



Effect of Trichloromethane on the Bond Strengths between Acrylic Teeth and Different Heat-cured Denture Bases: A Comparative Study

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ABSTRACT

Aim: This study is to evaluate the role of 1:1 v/v 30% trichloromethane and monomer solvent in enhancing the durability of bonding between cross-linked acrylic teeth and different heat-cured denture bases with or without mechanical preparations made on ridge lap portion of the artificial teeth.

Materials and methods: Two high impact denture base resin materials (Trevalon HI, DeTrey, UK, and DPI Tuff, Mumbai) and one nonhigh impact denture base resin material (DPI Quick Set, Mumbai) were selected to form three groups. Each group contains 30 specimens prepared by five different methods. A mixture of 30% trichloromethane and monomer, mixed in the ratio of 1:1 and applied for 1 minute on the ridge lap area of experimental specimens of methods—B, C, D and E (Specimens of method—A being control group, where no alterations were made at the ridge lap portion of acrylic teeth) before curing. Hounsfield universal testing machine is employed to evaluate the comparative bond strengths.

Results: No significant difference was seen in bond strengths between specimens of experimental methods in all groups. When each group was assessed separately method B specimens in group 1 (739.2 N), group 2 (758 N) and method D specimens in group 3 (729 N) showed highest mean bond strengths. Control group specimens showed the least bond strength (400-460 N) in all groups with more adhesive failures.

Conclusion: Ridge lap portion of the specimens treated with chemical solvent as in method B showed increased bond strength in groups 1 and 2. Hence, this is a preferred method.

Clinical significance: Evaluation of effect of different chemical and mechanical preparations at the ridge lap areas of acrylic teeth before acrylization helps the clinician and technician to overcome the problem of debonding of teeth from denture bases and in turn provides better quality prosthesis to the patient.

Keywords: Trichloromethane, High impact denture resins, Cross-linked acrylic teeth, Shear compressive bond strength, Interpenetrating polymer network.

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INTRODUCTION

Debonding of teeth from the denture bases is one of the most common problems in prosthodontic practice. In most instances, such problems are encountered in the anterior region.^{1,2} Many factors affect the bonding like poor laboratory technique involving faulty dewaxing procedure, indiscriminate use of separating medium,^{4,7} excessive fatigue by heavy uneven masticatory loads, and parafunctional habits of the patient.^{5,6} Many attempts have been made to improve the bond strength like chemical treatments,^{3,13,17} mechanical modifications,^{18,19} placing diatorics²³ varying polymerization temperatures,^{20,21} using visible light-cured denture base resins,²² and curing resins by microwave methods, using porcelain and plastic teeth etc.^{8,12} but most of these techniques showed mixed results. Earlier studies were aimed with either chemical or mechanical modifications alone to improve the bonding between artificial teeth and denture bases. The present *in vitro* study is aimed at (1) comparing the bond strengths between cross-linked resin teeth and different heat-cured denture base resins with or without application of 1:1 v/v 30% trichloromethane and monomer solvent, in presence of mechanical modifications, (2) evaluating the modes of adhesive and cohesive failures and (3) investigating variables which might affect the bond strength.

MATERIALS AND METHODS

Materials and armamentarium used in the study: Heat-cured resin denture base materials Trevalon HI (Detrey UK), DPI Tuff (DPI, Mumbai), and DPI Quickset (DPI, Mumbai).

a. Cross-linked acrylic teeth (Cosmo-HXL acrylic teeth, shade A2, Dentsply India Pvt Ltd).

- b. 1:1 v/v of 30% trichloromethane and monomer (MMA) solvent.
- c. Polyvinyl siloxane, impression material (3M Express™ STD).
- d. Hounsfield Universal Testing Machine (Germany).
- e. Denture flask with clamp (Kavo, Germany).
- f. Hydraulic pressure gauge (Kavo, Germany).
- g. Digital acrylizer.

Standardization of Specimen

A total number of 90 cross-linked maxillary central incisors (Cosmo HXL acrylic teeth) of same mold with regard to size and shape were selected to be bonded with three different types of heat-cured denture base resins. For study purpose, the test samples were divided into three groups as follows:

- *Group 1*: Consists of 30 specimens prepared from DPI-quick set.
- *Group 2*: Consists of 30 specimens prepared from Trevalon HI.
- *Group 3*: Consists of 30 specimens prepared from DPI Tuff.

The central incisors were attached on the beveled surface of a wax block and aligned in such a way that long axis of the tooth is at an angle of 45° from the base of wax block. All study groups have five methods and each method has two wax blocks consisting of six teeth samples being prepared. Thus, each group consists of 30 test specimens (6 × 5 = 30) and total of 90 specimens (30 × 3 groups). The impression of the master mold is made using additional polyvinylsiloxane putty impression material (3M Express™ STD). The artificial incisor teeth were placed in the putty mold and wax is poured in it to make a series of identical wax models of equal dimension. For each group, the test specimens were prepared by the following methods:

- *Method A*: No alterations made at the ridge lap portion of acrylic teeth (control group).
- *Method B*: Saddle areas of the acrylic teeth were surface treated with the application of 1:1 v/v 30% trichloromethane and monomer solvent for 1 minute each.
- *Method C*: The glossy surface of saddle area of the acrylic teeth were grounded to remove the surface glaze using fine carborundum stone and surface treated as in method B (Fig. 1).
- *Method D*: Vertical grooves of 2 mm deep and 2 mm wide are prepared on the saddle area of acrylic teeth labiopalatally using a straight fissure bur and surface treated as in method B (Fig. 2).
- *Method E*: Horizontal groove of 2 mm deep and 2 mm wide are prepared mesiodistally on the saddle area of acrylic teeth using a straight fissure bur and surface treated as in method B (Fig. 3).

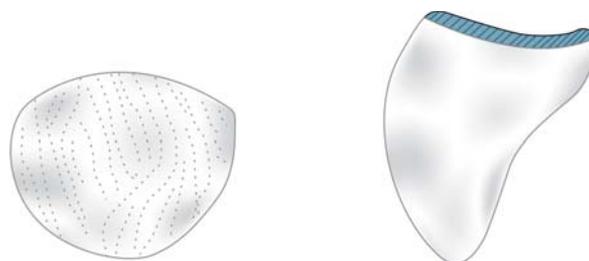


Fig. 1: Removal of surface glaze

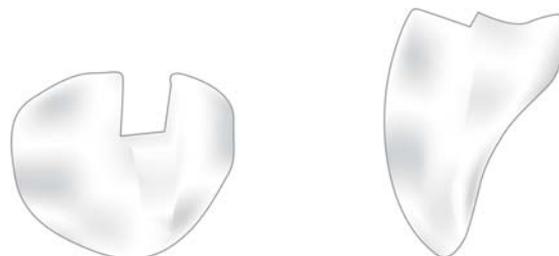


Fig. 2: Vertical groove

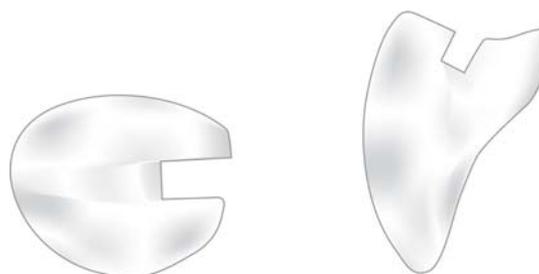


Fig. 3: Horizontal groove

Preparation of the Molds

The prepared wax blocks containing the specimens of different groups were invested in separate denture flasks (Kavo, Germany) with type III dental stone by two-pour method following the manufacturer's instructions. Flasks were kept under tight closure in the clamps. After one hour when the stone had set, the flasks were kept for dewaxing by immersing in boiling water bath for 5 minutes. The mold halves of flask were separated, flushed with hot household detergent solution and subsequently cleaned with boiling water. The two halves of the flask were allowed to cool down and after confirming that no wax residue is left on the mold surfaces, they were coated with cold mold seal (DPI, Mumbai) except on the saddle portion of artificial teeth.

Surface Treatment and Curing the Specimens

The saddle portions of all the specimens belonging to the methods—B, C, D and E in all the three groups were surface treated with mixture of 1:1 v/v 30% trichloromethane and monomer solvent for 1 minute prior to packing of resin material. The samples of three denture bases were proportioned and mixed in a clean jar separately according

Table 1: Manufacturer's recommendations of different denture base resins

Denture base resin	Powder/liquid ratio	Dough time at 25°	Working time at 25°
Group I—DPI Quickset	24 gm: 10 ml	10 minutes	12 minutes
Group II—Trevalon HI	25 gm: 11 ml	15-25 minutes	8 minutes
Group III—DPI Tuff	24 gm: 10 ml	10 minutes	12 minutes

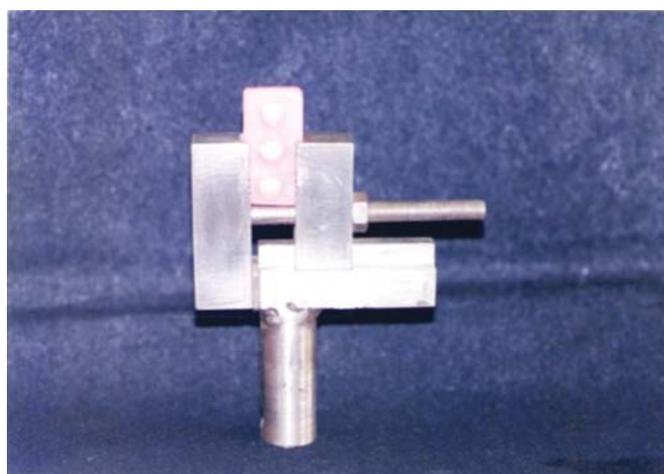
to the manufacturer's recommendations (Table 1). Latex gloves were used to avoid any contamination and same operator performed the entire procedure. All specimens were stored at $25 \pm 2^\circ$ for 7 days in distilled water to ensure complete polymerization before subjecting to testing procedure.

Testing Bond Strength

Test specimens were subjected under Hounsfield universal testing machine, Germany, for testing shear compressive strength described by British standard 3990 for testing bonding of teeth to heat-cured denture bases. Each specimen is held securely in a custom made jig in order to avoid any change of position (Fig. 4).

Shear compressive load is applied with a 3 mm knife edge rod at an angle of 45° to the palatal surface at a cross head speed of 5 mm/min until bond failure occurs. The digital monitor connected to Hounsfield testing machine shows the bond strength of each specimen in Newtons (N) (Fig. 5). The tests were performed under uniform atmospheric conditions of $28 \pm 2^\circ$ and 58% relative humidity and measured values were noted.

For all specimens, the interface failures were inspected and grouped as adhesive, i.e between tooth and resin base, and cohesive, i.e either in tooth or denture base. The readings were then subjected to statistical analysis for comparison using one-way ANOVA (F-test) and the significance is determined by employing Newman-Keuls multiple range test.

**Fig. 4:** Jig holding specimen**Fig. 5:** Specimen being loaded

RESULTS

The comparative bond strengths of group 1 specimens tested in different methods were found to be statistically significant ($p < 0.05$) except between methods 1D and 1E. The specimens of method 1B had highest mean bond strength (739.2 N) followed by 1E, 1D, 1C and 1A respectively (Table 2).

The bond strengths of group 2 specimens (Trevalon HI) in different methods were found to be statistically significant ($p < 0.01$). Method 2B showed the highest mean bond strength of 758.1 N followed by methods 2D, 2E, 2C and 2A respectively (Table 3).

The specimens of method 3D showed the highest mean bond strength at 729.2 N followed by 3E, 3B, 3C and 3A respectively (Table 4) were found to be statistically significant ($p < 0.01$).

In controlled group, the mode of cohesive failures are 11% and adhesive failures 89% (Graph 1). In experimental group, the cohesive failures are 93% and adhesive 7% (Graph 2).

DISCUSSION

Acrylic resins have been used in fabrication of denture bases since 1937. Polymethylmethacrylate resin used in fabrication of denture bases is similar to that used for artificial teeth hence it has ability to bond chemically with it. This chemical bond occurs in two stages: (1) The polymerized denture base resin comes in physical contact with tooth resin and (2) the polymer network of denture

Table 2: DPI heat cure

Methods	Range (N)	Mean ± SD	Difference between methods			
			IB	IC	ID	IE
IA	431.7-488.5	460.1 ± 28.4	p < 0.01	p < 0.05	p < 0.01	p < 0.01
IB	716-762.5	739.2 ± 22.9	–	p < 0.01	p < 0.01	p < 0.01
IC	579.4-640	609.7 ± 27.6	–	–	p < 0.01	p < 0.01
ID	686.3-733.5	707.9 ± 19	–	–	–	NS
IE	695.7-748.3	729.0 ± 22.0	–	–	–	–

NS: Not significant

Table 3: Group 2—Trevalon HI

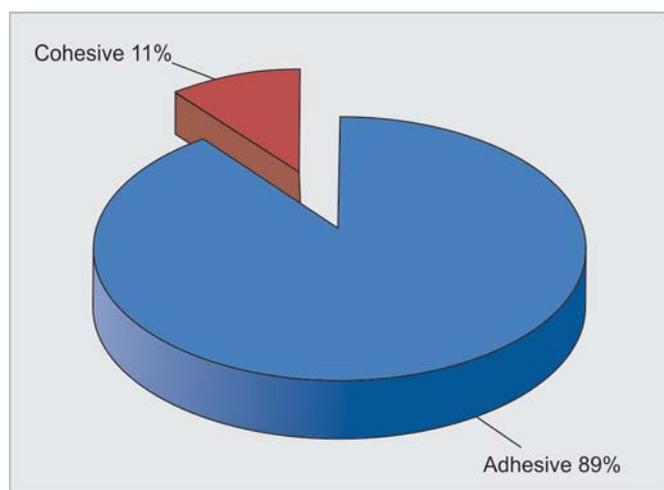
Methods	Range (N)	Mean ± SD	Difference between methods			
			IIB	IIC	IID	IIE
IIA	378.7-423	400.8 ± 22.2	p < 0.01	p < 0.05	p < 0.01	p < 0.01
IIB	730-786.3	758.1 ± 28.2	–	p < 0.01	p < 0.01	p < 0.01
IIC	598.3-44.7	627.3 ± 19.2	–	–	p < 0.01	p < 0.01
IID	676.3-720	705.0 ± 22.6	–	–	–	NS
IIE	641-686.5	660.6 ± 21.0	–	–	–	–

NS: Not significant

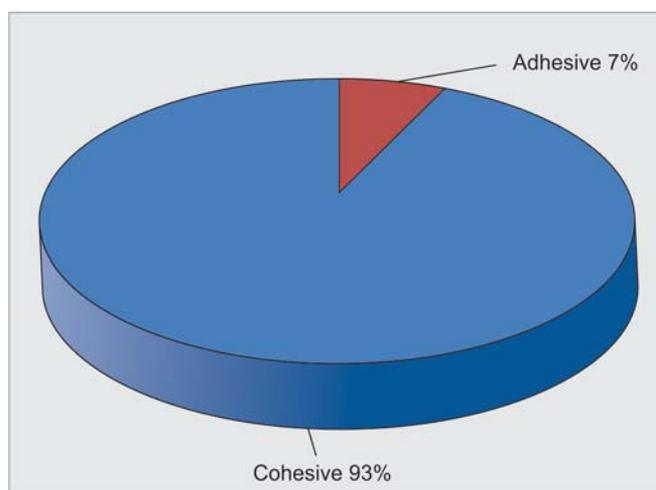
Table 4: Group 3—DPI tuff

Methods	Range (N)	Mean ± SD	Difference between methods			
			IIIB	IIIC	IIID	IIIE
IIIA	371.3-432.2	401.7 ± 30.4	p < 0.01	p < 0.01	p < 0.01	p < 0.01
IIIB	601.2-639.7	619.9 ± 13.9	–	p < 0.05	p < 0.01	p < 0.01
IIIC	565.1-651.8	585.6 ± 20.9	–	–	p < 0.01	p < 0.01
IIID	709.3-749.2	729.2 ± 17.5	–	–	–	NS
IIIE	686.5-736.2	709.4 ± 19.3	–	–	–	–

NS: Not significant



Graph 1: Control group



Graph 2: Experimental group

base resin reacts chemically with tooth resin polymer to form an interpenetrating polymer network (IPN).²²⁻²⁴ The addition of cross-linking agent in the artificial teeth intervenes with the IPN and reduces the efficiency of bonding between the artificial teeth and denture bases.¹¹

Teeth debonding from the dentures can be a frustrating experience to both the patients and dentist. Darbar et al^{1,2}

states that 33% of bonding failures occur in anterior region only. According to Catterlin et al⁴ the probable reasons for bond failure are (1) presence of foreign material, (2) incomplete wax elimination and contamination with tin foil substitutes, (3) stress areas, like sharp notches, diastemas, etc. and (4) the rate and time available for the distribution of monomer into denture base resin prior to curing can affect

the efficiency of bond strength. Vallitu et al¹⁰ concluded that removal of surface glaze by grinding at the gingival portion of acrylic teeth before packing might expose high cross-link surface that reduces the bond strength.

The ridge lap areas of method B specimens treated with trichloromethane and monomer solvent for 1 minute showed greater bond strengths than the control group specimens. In a similar study conducted by Yukata Takahashi¹⁵ and Rupp et al¹⁷ showed that the application of methylene chloride and monomer solvent significantly enhanced the bond strength, when compared to application of monomer alone, owing to swelling and penetrating nature of methylene chlorides, such as dichloromethane. And, the results in the present study coincided with previous attempts.

The topographic analysis of method C specimens revealed pores and channels which provided additional micromechanical retention and also had the advantage of trichloromethane in improving bonding showing greater bond strengths than the controlled group specimens. These results are coincided with previous studies.^{14,16}

The specimens prepared with vertical and horizontal grooves as in methods D and E respectively showed increased bond strength compared to control group as the grooves increased the surface area and allow more polymerized denture base resin to interact with and, secondly, the grooves created a path of resistance to fracture in a direction different from the tooth-denture base junction that acts as short lever arm as it is closer to the point of application; this requires a greater force to separate the tooth from denture base¹⁷⁻¹⁹ (Tables 2 to 4).

Morrow et al⁹ compared the bond strengths of plastic teeth to conventional and high impact resins. And, the results showed that standard resins possess slightly higher bond strengths (11%) than high impact resin. This result is in contrast with the present study because tensile strength was used in the previous study, whereas compressive strength was employed in the present study.

In order to simulate a clinical situation, a shear compressive force was applied using Hounsfield universal testing machine at an angle of 45° on palatal surface of central incisor teeth. This contact was chosen as it is the average angle of contact found in class 1 occlusion between maxillary and mandibular teeth.⁶

It is evident from this study that experimental group specimen showed cohesive failures and that indicates the chemical solvent facilitated the formation of IPN, whereas, in the control group, adhesive failures dominated (Graphs 1 and 2).

CONCLUSION

The following conclusions can be drawn from the present study:

1. Within limitations of this study, application of 1:1 v/v 30% trichloromethane and monomer solvent significantly enhanced the bond strengths in both high impact and conventional heat-cured resins.
2. Owing to interpenetrating polymer network (IPN) formed between teeth polymer and denture base resin in experimental specimens, the failure modes are predominantly cohesive.
3. Chemical and mechanical modifications significantly improved the strengths in high impact resins than the conventional resins.

The values remained within the range of clinical acceptability. This study is limited to heat-cured acrylic resin materials only, hence, we are of opinion that further studies must be conducted to know the effect of chemical and mechanical preparations on bond strength between cross-linked acrylic teeth and light-cured and microwave-based denture materials.

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