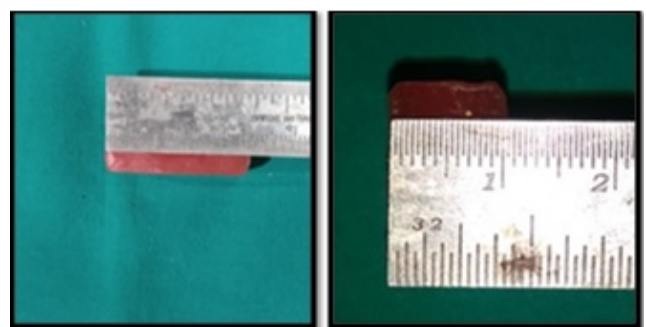


Fig. 1:

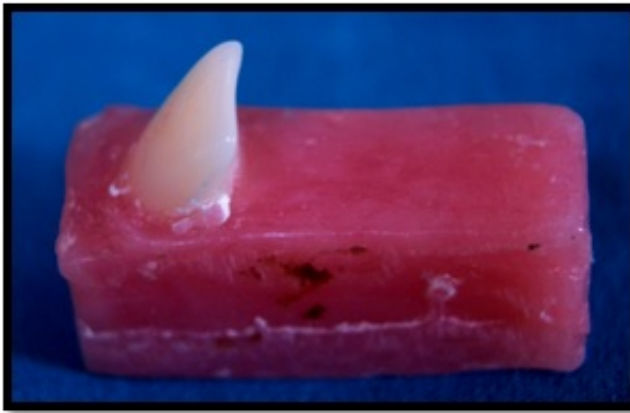


Fig. 2:

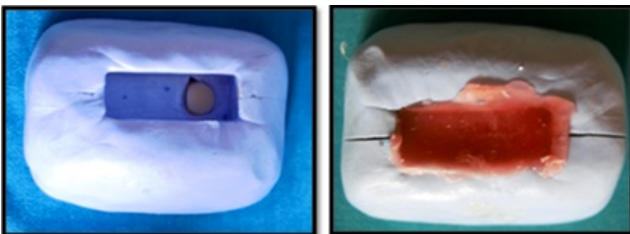


Fig. 3:

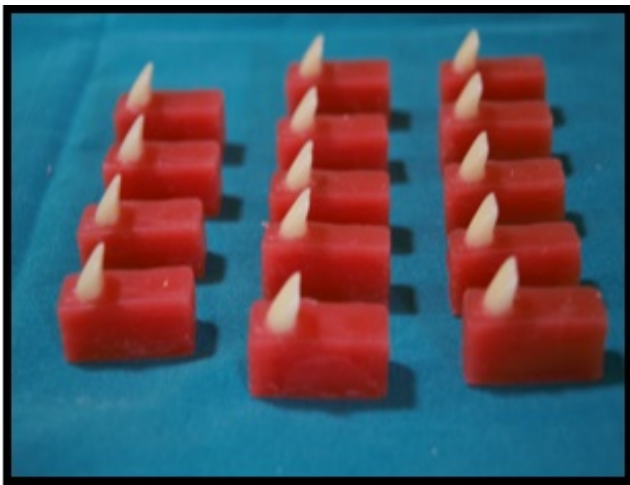


Fig. 4:

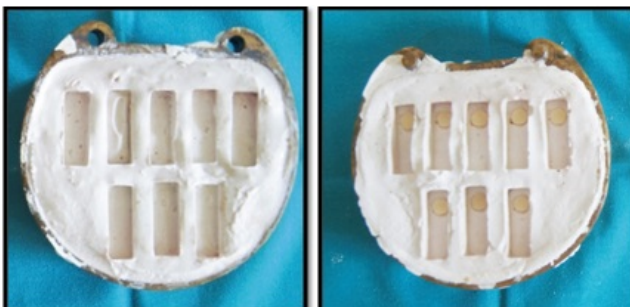


Fig. 5:

3.3. Surface treatment of the test specimen

After ensuring that all the wax is eliminated from the ridge lap surface of the teeth they were treated by the following surface treatments: (Figure 6)

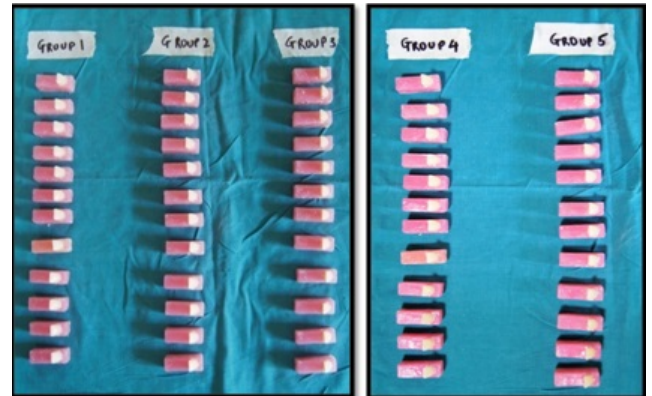


Fig. 6:

Group 1: Control (no treatment)

Group 2: Sandblast group (treated with 250 μ aluminium oxide at 4psi for 5 sec in a circular motion at a distance of 5mm from the tooth)

Group 3: monomer group (treated with DPI heat cure monomer liquid applied with a cotton swab on the ridge lap area for 180 sec and then dried)

Group 4: Sandblast and monomer (ridge lap area treated with sandblasting similar to group2 followed by monomer liquid application for 180 sec).

Group 5: Dichloromethane group (treated with dichloromethane chemical applied with a cotton swab on the ridge lap area for 10 sec.)

After surface treatment of teeth the mould space was packed with DPI heat cure acrylic material and cured according to the manufactures instructions by using compression moulding technique with a short curing cycle in an acrylizer for 1hr 20mins. The specimens were retrieved after deflasking and were trimmed and polished. The specimens were segregated in respective packets and stored in water till testing was done under a universal testing machine.

3.4. Testing the samples

A metal jig was fabricated in order to hold the specimens in place under the Universal Testing Machine (Figure 7). The sample was held in such a way that a compressive load was applied on the palatal surface using a 2mm diameter testing needle. Constant load at a cross head speed of 1mm/min was applied till debonding of the tooth occurred and it was recorded by a computer software connected to the testing machine (Figure 8).

The computer recorded the load applied in kilograms (kg). This was converted to Newtons (N) by the formula

$$N = \text{kg} \times 9.8$$

The bond strength (MPa) was measured by the formula:

$$\text{bond strength} = \frac{\text{load (N)}}{\text{surface area (mm sq.)}}$$

The surface area was measured by $A = \pi r^2$.

The force required to debond the teeth was tabulated for all the groups.

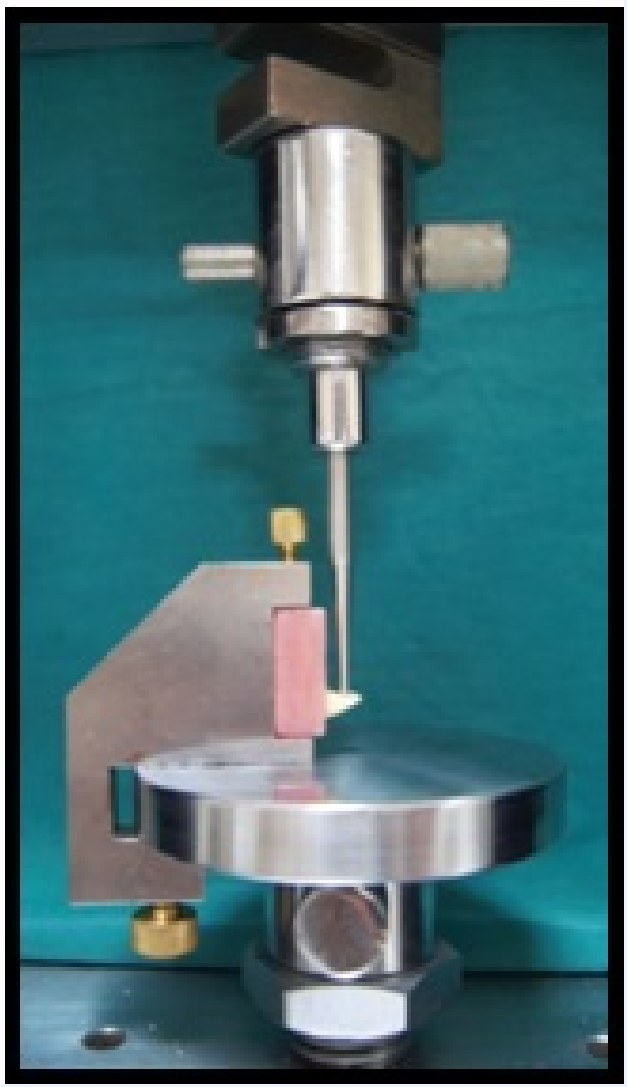


Fig. 7:

3.5. Failure analysis of specimens

Specimens from each group were selected and the area of fracture was visually observed under a magnifying lamp of 8x magnification lens, these were divided into adhesive, cohesive or combined types of bond failure.

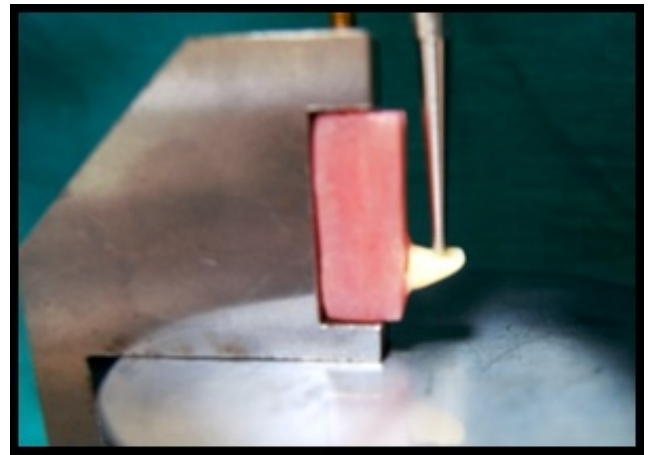


Fig. 8:

Specimens which showed no traces of damage to the denture tooth or denture base were said to show adhesive failure i.e. debonding occurred exactly at the tooth and denture interface. Specimens that showed debonding with denture tooth material bonded to the denture base were considered cohesive i.e. debonding occurred due to fracture within the acrylic tooth and those showing both were considered combined type. The images of the debonded specimens depicting the type of failures are showed in (Figure 9).



Fig. 9:

3.6. Statistical analysis

SPSS software (version 22) was used for analysing the data.

Mean and standard deviation of bond strength values of all 5 groups were obtained.

One- way ANOVA was conducted to check for significant difference of bond strength between the five test groups.

Post –Hoc test was performed to check for inter group significance of bond strengths.

Fracture analysis was done for type of fracture seen in sample groups.

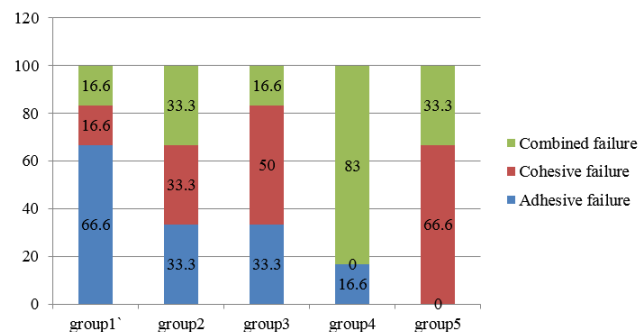
4. Results

The present study evaluated the bond strength after surface treatment with various chemical and mechanical methods. The bond strength of denture tooth to the base was tested. The load required to fracture the bond between the tooth and denture base was obtained in Kgs and converted to Newtons to get bond strength in MPa by using the mentioned formula.(Table 1)

A one way ANOVA was performed to determine the significant difference in the average bond strength across different groups. There was a statistically significant difference in the average bond strength between the five groups.

Failure analysis was done by visually observing the debonded samples (Graph 1). The above graph shows the percentage of type of failure seen in each group after debonding.

Control group shows highest percentage of adhesive failure. Dichloromethane shows highest percentage of cohesive failure and no adhesive failure. Maximum percentage of combined type of failure was seen in sandblasting and monomer group.



Graph 1: Comparison of failure analysis: representing Adhesive, Cohesive, Combined failures.

5. Discussion

Heat cure acrylic resins and acrylic denture teeth have been used as prosthetic restorations for edentulous ridges. Even though they are used extensively the durability of this prosthesis is a major issue.

Debonding from the denture base is a major issue faced by patients using acrylic dentures. Bonding between acrylic teeth and the denture base is chemical in nature and depends on the softening of the resin at the base of the teeth with monomer from the “dough” of denture base material.³

Bond failures could either be adhesive or cohesive. Adhesive failure occurs if there is no trace of any denture base resin on the tooth surface after the fracture, cohesive failure occurs if there is a presence of any trace denture base resin on the surface of denture teeth or remnants of the

denture tooth on the denture base. The denture teeth often separate from the denture base without any damage to the denture base or teeth indicating mainly adhesive failure.^{4,5}

Over the years various authors have conducted studies to check for effects on bond strength after surface treatment of the acrylic denture teeth. Various surface treatments done were:

1. Diatoric notches(vertical and horizontal in the ridge lap area^{6,7}
2. Dichloromethane solution⁸
3. Treating with methyl methacrylate monomer^{9,10}
4. Sandblasting with aluminium oxide particles¹¹
5. Using lasers¹²
6. Tetrahydrofuran¹³
7. Acetone¹⁴
8. Bonding agents¹⁵

In the present study four different surface treatments were performed and the bond strengths were compared with each other and that of an untreated group.

Previous studies state that the type of denture teeth used affected the bond strength after denture processing.⁹ Premadent[®] acrylic teeth (cross linked) which is a commonly available commercial brand was used in this study.

Acrylic teeth are more prone to wear in the oral cavity due to masticatory forces. Coffey et al. Tested the wear resistance of conventional acrylic resin and Interpenetrating Polymer Network reinforced acrylic resin teeth and found that Interpenetrating Polymer Network reinforced acrylic resin teeth have higher wear resistance.¹¹

Factors affecting the strength of the bond are often related to the basic properties of the materials used as denture base and artificial teeth. It has been stated that for bonding to occur, the monomer-polymer mix should either swell or dissolve the ridge lap portion (bonding surface with denture base) of the tooth. However, as the degree of cross-linking of teeth or base resin increases, the polymer swells less and bonding becomes more difficult.¹⁶

Clancey reported that heat-cured plastic teeth were 40% higher in bond strength than with IPN cross-linked teeth.¹⁷ The swelling phenomenon of acrylic resin polymer teeth due to the diffusion of monomers from the denture base polymers was demonstrated by Vallittu et.al and by increasing the polymerization temperature, the monomers of the denture base polymers diffused more effectively into acrylic resin polymer teeth. This increased the bond strength between the polymer teeth and the denture base polymer.¹³

In the present study cross linked acrylic teeth were used as control (group1) without any modifications in the ridge lap area to assess the baseline bond strength between acrylic teeth and denture base. The baseline bond strength was found to be 3.44±0.7 which was the least, and on visual examination maximum amount of adhesive failure was seen

Table 1: Mean and standard deviation of bond strength among five groups (1.control, 2.sandblasting, 3.monomer, 4.sandblast& monomer, 5. dichloromethane)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
1	12	3.44	.75	.22	2.96	3.92
2	12	4.03	.62	.18	3.64	4.43
3	12	4.03	.79	.23	3.53	4.54
4	12	4.61	.65	.19	4.20	5.04
5	12	5.27	.93	.27	4.68	5.87
Total	60	4.28	.96	.12	4.03	4.53

in this group.

Earlier studies in which the ridge lap area was sandblasted with 50μ of aluminium oxide showed marginal improvement in the bond strength. A study by Chung et al revealed that sandblasting the ridge lap area with 50μ could only remove the glaze on the ridge lap area but had no significant effect in improving the bond strength between the denture base resin and acrylic resin teeth. They also reported that sandblasting the ridge lap area with 250μ of aluminium oxide particles under 5kg cm of pressure with a circling motion from a distance of 8mm distance for 5seconds significantly increased the bond strength between acrylic resin teeth and denture base resin.⁵

Spratley evaluated bonding of resin denture teeth and suggested that a rough surface may trap wax residue resulting in a decreased bond strength.¹⁸

In the present study the group that was treated with 250μ sandblasting (group 2) showed a minimal amount of difference in bond strength values(4.03Mpa) compared with that of control group (group 1).

Similar results were obtained with the MMA monomer group (group 3) where the bond strength was around 4.03 ± 0.7 Mpa. The group 4 (sandblast+monomer) shed a bond strength of 4.61 ± 0.6 Mpa. The difference in bond strength values for group 2, group 3 and group 4 was not significant. Which means sand blasting and monomer treatment did not bring about any drastic improvement in bond strength values. These results were coinciding with the study conducted by Barpal et al., Differences in types of denture teeth, acrylic resin, and experimental technique may contribute to the variability of reported results, in the group containing Lucitone teeth showed highest failure loads when the ridge lap was left with an intact glaze and did not have a diatoric, with no significant influence from the use of monomer.²

Air abrasion supposedly increases shear bond strength either by augmenting free surface energy of the newly abraded resin surface or by causing severe irregularities and undercuts in the ridge lap surface area, improving micromechanical retention. In addition, wetting the acrylic resin surface with methyl methacrylate monomer increases the bond strength between resin polymers.¹⁹

In the present study, the evidence that Dicholoromethane enhances the bond strength is appreciated. Denture teeth that were treated with Dicholoromethane (group 5) showed highest mean values of bond strength (5.27 ± 0.9) compared with that of the control group (group 1) and the remaining test groups.

Takahashi et al studied that painting the ridge lap area with 1:1 ratio of monomer and dichloromethane considerably increased the bond strength between the acrylic resin teeth and denture base resin. Dichloromethane is a non polymerizable solvent that swells the surface of the denture tooth resin, thereby allowing the monomers from the polymerizing denture base resin to penetrate further into the denture tooth and form a more extensive interwoven polymer network. The micro-roughness present on dichloromethane treated denture teeth also suggests that mechanical retention plays a role in improving the bond strength. Hence, the ridge lap area of the acrylic resin teeth treated with dichloromethane has shown improved in the bond strength when compared to the control group.²⁰

Dicholoromethane produces pores and channels on the surface of acrylic resin teeth which frequently interconnect. This effect is also observed when dichloromethane is applied to heat cure denture base resin. Diffusion of dichloromethane into the resin material is brought about by the prepolymerising pearls of PMMA.¹⁹

When a denture tooth is fractured away from a sample of a denture base, the fracture path must not occur along the interface between the tooth and denture base, i.e. the fracture must be cohesive.³

In the present study highest percentage of cohesive failures were observed in dichloromethane group (group5) indicating that the bond between the treated tooth and denture base was strong leading to cohesive failure within the tooth itself.

Nagai et al. Observed micromechanical retention as a mechanism to explain the advantage of dichloromethane in improving bonding.²¹

The mean force required to fracture the denture tooth from the denture base was around 203.16N, according to Tzakis et.al the normal biting force exerted by complete denture wearers is around 90N. The biting force exerted by implant supported overdentures is around 119.83N.²²

The results proved that the control group had the least bond strength when compared with that of the surface modified groups. Among the surface treated groups the denture teeth treated with dichloromethane group had the highest bond strength.

6. Limitations

1. The present study did not simulate all the oral conditions.
2. Thermocycling was not performed in this study. Thermocycling is a treatment that theoretically allows repeated expansion and contraction of the tooth and denture base resin components, thereby stressing the bond and simulating the oral condition.
3. Reproducing the biting forces and stresses exerted by patients on the prosthesis is not possible.

7. Conclusion

Within the limitations of this study, the following conclusions were made:

1. Significant improvement in bond strength was obtained after surface treatment between acrylic teeth and the denture base resins as compared with untreated samples, i.e., control group
2. Dichloromethane improves bond strength greater than sandblasting and monomer treatment or a combination of both. Hence, application of dichloromethane is advised as its application is easy and quicker.
3. Failure type after surface treatment with dichloromethane was predominantly cohesive i.e. the bond strength between the tooth and denture base was stronger than the fracture resistance of the tooth.

8. Conflict of Interest

The authors declare that there are no conflicts of interest in this paper.

9. Source of Funding

None.

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Author biography

Mrinali Maria Viegas, Post Graduate

Vidya S Bhat, Professor

Sanath Kumar Shetty, Professor and HOD

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