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Comparative evaluation of bond strength of denture base resin to acrylic resin teeth following different surface treatments: An *In vitro* study

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Abstract
Acrylic resin denture base material has been available to the dental profession for over 60 years, and although materials with superior properties have been on the market for some time, it still remains the most popular choice of clinicians. The requirement of the simple processing equipment and low cost of the fabrication process are the reasons for its continued popularity. However, debonding of acrylic teeth from denture base resins remains a problem for both patients and clinicians. The failure rate of acrylic dentures resulting from fracture has been reported to be unacceptably high, with the most prevalent type of failure documented being debonding or fractures of the teeth A series of studies have attempted to determine the quality of denture tooth bonding produced by commonly employed dental laboratory conditions. The present study was under taken to evaluate and compare the effects of chemical and mechanical treatment of the ridge lap surface of acrylic teeth on the bond strength of acrylic resin teeth to denture base resins.

Keywords: Bond strength, denture base resins, acrylic resin teeth

Introduction
Natural tooth loss is a matter of great concern to majority of people and their replacement by artificial substitutes, such as dentures is vital to the continuance of oral health. Any damage to the prosthesis subjects the patient to immense psychological stress. Conventionally, heat curing is used as the mode of polymerization for acrylic resins. Prefabricated acrylic resin teeth for dentures were introduced in 1940. Apart from the advantage of time saving, ease of fabrication and economy, these teeth bond chemically to the denture base material and have a life like translucent quality, even in thin sections of less than 1 mm. Adequate bonding of acrylic resin teeth to the denture base resin is necessary because it increases stiffness and strength since the teeth become an integral part of the prosthesis. For an effective chemical bond, the polymerizing denture base resins must come into direct physical contact with the denture teeth resin and the polymer network of the denture base resins must react chemically with the denture tooth resin polymer to form an interwoven polymer network [1]. Foreign materials like wax remnants, tin foil substitute used as mold separating agent may interfere with the direct physical contact between the polymerizing denture base resins and the denture teeth resin, thereby adversely affecting the bond strength [2]. In a bid to solve the problem of teeth debonding from the denture bases, various studies [3, 4] have been made to improve the bond strength by chemical or mechanical preparation of the denture teeth prior to bonding.
Huggert R, John G, Jagger R G *et al*. [5] in 1982 tested the bonding potential of three types of anterior plastic teeth, each having varying degrees of copolymerization with a heat cured and an autopolymerizing resin. Teeth as supplied by the manufacturer, were compared to those where the ridge lap surface were modified by Grinding, Grinding and re-polishing, Cutting a retention groove. The specimens were prepared and tested in a tensile-shear mode in batches of six, with a crosshead speed of 5 mm / min. It was reported that the ridge lap modification failed to improve the strength of the bond between the teeth and the denture base resins.

Catterlin R K, Plummer K D, and Gulley M E [6] in 1993 studied effect of tin foil substitute contamination on bond strength. Eighty maxillary right central incisors were bonded with Lucitone denture base material. After wax elimination Tin foil substitute was carefully applied to the plaster avoiding contact with the denture teeth (Control group) Tin foil substitute applied to both the plaster and the denture teeth (Experimental group).The study concluded that contamination of acrylic resin denture teeth with tin foil substitute significantly reduced the bond strength.

Cardash H S, Liberman R and Helft M [7] in 1986 investigated the effect of cutting retention grooves in the tooth ridge lap area on the bond strength. 60 central incisor teeth of the same mold were bonded with one brand of heat cured denture base resin. Specimens were divided in four groups:

Group A – No preparation

Group B– Groove 2 mm deep and 2 mm wide with straight fissure bur

Group C – Groove 2 mm deep and 2 mm wide with inverted cone bur

Group D – Half round groove 2 mm in diameter with a round bur.

Triangular shaped models with teeth bonded to two sides were used for the study. A vertical compressive shear load was applied at a rate of 5 mm / min at an angle of 130 degrees to the long axis of each tooth.No statistically significant advantage was derived by preparing retention grooves of different shape in the ridge lap surface of the denture teeth.

Spartley M H [8] in 1987 investigated the effect of contamination by wax, petroleum jelly and sodium alginate on the bond strength. Acrylic and porcelain teeth of identical size and shape were used for the study. Wax was eliminated by flushing the flask with hot water in a wax elimination machine and sodium alginate applied as cold mold seal.

Contamination with petroleum jelly and sodium alginate solution did not affect the adhesion. Wax was found to be the principal contaminant and a cause for adhesive failure.

Takahashi Y *et al*. [9] in 2000 investigated the bond strength of denture teeth with denture base resins. The denture teeth were untreated, prepared with diatorics, or treated with dichloromethane. The denture base materials used in the study were heat cured, micro-wave cured and a pour type of resin.. The bond strength between the denture teeth and denture base resins was improved by the preparation of a diatoric on the palatal aspect of the teeth. Treatment of the ridge lap surface of the teeth with dichloromethane further enhanced the bond strength.

The present study was under taken to evaluate and compare the effects of chemical and mechanical treatment of the ridge lap surface of acrylic teeth on the bond strength of acrylic resin teeth to denture base resins.

Aims and Objectives

- To evaluate the effect of mechanical treatment of ridge lap surface of acrylic resin teeth on the bond strength of acrylic resin teeth to denture base resins.
- To evaluate the effect of chemical treatment of ridge lap surface of acrylic resin teeth on the bond strength of acrylic resin teeth to denture base resins.
- To evaluate the effect of tin foil substitute contamination on the bond strength of acrylic resin teeth to denture base resins.

Materials and Methods

The materials used for the study are.

Prefabricated acrylic resin denture teeth: One brand (Premadent) of cross linked acrylic resin teeth were used in this study. In order to standardize the tooth size, only the maxillary central incisors of the same mould (P4) was used.

Denture base resin: D P I Heat cure improved polymethylmethacrylate denture base resin

Fig 1: DPI Heat cure denture base resin

Chemicals

Methylmethacrylate monomer

Dichloromethane

DPI Cold Mold Seal

Equipments

Fig 2: Universal Testing machine (Schimadzu Inc.)

Fig 3: Acryliser (Kavo Inc.)

A total of 48 teeth were used for the study. 48 teeth were distributed in 8 different groups with six samples in each group

Groups with no mechanical treatment of the ridge lap area

Group I	Control group with tin foil contamination on the ridge lap area of acrylic resin teeth wiped off with dry cotton.
Group II	Group with tin foil contamination of the ridge lap area.
Group III	Group with tinfoil contamination followed by methylmethacrylate application on ridge lap area.
Group IV	Group with tin foil contamination followed by dichloromethane application on the ridge lap area.

Groups with mechanical treatment of the ridge lap area

Group V	Group with tin foil contamination on the ridge lap area of acrylic resin teeth wiped off with dry cotton.
Group VI	Group with tin foil contamination of the ridge lap area.
Group VII	Group with tinfoil contamination followed by methylmethacrylate application on ridge lap area.
Group VII	Group with tin foil contamination followed by dichloromethane application on the ridge lap area.

Methodology for the preparation of the test specimen

Test specimens were prepared by aligning the long axis of the 6 teeth (3 on both sides) at 45 degrees to the sides of a rectangular wax block, which was contoured to a size of 70 X 40 X 10 mm. For groups V to VIII the ridge lap area of the acrylic resin teeth were roughened with acrylic trimming stones to remove the glossy surface. The wax contacted only the ridge lap area of the teeth. The wax blocks were flasked in a conventional metal flask using dental plaster. Dewaxing was done by placing the flask in boiling water for 5 to 7 minutes and then flushed with running boiling water to remove the wax completely.

Tin foil substitute applied. For the control group tin foil substitute is carefully applied to the plaster, avoiding contact with denture teeth and the tin foil substitute present on the ridge lap area of the teeth is wiped off with dry cotton. After dewaxing, the ridge lap area of the acrylic resin teeth were lightly coated with methylmethacrylate monomer for groups III and VII, and dichloromethane for groups IV and VIII, 10 minutes prior to packing. The flasks were packed with improved heat cure denture base material following manufacturer's instructions. The flasks were allowed to bench cure for 30 minutes. Thermostatically controlled water bath was used for acrylisation. The test specimens were subjected to gradual heating by placing the flasks in water bath at room temperature to 65 ^{0}C (159 ^{0}F) for 90 minutes and then boiling at 100 ^{0}C for 1 hour. After completion of the polymerization cycle, flasks were bench cooled overnight at room temperature before deflasking. The test specimens were retrieved and minimal adjustments were attempted for final corrections. Acrylic resin surrounding the necks of the teeth, if any, was removed using acrylic trimming burs.

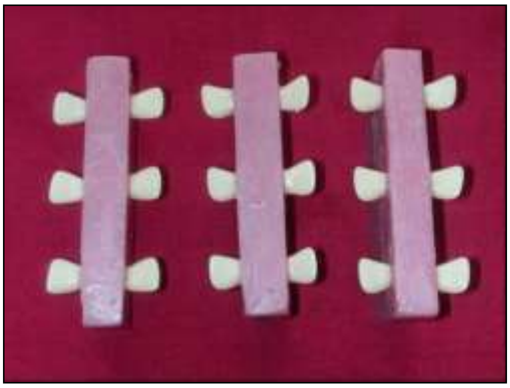

Fig 4: Test Specimens

Testing of the Specimens

The prepared specimens were subjected to load testing using a computer coordinated Universal Testing Machine (Schimadzu Inc.). The test specimens were placed in the lower jaw of the load testing machine and a vertical rod mounted on the upper jaw of the Universal Testing Machine was aligned to apply load on the palatal aspect of the specimen denture teeth.

Fig 5: Test Specimen loaded in Universal Testing Machine

A crosshead speed of 0.5 mm / min was used for testing the bond strength. Load was applied until the denture teeth separated from the denture base resin.

Fig 6: Specimens after testing

The computer attached to the Universal Testing Machine recorded the resulting bond strength values. The results were recorded and statistically analyzed.

Results

The mean bond strength of acrylic resin teeth without any mechanical treatment ranged from 256.1098 N to 321.915 N

(Table-1), where as those with mechanical treatment of the ridge lap area of acrylic resin teeth varied from 270.196 N to 425.334 N (Table-2)

Table 1: Mean tensile bond strength of specimens without mechanical treatment

	Group I	Group II	Group III	Group IV
Sample 1	270.675	236.265	336.843	309.546
Sample 2	313.983	243.843	315.585	339.218
Sample 3	265.953	254.968	355.734	326.265
Sample 4	284.484	231.568	273.718	271.796
Sample 5	256.906	290.703	283.89	287.359
Sample 6	320.015	279.312	365.718	292.984
Mean	285.336	256.11	321.915	304.528
Std. Deviation	26.1646	24.012	37.6675	25.3002
Maximum	320.015	290.703	365.718	339.218
Minimum	256.906	231.568	273.718	271.796
Range	63.109	59.135	92	67.422

Table 2: Mean tensile bond strength of specimens with mechanical treatment

	Group V	Group VI	Group VII	Group VIII
Sample 1	343.453	243.968	445.781	410.468
Sample 2	338.156	318.296	424.046	381.406
Sample 3	406.124	247.468	466.515	384.609
Sample 4	347.781	284.406	392.406	402.281
Sample 5	388.187	254.203	419.634	391.031
Sample 6	340.515	272.832	403.624	423.754
Mean	360.703	270.196	425.334	398.925
Std. Deviation	28.979	28.2 231	27.2165	16.3411
Maximum	406.124	318.296	466.515	423.754
Minimum	338.156	243.968	392.406	381.406
Range	67.968	74.328	74.109	42.348

Table 3: Results of Two-Way ANOVA (Analysis of Variance)

	Df Effect	MS Effect	Df Error	MS Error	F	p-level
Chemical	3	27497.86	40	745.525	36.8838	1.35E-11
Mechanical	1	61892.54	40	745.525	83.0187	2.63E-11
Interaction	3	4854.084	40	745.525	6.51096	0.001084

df – degrees of freedom, F – F value
MS – Mean Sum of Square, p -level – Probabilities

Table 4: Probabilities (p-value) for Post Hoc Tests using Scheffe' Test

	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII
Mean Bond Strength	285.3360	256.1098	321.9147	304.5280	360.7027	270.1955	425.3343	398.9248
Group I		0.835386	0.616348	0.980731	0.00774	0.995331	8.76 E -08	1.03 E-05
Group II	0.835386		*0.032053*	0.254045	5.25 E–05	0.997026	5.46 E–10	5.3 E– 08
Group III	0.616348	*0.032053*		0.989181	0.542142	0.182673	6.48 E–05	0.00597 4
Group IV	0.980731	0.254045	0.989181		0.111251	0.689837	2.79 E–06	0.000322
Group V	0.00774	5.25E-05	0.542142	0.111251		0.000633	*0.037719*	0.561 178
Group VI	0.995331	0.997026	0.182673	0.689837	0.000633		6.08 E -09	6.63 E–07
Group VII	8.76 E-08	5.46E-10	6.48 E –05	2.79 E–06	*0.037719*	6.08 E-09		0.896047
Group VIII	1.03 E-05	5.3 E–08	0.005974	0.000322	0.561 178	6.63 E–07	0.896047	

Bolded figures: p –value < 0.01 – Highly significant
Italic figures: p-value < 0.05 – significant at 5 % level
p-value >0.05 – Not significant

Discussion

The control group had mean bond strength of to 285.336 N. The highest bond strength was noted for group III (with monomer application on ridge lap area) with mean bond strength of 321.915 N followed by group IV with a mean of 304.528 N. The lowest bond strength was recorded for group II. Highest bond strength was noted for the group VII of 425.334 N followed by group VIII and group V in that order. The lowest strength was noticed for group VI with a mean value of 270.196.

The Post-Hoc tests following Sheffe' tests shows statistically significant differences in the bond strength between Group I and Group V, which explains that roughening of the ridge lap area of the acrylic resin teeth increases the bond strength. This is also evident from the significant differences in the bond strength between the groups III and VII and groups IV and VIII. (Table-3)The increase in the bond strength following mechanical treatment of ridge lap area may be attributed to two reasons.

- The mechanical treatment of the ridge lap area of teeth increases the surface area on the denture teeth available for the polymerizing denture base resins to interact.
- The mechanical treatments aids in better penetration of the acrylic resin and also produce some surface

irregularities into which the denture base resins flows in the dough stage during packing. This eventually provides mechanical retention following their polymerization.

The Two-Way ANOVA for comparison of variable shows that the interaction between mechanical treatment and chemical treatment to be highly significant (Table-4).

This means that the chemicals act differently on the acrylic resin teeth with and without mechanical treatment. The action of chemicals on the specimens with roughened ridge lap area is greater than on those with glossy ridge lap area. This is probably because the roughening of ridge lap area allows more penetration of the chemicals into the polymer network of teeth. There is no statistically significant difference in bond strength between groups I, II, III and IV which shows that the chemicals have less effect on glossy ridge lap surface. The significant difference in the bond strength of group VI with groups V, VII and VIII shows that tinfoil contamination of the ridge lap area significantly reduces the bond strength.

For an effective chemical bonding between the acrylic resin teeth and the denture base resins the polymerizing denture base resins must come into physical contact with the denture tooth resin and the polymer network of the denture base resin must react chemically with the denture tooth resin polymer to form an interwoven polymer network. The contamination with tin foil substitute used as a mold-separating agent interfere with the contact between the polymerizing denture base resin and the denture tooth resin thereby adversely affecting the bond strength.

Thean *et al*. [8] in their studies in 1996 suggested that the removal of surface contaminants like cold mold seal wax remnants from the bonding surfaces of the denture tooth prior to packing is more important than mechanical preparation of the tooth surface.

There is significance at 5% level in the bond strength between groups V and VII, where as there is no significance difference between groups V and VIII, which shows that the application of methylmethacrylate monomer on the ridge lap area is more effective in increasing the bond strength, compared to dichloromethane. However the study also shows no much significance in the difference in bond strength between groups VII and VIII. Dichloromethane is a polymerisable solvent which facilitates the swelling of the denture tooth polymer and thereby enhancing the diffusion of the polymerisable methylmethacrylate monomer from the denture base resins. The application of methylmethacrylate monomer on the ridge lap area prior to packing aids in more penetration of the polymerisable monomer into the denture teeth polymer there by increasing the strength of interwoven polymer network. The methylmethacrylate applied on the ridge lap area also act by removing the surface contaminants like wax remnants and tin foil substitute used as cold mold seal, there by providing more physical contact between the polymerizing denture base resins and denture tooth resin.

Conclusion

From the study the following conclusions were drawn

- The mechanical treatment of the ridge lap area of acrylic resin teeth significantly increased the bond strength.
- The chemicals like methylmethacrylate monomer and dichloromethane are more effective in increasing the bond strength in roughened ridge lap surface when compared to glossy ridge lap surface.
- Application of methylmethacrylate monomer on roughened ridge lap area significantly increased the bond strength.
- Tin foil substitute contamination of the ridge lap area consistently reduced the bond rength in all the specimens with a significant reduction observed in mechanically treated specimens.

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