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# Evaluation of the Bond Strength of Cross - Linked Acrylic Resin Teeth with Heat and Auto Polymerized Denture Base Resins after Different Surface Treatments - A Comparative in - Vitro Study

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**Abstract:** ***Context: Adequate bonding of acrylic resin or composite teeth to denture base resin is necessary because it increases stiffness and strength, since the teeth become an integral part of the prosthesis. The strength of bond achieved at the interface of acrylic teeth and denture base may be significantly improved by various methods. Aim: To compare and evaluate effect of different surface treatments on the bond strength of acrylic and composite teeth with denture base materials. Settings and Design: An in - vitro study. Methods and material: Study samples were specimens of cross - linkedacrylic Central Incisors, which were divided into 2 main groups (A and B) groups and 4 sub - groups (I - IV). In order to simulate a clinical situation, a shear load was applied at cingulum of central incisor at 135° to its long axis using Universal Testing Machine at a cross head speed of 5 mm/min, until failure occurred. This angle was chosen to simulate the average angle of contact between maxillary and mandibular anterior in class I occlusion. Statistical analysis used: Data was tabulated and statistically analyzed, using one - way ANOVA multiple range test. A p value of <0.05 was considered as statistically significant. Results: The results of the current study clearly indicated that the incorporation of mechanical and chemical surface treatments significantly influence the bonding between denture teeth and denture base resin. Conclusion: The study results conclude that in order to minimize the incidence of debonding, the ridge lap glaze removal of acrylic teeth by combination of sandblasting followed by acid etching would probably be the most optimal combination.***

**Keywords:** Bond strength, central incisors, denture base resins, in - vitro study

**Key Messages –**This study focuses on the importance of the bond strength at the of acrylic teeth and denture base and demonstrates that the combination of sandblasting and acid etching showed highest bond strength values followed by sandblasting and then acid etching.

## 1. Introduction

Acrylic resin teeth for dentures were introduced in 1940 and are preferred over porcelain teeth because of their ability to bond chemically to denture base resin, ease to trim and relatively low cost. Recent advances lead to the introduction of highly cross - linked acrylic teeth with better fracture resistance, abrasion resistance and stain resistance. However, on the other hand its bonding ability to denture base resin was found to be reduced.1 This is because, in case of cross –linked teeth, crystalline regions act as physical cross - links, which prevents complete chain separation and retards dissolution. Also, less unlinked polymer chains are available for the development of an interwoven polymer network (IPN) between teeth and the denture base.2

Debonding of acrylic teeth from the denture base is a common mode of failure. The bond between acrylic teeth and denture base material may be influenced by the type of resin base material and its physical and chemical properties and contamination of bond interfaces during lab procedures. The failure of the bond between the denture tooth and denture base resin may be excessive stress failure or fatigue.3Debonding of denture teeth to the denture base can occur adhesively or cohesively. This problem is even more serious in implant supported dentures where use of both highly cross - linked acrylic teeth and high impact denture base resins is desirable for their improved physical and mechanical properties.4

This is because of increase in forces applied to prosthetic components due to superior chewing capacity, increases the risk of displacement of the artificial teeth from the denture

base. In a study of 391 consecutively tested implant patients, Engelmeir[1] reported that resin tooth fractures were the most common prosthetic complication. Even certain clinical conditions like, anterior ridge prominence and less interocclusal space leads to excess trimming of acrylic teeth and base, resulting in a weak interface where denture base polymer debonds adhesively in the region of the highly cross - linked matrix of the teeth. Differences in types of denture teeth, acrylic resin, and experimental techniques may contribute to the variability of reported results. However, there are conflicting evidences regarding benefits of mechanical and chemical surface treatments of teeth, as the effect seems to depend on the brand of tooth and denture base resin.[5, 6]

The observations emerging from the literature review on the denture teeth retention in denture base prompted to conduct the present study. Hence this study was designed and conducted with the aim to compare the effect of different surface treatments on the bond between cross linked acrylic teeth and heat polymerized and auto polymerized denture base materials.

## 2. Subjects and methods

This is an in - vitro study performed to evaluate effect of preprocessing surface treatments on the bond strength of acrylic teeth. The materials used for conducting the study were (Acryrock, (Ruthinium) (A2, 53) Prefabricated cross linked acrylics resin teeth, Maxillary anterior mold (size U shade, right side), DPI (Heat cure denture base resin), DPI - (RR - self cure denture base resin), aluminium oxide (BEGO) used for air abrasion (50 Micron), phosphoric acid (KERR) as 37%, Etchant gel, Dental plaster (Kalabhai), Dental stone (kalabhai), Alginate separating media (cold mold seal, DPI) and Modelling wax.

**Armamentarium and equipment's –** Rubber Bowl and spatula**,** Wax knife**,** Wax Bath (Vilman), Measuring jar**,** Porcelain Jar**,** Camel hair brush**,** Acrylizer (Vilman), Mechanical vibrator (Confident), Micromotor and hand piece (Marathon), Round bur**,** Straight fissure bur**,** Acrylic trimming bur**,** Lecron's carver**,** Sand paper (80, 100, grits) and Universal testing machine (Hounsfield).

## 3. Methodology

**a) Fabrication of the metal die:** A metal die was fabricated with the dimension of a paraffin wax block measuring 45x13x13 mm (Figure 1). In order to standardize the angulations of tooth and to bond it to heat cure polymerizing denture base resin, a metal slit of nearly 2mm was fabricated in metal. The tooth i. e. maxillary central incisor was placed at$45^0$ angulation contacting (ridge lap area) with the molten wax, which was later processed respectively in heat cure and auto polymerizing denture base resin.

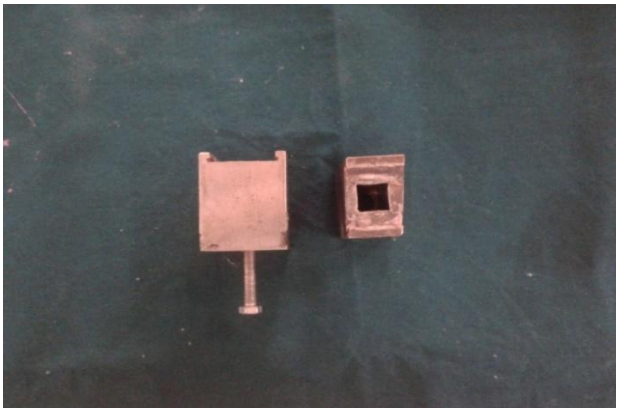

**Figure 1:** Prefabricated metal die

**b) Standardization of specimen -** A total number of 160 maxillary central incisors, of same mold with regard to size and shape were selected to be bonded with two differently polymerized denture base resins. The test samples (maxillary central incisors) of acrylic resin teeth were divided into 4 groups. Group A: Test samples of acrylic teeth processed with heat cure denture base resin. Subgroup I (control): Denture teeth without any surface treatment. Subgroup II: Denture teeth with an aluminium oxide air abrasion and Subgroup III: Denture teeth with application of acid etchant (ortho phosphoric acid) 37/. SubgroupIV –Denture teeth with combination of acid etching and aluminum oxide air abrasion. Group B: Test samples of acrylic teeth processed auto polymerizing denture base resin. Subgroup I (control): Denture teeth without any surface treatment. Subgroup II: with an aluminum oxide abrasion and Subgroup III: . application of acid etchant (ortho phosphoric acid) 37/. Subgroup IV combination of acid etching and aluminium oxide air abrasion. The surface treatments were done at the ridge lap area.

**c) Preparation of surface treated teeth:** The test specimens which were being used for Subgroup II of each group were surface treated with a aluminum oxide abrasion (BegoGermany). The test specimens which were being used for Subgroup III of each group were surface treated with an acid etching gel (Kerr). Every sample was surface treated by same operator. The last specimens which were being used for subgroup IV were surface treated with a combination of Aluminium oxide abrasion and acid etching gel.

**d) Preparation of wax models:** These test specimens (central incisors) were positioned to simulate ideal arrangement and were polymerized using heat cure denture base resin and auto polymerizing denture base resin. The wax model dimension (45 x 13 x 13) mm with a tooth positioned simulating arrangement of teeth in conventional denture was used for making index Molten modeling wax is poured in metal die to create a virtual space to be filled by heat cure denture base resin. Thus, the test specimen, (modeling wax) which was melted using a wax bath was poured into the prefabricated metal die and finally 80 identical wax models were obtained. This wax assembly was positioned in a base of denture processing flask. Dental plaster was poured up to plaster wax border, and plaster was allowed to set. Separating medium was applied to the base of the plaster. Flask was placed in dewaxing unit for 10 min in boiling water and complete wax removal was done with

boiling water. After wax removal, cold mold seal (separating medium) was applied to the base and counter flasks. These Specimens were divided into 4 groups with 20 teeth in each group.

**e) Processing of specimens using heat cure denture base resin -** A mixture of polymer and monomer in the ratio of 3: 1 by volume was proportioned prior to mixing. Mixing was done in porcelain jar and once the mix reached the dough consistency it was kneaded by hand to increase its homogenicity and integrity and then packed in the mold.

f**) Processing of specimens using auto polymerizing denture base resin -** A thin and uniform layer of vaseline was applied on all the inner surfaces of prefabricated metal die. A mixture of polymer and monomer in the ratio of 3: 1 by volume was proportioned prior to mixing. Mixing was done in porcelain jar and once the mix reached the dough consistency it was kneaded by hand to increase its homogenicity and integrity and then packed in the mold. Here the central incisor was placed by holding it between the slit for proper support and fracture load was tested using the Universal Testing Machine (UTM) (Figure 2 and Figure 3)

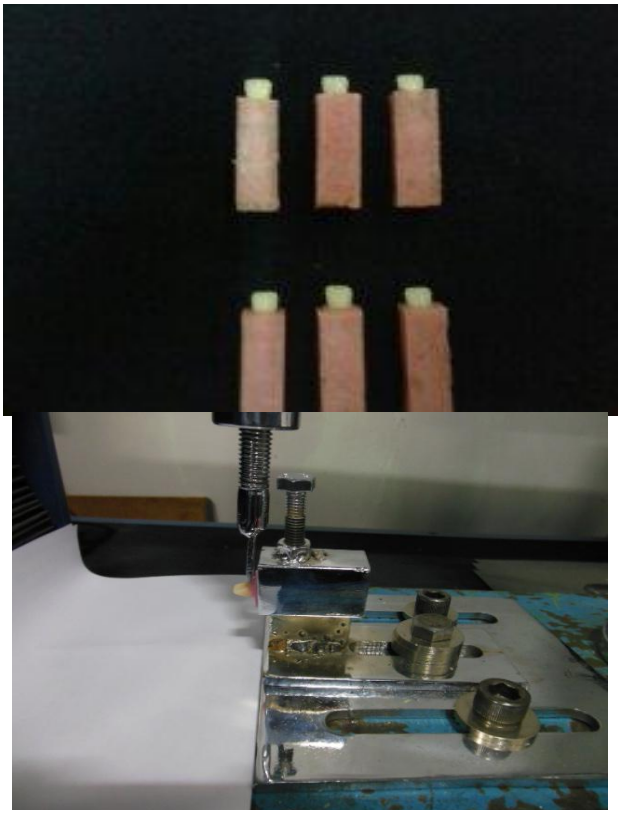

**Figure 2:** Self - cure and Heat cure blocks Figure 3: Fracture load under UTM

## 4. Results

This in - vitro study was conducted with the aim to compare and evaluate effect of different surface treatments on the bond strength of acrylic teeth with denture base materials. After the test sample was mounted to the jig, shear load was applied at cingulum of central incisors at 135° to its long axis using Universal Testing machine, until failure occurred. The reading obtained on the digital monitor attached to the testing machine were calculated, tabulated and statistically analyzed, using one - way ANOVA multiple range test. A P - value of less than 0.05 was considered as statistically significant. From the study following results were obtained. Comparison of mean maximum load with respect to heat cure and self - cure group:

**Table I**

| | | Number of samples | Mean | SD |
|---|---|---|---|---|
| Group A (Heat Cure) | Control | 20 | 763.50 | 97.78 |
| | Sand blasted | 20 | 858.10 | 87.54 |
| | Acid Etched | 20 | 835.58 | 112.84 |
| | SB + AE | 20 | 853.12 | 126.10 |
| | Total | 80 | 827.57 | 111.74 |
| Group B (Cold Cure) | Control | 20 | 500.15 | 146.15 |
| | Sand blasted | 20 | 453.38 | 122.95 |
| | Acid Etched | 20 | 416.60 | 118.98 |
| | SB + AE | 20 | 708.25 | 155.39 |
| | Total | 80 | 519.59 | 175.75 |

**Table II**

| | | Number of samples | Minimum | Maximum |
|---|---|---|---|---|
| Group A (Heat Cure) | Control | 20 | 533.12 | 920.22 |
| | Sand blasted | 20 | 691.88 | 967.26 |
| | Acid Etched | 20 | 557.62 | 987.46 |
| | SB + AE | 20 | 580.16 | 1024.10 |
| | Total | 80 | 590.51 | 674.76 |
| Group B (Cold Cure) | Control | 20 | 298.90 | 863.60 |
| | Sand blasted | 20 | 284.20 | 750.68 |
| | Acid Etched | 20 | 254.80 | 600.74 |
| | SB + AE | 20 | 313.60 | 919.24 |
| | Total | 80 | 287.87 | 783.54 |

**Table I and II** shows results for mean maximum load with heat cure and cold cure group and shows maximum and comparative failure load values (Newton) of different subgroups (I, II, III IV) of each group. The comparative analysis of failure load value between different subgroups prepared with different surface treatments was found to be statistically significant (P<0.05). **Table III A and Table III B** gives the comparative analysis of failure load value between different subgroups prepared with different surface treatments which was found to be statistically significant (P<0.05). By using Tuckey's test, it was found that there is significant difference between group A SUBGROUPS like group A I with group AII, group AI with AIII, group AI with AIV. Similarly, pairwise comparison between group B were evaluated statistically.

The test results were significant. By using Tuckey's test it was found that there is significant difference between different surface treatments on the teeth surface before processing them in heat cure acrylic resin and auto polymerizing acrylic resin. The graphs show mean fracture load (N) with minimum and maximum fracture load with respect to heat cure acrylic resin and auto polymerizing acrylic resin**.**

**Table III A:** Tukey's test for multiple comparison - Pair wise Comparison for Group A (Heat Cure)

| | | Mean Difference | Std. Error | P – value | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Control | Sand blasted | - 94.60 | 33.86 | 0.03* | - 183.54 | - 5.66 |
| | Acid etching | - 72.08 | 33.86 | 0.15 | - 161.03 | 16.86 |
| | SB + AE | - 89.63 | 33.86 | 0.05* | - 178.57 | - 0.69 |
| Sand blasted | Acid etching | 22.52 | 33.86 | 0.91 | - 66.42 | 111.46 |
| | SB + AE | 4.97 | 33.86 | 1.00 | - 83.97 | 93.91 |
| Acid etching | SB + AE | - 17.55 | 33.86 | 0.95 | - 106.49 | 71.40 |

* p value <0.05 statistically significant

**Table III A:** Tukey's test for multiple comparison- Pair wise Comparison for Group B - Pair wise Comparison for Group B

| | | Mean Difference | Std. Error | P – value | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Control | Sand blasted | 46.766 | 43.237 | .702 | - 66.809 | 160.340 |
| | Acid etching | 83.547 | 43.237 | .223 | - 30.027 | 197.121 |
| | SB + AE | - 208.110 | 43.237 | < 0.001 | - 321.684 | - 94.535 |
| Sand blasted | Acid etching | 36.782 | 43.237 | .830 | - 76.793 | 150.356 |
| | SB + AE | - 254.875 | 43.237 | < 0.001 | - 368.449 | - 141.301 |
| Acid etching | SB + AE | - 291.657 | 43.237 | < 0.001 | - 405.231 | - 178.082 |

## 5. Discussion

Acrylic teeth are the most popular artificial teeth for denture construction. Unlike porcelain teeth, they are suitable for a chemical union between the teeth and the denture base resin. Debonding of denture teeth from a denture base remains a major problem in prosthodontic practice. Studies that have evaluated the frequency of various denture repairs have found tooth debonding to be the most frequent reason for repair of conventional prosthodontics.

With the increased use of implants and commensurate increase in forces applied to prosthetic components, it is probable that tooth debonding will become an even greater clinical problem. In a study of 391 consecutively treated implant patients, Engelmeir[1]reported that resin - tooth fractures were the most common prosthetic complication. Failure of the tooth - denture bond may be caused by excessive failure or by fatigue. The strength of the bond is related to the composition of the material, for example, to the extent of co - polymerization of the acrylic denture base. Poor laboratory technique, including faulty boil - out technique and indiscriminate use of separating medium in particular have been held responsible for preventing optimum tooth denture base bond strength, thus causing many failures.

Over the years many researchers have tried to improve the bond strength by mechanically altering the ridge lap surface. However, the results have been mixed and conflicting. Civjan et al (1972) [7] reported that adequate retention of acrylic teeth to fluid resin in denture base can be obtained by grinding of the ridge laps.

Cardash et al (1986) [8] found that no statistically significant advantage was derived by preparing retention grooves of different shapes in the ridge lap surface of the denture teeth. But contradicting the earlier study, Cardash et al (1990) [8] reported that the vertical retention grooves cut in the ridge lap surface of the teeth increased retention to acrylic resin. Vertical grooves placed on denture enhance their bonding, yet the advantage of the horizontal grooves is unclear. Barpal et al (1998) [9] reported that a diatoric significantly decreased the failure load in Lucitone resin, but actually increased it in lvocap resin.

Zuckerman (2003) [10] reported that the teeth that separate most often from the denture base are the maxillary incisors and canines. These denture teeth often separate from the denture base without any evidence of damage to the denture base or the teeth. The teeth usually can be replaced in their undamaged recesses within the denture base. These findings suggest the following: i) Adhesion of the dislodged teeth to the denture base was insufficient to create a reliable union between the parts, ii) The material from which the teeth or the denture base are fabricated is slightly flexible, and iii) The teeth probably were retained in the denture base by a weak mechanical union. The best bonds were reported when denture base acrylic was processed to acrylic teeth by use of different surface treatments. The bond between denture teeth and, heat polymerized denture base has been reported as similar to the bond created by cold polymerized resin.1[0, 11]

The present study was conducted to compare and evaluate effect of different surface treatments on the bond strength of acrylic teeth with denture base materials and also to compare and evaluate in heat and self - cure acrylic resins. In order to simulate a clinical situation, a shear load was applied at cingulum of central incisor (11) at 135º to its long axis using Universal Testing Machine at a cross head speed of 3 mm/min, until failure occurred. This angle was chosen to simulate the average angle of contact between maxillary and mandibular anterior in class I occlusion.

In this study, the samples prepared with different surface treatments on the ridge lap of teeth, subgroup II of acrylic teeth processed with heat cure acrylic resin group showed highest failure load value (858.10 Newton) followed by subgroup IV of acrylic teeth (853.12 Newton), subgroup III (835.58 Newton). Tooth base roughening with different mechanical and chemical surface treatments provided slightly higher bond strength values than those achieved with other surface modification; it is likely that roughened surfaces provide a wider contact area with denture base resin and greater micro mechanical retention, justifying the slightly higher bond strength tendency in these groups.1[2]

The study samples prepared with acrylic teeth; Group A showed highest load value followed by group B. The bond between acrylic teeth with heat cure denture base was found better than cold cure acrylic resin. As per Rendon (2007) [13]; the bonding of artificial tooth resin to denture base acrylic resin has been related to the ability of monomer to diffuse into the tooth resin. The degree of monomer diffusion is related to the degree of cross - linking of a polymer. The acrylic teeth used in this study were highly cross - linked polymer with negligible filler content.1[4]

If a polymer is highly cross - linked, it has difficulty diffusing monomer in organic solvent. Consequently, the monomer diffusion in acrylic teeth is superior making its bonding with denture base resin better.1[5]

The samples made with auto polymerizing self - cure acrylic resin and heat cure acrylic resin between Group A and Group B significant difference was found in failure load values and was more for Group A than Group B; With acrylic teeth and heat cure acrylic resin showed significantly higher results. The heat polymerization enables both a high degree of polymerization and an excellent adhesive bond to resin teeth.

## 6. Conclusion

The present in vitro study was carried out to evaluate the efficacy different surface treatment methods (sandblasting, acid etching, and combination) on the bond strength of cross - linked acrylic resin teeth with heat polymerized and auto polymerized acrylic resins. Among all the eight groups, the sand blasting (subgroup A II) showed the highest mean bond strength, the control (subgroup B) showed the lowest mean bond strength. The sandblasting surface treatment (subgroup (A) II) showed the highest mean bond strength, followed by combination (subgroup A, IV) and then acid etching (subgroup AIII) N and then control subgroup. Among specimens processed with (Group A). There was a statistical significance in the values of the four subgroups within the group A**.** The combination surface treatment (subgroup BIV) showed the highest mean bond strength, followed by control (subgroup BI) and then sandblasted (subgroup BII) and then acid etched subgroup. This study demonstrated that the combination of sandblasting and acid etching showed highest bond strength values followed by sandblasting and then acid etching.

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