# Effect of surface treatments and thermocycling on shear bond strength of various artificial teeth with different denture base materials

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## ABSTRACT

Background: Separation and deboning of artificial teeth from denture bases present a major clinical and labortory problem which affect both the patient and the dentist. The optimal bond strength of artificial teeth with denture base reinforced with nanofillers and flexible denture bases and the effect of thermo cycling should be evaluated. This study was conducted to evaluate and compare the shear bond strength of artificial teeth *(acrylic and porcelain)* with denture bases reinforced by 5% Zirconium oxide nanofillers and flexible bases under the effect of different surface treatments and thermo cycling and comparing the results with conventional water bath cured denture bases.

Material and methods: Two types of artificial teeth; acrylic and porcelain were used and prepared for this study. Five specimens of each tooth type were processed to each denture base materials after the application of different surface treatments; these teeth were bonded to heat polymerized, nano composite resin and flexible denture bases. Specimens were thermo cycled and tested for bond strength until fracture with an Instron universal testing machine. Data were analyzed with analysis of variance and student T-test. Photomicrographic examinations were used to identify adhesive and cohesive failures within debonded specimens.

Results: The mean force required to fracture the specimens were obviously larger for nanocomposite specimens compared with the heat cured and flexible specimens. The most common failure was cohesive within the tooth or the denture base. With each base material, the artificial teeth which were treated with thinner exhibited highest shear bond strength. Thermocycling had deleterious effect on the flexible denture base specimens. In general, nanocomposite and heat cured groups failed cohesively within the artificial tooth. While the valplastic groups failed adhesively at the tooth denture base interface.

Conclusions: Within the limitations of this study, the type of denture base materials and surface treatments of the tooth selected for use may influence the shear bond strength of the tooth to the base. Selection of more compatible combinations of base and artificial teeth may reduce the number of prosthesis fractures and resultant repairs.

Key words: acrylic teeth, porcelain teeth, Nano composite denture base, thermo cycling, flexible denture, thinner, hydrofluoric acid, shear bond strength, photo-microscope. (J Bagh Coll Dentistry 2013; 25(1):5-13).

## INTRODUCTION

One of the benefits of using acrylic teeth instead of porcelain teeth is their ability to chemically bonding to denture base.[1] Two processes affect the achievement of such a chemical bond. First, the polymerizing denture base must come into intimate contact with the denture tooth. Second, the polymer network of the denture base must react chemically with the acrylic tooth polymer to form an interwoven polymer network. Equalized solubility or compatibility of the two polymers is essential for the interwoven polymer and thus for the strength of the bond. [2] Foreign materials which interfere with the contact between the polymerizing denture base and the tooth, thereby adversely affecting the bond strength.

Presence of tinfoil substitute used as a mold separating agent on the artificial tooth significantly lowers the tooth denture base bond. [3]

Chemical or mechanical preparation of the artificial teeth ridge lap before the processing had multiple effects on the bond strength. [4] Mechanical retention is required when acrylic resin is bonded with acrylic teeth. The teeth with vertical grooves showed significantly superior bond strength in all tooth types and resin combinations and that was due to the increase in the surface area.[5] Porcelain teeth that were air abraded with aluminum oxide particles showed significantly lower bond strength after thermo cycling.[6]

Solvent wetting of the teeth enhance the bond between teeth and denture bases. On academic basis, the monomer softened the surface of the teeth and diffuses into the tooth polymer. On polymerization, an interdigitation network of polymer units bonds the denture base to the tooth. [7] The absence of the influence of the solvent on the

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bond strength was related to the high degree of cross linking of the acrylic teeth. Cross linking were done to improve the properties of the tooth such as fracture, abrasion and staining resistance. But, on the basis of bonding strength the cross linked teeth don't provide good bonding strength. [8]

Strongest bond was obtained between heat cured resin and plastic teeth. The bond between flexible resin and both types of teeth were entirely relies on the mechanical retention to retain the teeth, so that if there were no room to place retention holes in the teeth, they can be displaced over time. [9] On the other hand, heat cured resin reinforced with nanofillers had the highest interfacial shear bond strength between the resin matrix and nanofillers when compared with the conventional resin matrix. This super molecular bonding which fond to cover or shield the nanofillers and creates thick interfaces that enhances the bond between the resin molecules. [10]

Thermo cycling is essential in studies of micro-leakage because it exposes the restoration to simulated situations that normally stress the marginal seal. This is particularly important when the coefficient of thermal expansion of the restorative material is different from that of tooth structure. Thermo cycling was used to more closely simulate the oral conditions. The range of temperature used had an upper limit being 45-60 C° and lower limit 4-15C°, which were based on changes in temperature that are within normal extremes in the oral cavity and induce an opening between the tooth and restoration. [11] This theoretically allowed for repeated expansion and contraction of the tooth and denture base components thereby stressing the bond. The secondary benefit of thermo cycling was hydration of the specimens, which further simulated the clinical conditions. [12]

This study was conducted to evaluate the shear bond strength of artificial teeth *(acrylic and porcelain)* bonded to the following denture bases: conventional water bath, resin reinforced with 5% $ZrO_2$ nanofillers and flexible (nylon) denture bases after application of different surface treatment materials: thinner *(turpentine)* for acrylic teeth and acid etching *(hydrofluoric acid)* for porcelain teeth and the effect of thermo cycling (aging) on that bond.

# MATERIALS AND METHOD

A total of 120 specimens of maxillary central incisors were selected. For each denture base type; 60 acrylic teeth (Florident, china) and 60 porcelain teeth (Ivoclar, vivadent) were waxed onto the beveled surface of a rectangular wax block according to the Japanese standard for artificial teeth (JIST 6506, 1989) as shown in figure 1.
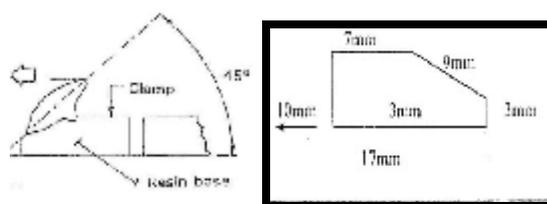


(A)        (B)
**Figure 1: A; the specimen configuration, B; the specimen's dimensions.**

The slope of the beveled surface aligned each artificial tooth long axis 45 degrees to the base of the wax block as shown in figure 2.



**Figure 2: Acrylic and porcelain teeth attached to waxed blocks.**

**Surface treatments**

The ridge lap surfaces of the artificial teeth were treated with chemical solvent thinner (Dyna- Coat Thinner Standard, Product of Netherlands) for acrylic teeth and hydrofluoric acid (Thomas baker India HF Analyzer) for porcelain teeth by using cotton bullets for 3 minutes. Photomicroscope pictures were taken to the surface of the teeth prior to and after the application of surface treatments and also after failures by using photomicroscope (H.B.H.Olympus, Japan).

**Mould preparation for the test specimens:**

The waxed patterns were coated with a separating medium and allowed to dry. A 120 gm dental stone type III (Elite model, Italy) slurry was poured into the lower half of the flask, then the

waxed patterns were inserted into the stone slurry to one-half of their depth and left to set.

After the stone was set, it was coated with separating medium and allowed to dry. For the flexible specimens wax sprues were prepared; major sprues with 6-8 mm in diameter and minor sprues of 2-4 mm in diameter and attached to selected areas from one side of the waxed patterns.[13] then the upper portion of the metal flask was positioned on the top of the lower portion and filled with 300 gm stone. Vibration was done to get rid of the air bubbles. Stone was allowed to harden before the metal flask was opened.

Wax elimination was performed using boiling water then metal flask was opened, the teeth were attached to the upper half of the flask while mold halos were left to the lower half. The mould was then carefully cleaned with detergent and washed thoroughly with boiling water to make sure all residues were eliminated. The flasks were allowed for cooling at room temperature as shown in figure 3.



**Figure 3: the upper and lower halves of the flask after wax elimination and flask opening**

**Preparation of denture bases:**
A.      Acrylic reinforced with 5% silanated $ZrO_2$ Nanofillers:
Silanation of ($ZrO_2$) fillers:
The introduction of reactive groups onto fillers surface was achieved by reaction of the 3-trimethoxysilylpropylmethacrylate, TMSPM, (Sigma Aldrich, Germany) with zirconium oxide nano-fillers (Sigma-Aldrich Germany). Addition procedure was done as follows: 30g of nano-fillers and 200 ml pure toluene solvent were placed into a glass flask then sonicated at ambient temperature of (37C°) for 20min. After that, the nano-filler and toluene were placed into a flask equipped with a magnetic stirrer (labinco, bv model l-81) at room temperature. Then, 1.5 gm of silane (5% wt to nano-filler) was added drop wisely by sterile syringe under rapid stirrer. The flask was covered

by para-film and the slurry was left standing in the flask for 2 days. The toluene solvent was removed by rotary evaporator (RE 510, Yamato, Japan) under vacuum at 60°C and rotation of 150 rpm for 30 min. Then the silenated nano-filler was dried in vacuum oven (Gallen bamp, England) at 60C° for 20 hours. After that nano filler were stored at room temperature before use. [14]
**Proportioning and mixing of the acrylic:**
Addition of nano-fillers:
The incorporation of modified Zirconium oxide nano-filler powder to monomer was done by 5% weight which is equal to 0.600 g silanated $ZrO_2$. An electronic balance (Sartorius BP 30155, Germany) with accuracy of (0.0001gm) was used. After the addition of $ZrO_2$ nano-filler to 6 ml monomer, the fillers were well dispersed in the monomer by ultra sonication, using a probe sonication apparatus (Soniprep-150, England) at 120 W, 60 KHz for 3 minutes to break them into individual nano-crystals [15] as shown in the figure 4.



**Figure 4: Nano-fillers were well dispersed in the monomer by ultrasonication as shown in A: before, B: during and C: after sonication.**

The suspension of the monomer with $ZrO_2$ nano-filler was immediately mixed with 11.400 g of acrylic powder (Spofa Dental Czechoslovakia) to reduce the possibility of particle aggregation and phase separation. The proportion for mixing of acrylic resin was (12 gm: 6 ml) P/L ratio. All materials were mixed and manipulated according to manufacturer's instructions. The mixing was carried out at once, in a clean and dry mixing vessel and mixed by a clean wax knife for 30 second. The mixture was then covered and left to stand until a dough stage was reached and then placed inside the mould. [15]

The flasks were immersed in water bath at 73C° for 90 minutes, raising the temperature to 100ºC and maintaining the boiling for 30 minute. Once the polymerization cycle was completed, the flasks were allowed to slow cooling in a water bath at room temperature before deflasking. [15]

**B- Flexible (Nylon) denture base material**

The procedure started with the heating cylinder inserted into the slot present inside the electrical furnace and the furnace was allowed to warm up till it reaches the preset heating which was 287°C, then the heating cylinder removed from the furnace. The flexible cartridge (flexible nylon granules valplast international corporation, USA) metal disc and the short solid metal cylinder Inserted into the heating cylinder and left inside the furnace for 11 minutes to allow the granules inside the cartridge to melt. During that time the flask, which previously preheated inside an oven set at 65°C for 30 minutes, removed from the oven and placed inside the injection unit (Plastic injection system, KCX-09B, China) in horizontal correct position with the aid of the projection present at the base of the injection unit. In this position the injection opening was at the top surface of the flask [16] as shown in figure 5.
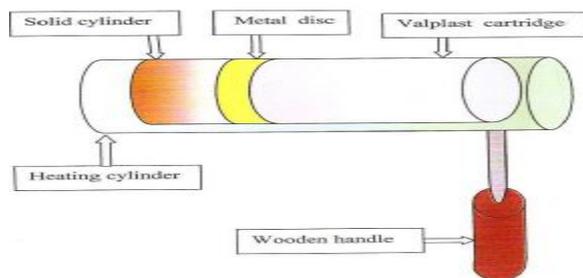


**Figure 5: the configuration of the injection system.**

The material was injected inside the flask by the use of the manual injection unit; the handle of the injection unit was tightened until both springs on the top side of the unit were closed to give a pressure of 5 bars. After 5 minutes the pressure was released and the flask is removed from the injection unit and allowed for cooling at room temperature. Then the flask was opened and the specimens were removed from the mold. [16]

**Finishing, polishing and conditioning of the specimens**

The sprues were cut off from the specimens with a cut off disc at a low pressure with continuous water cooling to avoid overheating the material. The edge of the specimen was trimmed with a grinding wheel (1500 rpm). All the specimens were hand finished using finer grades of silicon carbide paper (grades 120 to 500) with continuous water cooling. Overheating the specimens was avoided during finishing. The specimens were smoothed prior to polishing with the Smooth blue rubber

wheels on the mandrills. For polishing, Tripoli compound with a dry rag wheel was used to produce smoothness. Oil residues from the Tripoli compound were removed by washing with soap and water [17]. All specimens were stored at 37C° for 7 days in distilled water before the shear test. Then half of the specimens were tested by using instron machine (Instron Corporation, canton mass). The other half of the specimens were thermo cycled by thermocycling device (Haackt, Germany) between 5C° and 55C° in 60-second cycle for 3 days which means approximately 1000 cycles, and then they were tested immediately in the tenth day by the same machine. Shear load was applied at 45 degrees from the long axis of each denture tooth on the palatal surface at a cross head speed of 1.5 mm/min until fracture as illustrated in figure 6.
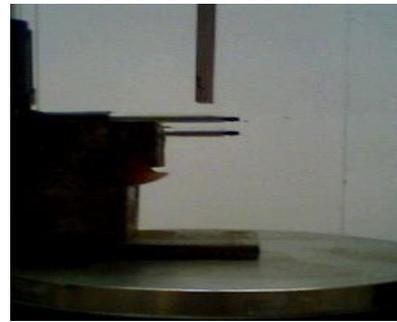


**Figure 6: Specimen attached to metal fixture fixed on the instron machine.**

For all specimens, the interface where failure occurred was inspected. The failure was classified as either adhesive or cohesive in nature as in figure 6.



**Figure 7: Fractured specimens under visual examination.**

Specimens were loaded until fracture and the load of fracture was recorded from the Instron graph reader in newton. [18] The shear bond strength were calculated based on the force *(F)* in *(N)* at fracture and adhesive surface area *(S)* in *(mm²)* and converted to *(Mpa)*. Where B.S = F / S and B.S =

Bond strength *(N/mm²)* or *(MPa)*, S= *(π / 4)* × D²; μ=22/7 or 3.14. D *(diameter) =* 5mm, S = 19.64 mm². [19]

The data were analyzed statistically using 3 way analysis of variance (ANOVA). The variables were surface treatments, denture base resin and thermo cycling. Student t-test for comparison and failure percentage was also applied.

## RESULTS

Results of shear bond strength means in Mpa were given in Table1 for acrylic teeth and table 2 for porcelain teeth bonded to heat, flexible and nano-composite denture bases.

The three way ANOVA revealed high significant difference in the bond strengths among the surface treatments, denture base resin and thermo cycling (P<0.001). There were also high significant differences in the artificial teeth surface treatments and denture base interactions (P<0.001) as shown in table 3.

**Effect of surface treatments**

T-test of surface treatments of artificial teeth showed that both the acrylic and porcelain teeth possessed higher bond strength than the control denture teeth (P<0.001) except for the flexible denture base. The application of thinner for acrylic teeth and hydrofluoric acid for porcelain teeth significantly improved the bond strength for all types of denture bases before and after thermo cycling as shown in tables 4 and 5.

**Effect of type of denture base materials**

T-test for comparison showed that the nano composite and heat cured denture base generally possessed significantly higher bond strength than the flexible cured denture base except for groups bonded to porcelain teeth were data revealed no significant differences as shown in tables 6,7,8,9.

**Effect of thermo cycling**

T-test of the comparison showed that the thermo cycling had no significant effects on the bond of acrylic teeth to heat cured denture base especially in the control group (P>0.05). While it possessed high significant effect on the shear bond strength of the flexible denture base bonded to both acrylic and porcelain teeth (P<0.001). On the other hand, results showed that thermo cycling had no significant effects on the bond of acrylic and porcelain teeth bonded to nanocomposite denture base (P>0.05) as shown in tables 10,11,12 and figures 7 and 8.

The photo microscopic examination of the un treated acrylic and porcelain teeth showed a homogenous surface devoid of irregularities. The treatment thinner creates pores and channels while with hydrofluoric acid porcelain teeth revealed loss of surface glaze.

The cohesive failure mode of the artificial teeth bonded to denture bases were shown in figures 9.

## DISCUSSION

All the data from the experiment were separated according to the artificial teeth type, the denture base type and before and after thermo cycling.

**Effect of surface treatments**

The use of thinner for acrylic teeth and hydrofluoric acid for porcelain teeth achieving high shear bond strength. Thinner is a strong solvent composed from multiple solvents. Dissolve away the micro debris and smooth out the surface and produced sponge like structure thereby increasing the number of active sites which facilitates the swelling of the denture tooth polymers and there by enhances the diffusion of the polymerizable materials, notably MMA, from the denture base resin. The strength of the bond depends on the degree of penetration of the solvent and the strength of the interwoven polymer network formed thereafter. [20] Hydrofluoric acid or other acids creates retentive channels which optimize the micromechanical bond between the ceramic and the resin. [21, 27]

**Effect of denture bases type**

Flexible resin does not appear to be capable of diffusing effectively into the tooth surface to ensure a satisfactory bond due to poor wetability as a result of higher viscosity and lack of polymerization reaction because these materials being heat pressed in to a denture form. [22] Also, the mismatch of polymerization reaction between artificial tooth and denture base when flexible is used does not provide the same free monomer transfer as is found in heat cured resins. [23] In addition, the higher temperature of polymerization of heat cured resin leads to higher and faster diffusion rates of the free monomer to the swelled beads of acrylic teeth leading to a stronger shear bonding strength. [24] Also, the long curing cycle of heat cured acrylic resin compared with the short curing cycle of flexible resin lead to produce a material with high molecular weight and strong bonds between the polymer chains. [24] on the other hand, nanocomposite denture base had the highest interfacial shear bond strength between the resin

matrix and nanofillers when compared with the conventional resin matrix. This super molecular bonding which was found to cover or shield the nanofillers and creates thick interfaces that enhances the bond between the resin molecules and creates higher molecular weight polymers. [10]

**Effect of thermo cycling**

Acrylic teeth and the acrylic resin denture base have nearly the same coefficient of thermal expansion $(80\text{-}81 \ X \ 10^6 \ /C^{\bullet})$ therefore, this similarity reduced the chance for the creation of thermal stress, so the bond strength was not affected by such thermal fluctuation. [25] Also, the smooth surface *(untreated)* facilitated a closer adaptation of denture base to the tooth surface during adaptation of resin to the tooth ridge lap during packing, thus minimizing voids creation[25]. Solvent treatments *(thinner)* of the acrylic teeth leads to the creation of channels and pores and also voids formed during solvent evaporation as revealed by microscopic examination which prevents a close adaptation of the tooth to the denture base resin during packing. [20] Moreover, since thermo cycling cause hydration of the specimens, so the material absorbed water and this had a damaging effect on the bonding. The water may peculate directly into the bond site, accumulates in the voids at the interface leading to swelling and consequently stresses build up at the denture base interface. [12]

Flexible resin was possibly more susceptible to partial cracks during finishing and polishing procedures on the lathe machine and then the additional stress of thermo cycling may had propagated the cracks to total fractures seen in most of flexible specimens. [22] On the other hand nanocomposite denture bases were no affected by thermo cycling due to the shielding effects on the silanated nonofillers. [10]

Thermo cycling had no effect on bond strength of porcelain teeth to nonocomposite denture base suggests that porcelain teeth relied primarily on the metal pins for retention in the denture base. The adhesion of the denture base to porcelain surface probably contributed so negligibly to the bond strength that further thermal assault made no difference in the bond strength. [26] The differences in the coefficients of thermal expansion between porcelain teeth and denture base were higher than that between acrylic teeth and denture base. It has been estimated that the coefficient of the denture base resin and aluminous porcelain were approximately $(80X10^6/C^{\bullet})$ and $(6.6 \ X10^6/C^{\bullet})$ respectively. Significant thermal stresses were anticipated to be induced at the porcelain teeth denture base junction during thermo cycling. Therefore, repeated expansion and contraction at the bonding sites play vital role in lowering the bond strength of porcelain teeth to denture base. [25]

# REFERENCES

1. Zukerman GK. A reliable method for securing anterior denture teeth in denture bases. J Prosthet Dent 2003; 89: 603-7.
2. Vallittu PK and Ruyter IE. Swelling of PMMA resin at the repair joint. Int J Prosthodont 1997; 10 (3): 254-58.
3. Cunningham JL and Benington IC. A survey of the pre-bonding preparation of denture teeth and the efficiency for de-waxing methods. J Prosthet Dent 1997; 25(2): 125-128.
4. Takahashi Y and Chai J. Assessment of shear bond strength between three denture reline materials and a denture base acrylic resin. Int J Prosthodont 2001; 14: 531-5.
5. Nishigawa G, Maruo Y, Okamoto M et al. effect of adhesive primer developed exclusively for heat curing resin on adhesive strength between plastic artificial tooth and acrylic denture base resin . Dent Mater J 2006; 25:75-80.
6. El–Sheikh MM and Powers JM. Tensile bond strength of porcelain teeth to denture resin before and after aging. Int J Prosthodont 1998; 11(1): 16-20.
7. Rached RN; Del-Bel Cury AA. Heat cured resin repaired with microwave cured one: bond strength and surface texture J Oral Rehabil 2001; 28: 370-375.
8. Consani RLX, Mesquita MF, Zampieri MH, MendesWB, Consani S. Effect of simulated disinfection by microwave energy on the impact strength of the tooth/acrylic resin adhesion. Open Dent J 2008; 2:13-7.
9. Chung KH, Chung CY, Chung CY, Chan DCN. Effect of preprocessing surface treatments of acrylic teeth and bonding to the denture base. J Oral Rehabil. 2008; 35: 268-75. (**IVSL**)
10. Saavedra G, Valandro LF, Leite FPP etal. Bond strength of acrylic teeth to denture base resin after various surface conditioning methods before and after thermocycling Int J Prosthet 2007; 20: 199-201.
11. Adeyemi AA, Lyons MF, Cameron DA. The acrylic tooth-denture base bond: effect of mechanical preparation and surface treatment. Eur J Prosthodont Res Dent 2007; 15: 108-14.
12. Schneider RI; Curtis ER and Clancy JMS. Tensile bond strength of acrylic resin denture teeth to a microwave or heat processed denture base. J Prosthet Dent 2002; 88(2): 145-150.
13. Arima T, Nikawa H, Murata H, Hamada T, Harsini. Composition and effect of denture base resin surface primer for reline acrylic resin. J Prosthet Dent 1996; 75(4):457-462.
14. Ayad NM, Badawi MF, Fatah AA .Effect of reinforcement of high impact acrylic resin with micro-Zirconia on some physical and mechanical properties.Rev Clin Pesq Odontol 2008; 4(3):145-151.
15. Mohammed A, Solhi l, Nodehi A, Mirabedini SA, Akbari K, Babanzadeh S .PMMA-grafted nano clay as

novel filler for dental adhesives. Dent Mater 2009; 25:339-47.

16. Rizgar MA. The effect of addition of radiopaque materials on some mechanical and physical properties of flexible denture. Ph.D. thesis. 2009. p.34.

17. Al–Ani MJ. The effect of different surface treatment on the transverse strength and deflection of repaired acrylic specimens. M.Sc. Thesis. College of Dentistry, University of Baghdad 2000. P: 9

18. Theane HP, Cuew CL, Goh KI. Shear bond strength of denture teeth to base: a comparative study. Quintessence. 1996; 27(6): 425-428.

19. Vergani CE, Machaclo AL, Giampaolo ET, Pavarina AC. Effect of surface treatment on bond strength between composite resin and acrylic resin denture teeth. Int J Prosthodontic 2000: 13(5): 383-386.

20. Delbert Trew. Coat oil was useful all-purpose home remedy. Texas Escapes. Blue Prints for Travel, LLC 2007; Ch4; P: 65.

21. Anusavice KJ. Phillip's science of dental materials. 10th ed. Philadelphia: W.B, Saunders Co; 2008, pp. 211, 220, 235, 237-271.

22. Negrutiu M, Sinescu C, Romanu M, Pop D, Laktos S. Thermoplastic resins for flexible framework removable partial dentures. Temisoara Med J.2005; 55: 295-299.

23. Consani RLX, Mesquita MF, Manesco IM, Correr-Sobrinho L. Sinhoreti Mac, Effect of microwave treatment on the shear bond strength of the denture tooth/acrylic resin. J Adhesion 2008; 84:937-48.

24. Cunningham JL. Shear bond strength of resin teeth to heat cured and light cured denture base resin. J Oral Rehabl 2000; 27: 312-316. (**IVSL**)

25. Garcia RCMR, Leon BLT, Oliveira VMB, Cury AADB. Effect of denture cleanser on weight, surface roughness and tensile bond strength of two resilient denture liners. J Prosthet Dent 2003; 89(5): 489-494.

26. Chai J, Takahashi Y, Takahashi T, Habu T. Bonding durability of conventional resinous teeth and highly cross-linked denture teeth to a pour type denture base resin. Int J Prosthet 2000; 13(2): 112-116.

27. Meng GK, Chung KH, Fletcher-Stark ML, Zhang H. Effect of surface treatments and cyclic loading on the bond strength of acrylic resin denture teeth with autopolymerized repair acrylic resin. J Prosthetic Dent 2010; 103(4): 245-252. (**IVSL**)

**Table 1: Descriptive analysis of shear bond strength in *(MPa)* for acrylic teeth bonded to heat, flexible and nanocomposite denture bases**

| Heat cured | Control | | Thinner | |
|---|---|---|---|---|
| | Before thermocycling | After thermocycling | Before thermocycling | After thermocycling |
| Mean | 2.342 | 2.308 | 9.623 | 9.673 |
| SD | 0.6 | 0.595 | 0.509 | 0.586 |
| Flexible | | | | |
| Mean | 0.323 | 0.187 | 0.255 | 0.136 |
| SD | 0.078 | 0.059 | 0.051 | 0.029 |
| Nanocomposite | | | | |
| Mean | 2.393 | 2.308 | 9.759 | 9.114 |
| SD | 0.051 | 0.078 | 0.433 | 0.051 |

**Table 2: Descriptive analysis of shear bond strength in *(MPa)* for porcelain teeth bonded to heat, flexible and nanocomposite denture bases**

| Heat cured | Control | | Hydrofluoric acid | |
|---|---|---|---|---|
| | Before thermocycling | After thermocycling | Before thermocycling | After thermocycling |
| Mean | 3.7 | 3.632 | 4.26 | 3.462 |
| SD | 0.118 | 0.147 | 0.176 | 0.051 |
| Flexible | | | | |
| Mean | 3.802 | 2.342 | 4.209 | 3.004 |
| SD | 0.51 | 0.539 | 0.579 | 0.222 |
| Nanocomposite | | | | |
| Mean | 3.887 | 3.717 | 4.43 | 3.955 |
| SD | 0.128 | 0.051 | 0.184 | 0.339 |

**Table 3: ANOVA table of differences of groups and between groups for acrylic and porcelain teeth bonded to heat, flexible and nanocomposite denture bases**

| Experimental groups | F-Test | P-Value | Sig. |
|---|---|---|---|
| Heat, flexible and nano denture bases bonded with acrylic teeth Control group | 32.99 | 0.003 | S |
| Heat, flexible and nano denture bases bonded with acrylic teeth Thinner group | 61.32 | 0.001 | HS |
| Heat, flexible and nano denture bases bonded with porcelain teeth Control group | 23.9 | 0.006 | HS |
| Heat, flexible and nano denture bases bonded with porcelain teeth Hydrofluoric acid group | 9.763 | 0.029 | S |

**Table 4: T-Test between control group and surface treatments groups for all denture bases bonded to acrylic teeth before and after thermo cycling**

| Heat cured denture base | | | |
|---|---|---|---|
| Control& Thinner | T test | P value | Significance |
| Before thermocycling | 14.07 | 0.003 | HS |
| After thermocycling | 11.315 | 0.008 | HS |
| flexible denture base | | | |
| Control& Thinner | T test | P value | Significance |
| Before thermocycling | 0.896 | 0.465 | NS |
| After thermocycling | 1.009 | 0.423 | NS |
| Nanocomposite denture base | | | |
| Control& Thinner | T test | P value | Significance |
| Before thermocycling | 26.96 | 0.001 | HS |
| After thermocycling | 113.21 | 0.001 | HS |

**Table 5: T-Test between control group and surface treatments groups for all denture bases bonded to porcelain teeth before and after thermocycling**

| Heat cured denture base | | | |
|---|---|---|---|
| Control& hydrofluoric acid | T test | P value | Significance |
| Before thermocycling | 4.27 | 0.051 | NS |
| After thermocycling | 1.899 | 0.0198 | NS |
| flexible denture base | | | |
| Control& hydrofluoric acid | T test | P value | Significance |
| Before thermocycling | 0.544 | 0.595 | NS |
| After thermocycling | 0.516 | 0.269 | NS |
| Nanocomposite denture base | | | |
| Control& hydrofluoric acid | T test | P value | Significance |
| Before thermocycling | 12.32 | 0.007 | HS |
| After thermocycling | 1.359 | 0.307 | NS |

**Table 6: T-Test between heat, flexible and nano composite denture bases bonded to acrylic teeth before and after thermocycling in the control group**

| | Control before thermocycling | | | Control after thermocycling | | |
|---|---|---|---|---|---|---|
| Denture bases | T test | P value | Significance | T test | P value | Significance |
| Heat and flexible denture bases | 5.47 | 0.032 | S | 5.75 | 0.029 | S |
| Heat and nano denture bases | 0.134 | 0.906 | NS | 0.001 | 11.00 | NS |
| flexible and nano denture bases | 56.36 | 0.001 | HS | 127.4 | 0.001 | HS |

**Table 7: T-Test between heat, flexible and nano composite denture bases bonded to acrylic teeth before and after thermocycling in the thinner treatment group**

| Denture bases | Thinner before thermocycling | | | Thinner after thermocycling | | |
|---|---|---|---|---|---|---|
| | T test | P value | Significance | T test | P value | Significance |
| Heat and flexible denture bases | 28.71 | 0.001 | HS | 24.25 | 0.002 | HS |
| Heat and nano denture bases | 0.274 | 0.81 | NS | 1.229 | 0.344 | NS |
| flexible and nano denture bases | 41.9 | 0.001 | HS | 26.93 | 0.001 | HS |

**Table 8: T-Test between heat, flexible and nano composite denture bases bonded to porcelain teeth before and after thermocycling in the control group**

| Denture bases | Control before thermocycling | | | Control after thermocycling | | |
|---|---|---|---|---|---|---|
| | T test | P value | Significance | T test | P value | Significance |
| Heat and flexible denture bases | 0.432 | 0.708 | NS | 4.935 | 0.039 | S |
| Heat and nano denture bases | 4.106 | 0.048 | S | 1.306 | 0.305 | NS |
| flexible and nano denture bases | 0.229 | 0.793 | NS | 4.863 | 0.041 | S |

**Table 9: T-Test between heat, flexible and nano composite denture bases bonded to porcelain teeth before and after thermocycling in the hydrofluoric acid treatment group**

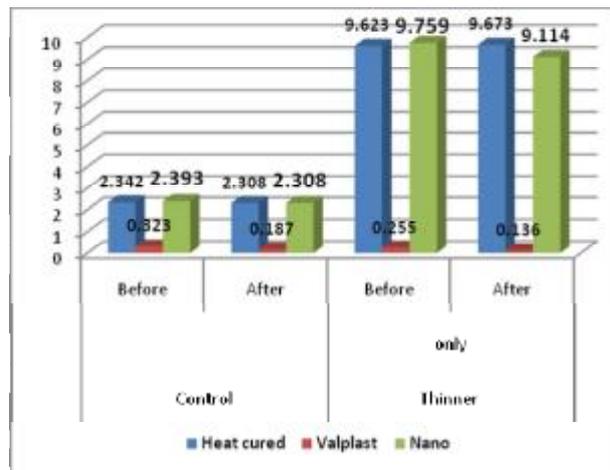| Denture bases | Hydrofluoric acid before thermocycling | | | Hydrofluoric acid after thermocycling | | |
|---|---|---|---|---|---|---|
| | T test | P value | Significance | T test | P value | Significance |
| Heat and flexible denture bases | 0.130 | 0.908 | NS | 4.225 | 0.049 | S |
| Heat and nano denture bases | 0.986 | 0.908 | NS | 2.442 | 0.135 | NS |
| flexible and nano denture bases | 0.564 | 0.629 | NS | 3.166 | 0.049 | S |



**Figure 7: Bar chart of the mean value of shear bond strength in *(MPa)* for all types of denture bases bonded to acrylic teeth before and after thermocycling.**
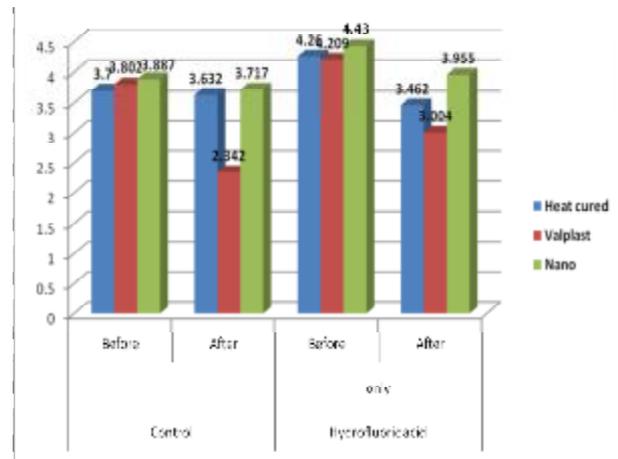


**Figure 8: Bar chart of the mean value of shear bond strength in *(MPa)* for all types of denture bases bonded to porcelain teeth before and after thermocycling.**



**Figure 9: A, Cohesive failure mode showing acrylic teeth remnants on base side. B. Cohesive failure mode showing porcelain remnants on base side.**