The shear bond strength of artificial teeth with denture bases

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ABSTRACT
Background: fracture and deboning of artificial teeth from denture bases are common clinical problems which are facing both the patient and the dentist. The optimal combination of artificial teeth with visible light cured (VLC) denture base resin and the effect of thermocycling should be evaluated. This study was conducted to evaluate and compare the shear bond strength of artificial teeth (acrylic and porcelain) with denture bases cured by water bath and visible light under the effect of different surface treatments and the effect of thermocycling with artificial saliva.

Material and methods. Heat polymerized (Densply) and visible light polymerized (Elite) acrylic resins were used. Two types of artificial teeth (acrylic, Florident) and (porcelain, Ivoclar vivadent) were prepared. Five specimens of each tooth type were processed to each of the denture base materials after the application of different surface treatments according to the manufacturer's instructions. Five specimens for each type of artificial teeth without surface treatments were also fabricated. Specimens were thermocycled and tested for strength until fracture with an Instron universal testing machine. Data were analyzed with analysis of variance and student T-test. A photomicrographic microscope was used to identify adhesive and cohesive failures within debonded specimens.

Results. The mean force required to fracture the specimens were obviously larger for heat cured specimens compared with the light cured 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 combined mechanical and chemical surface treatment exhibited the highest shear bond strength. Thermocycling had deleterious effect on the light cured specimens. In general, heat polymerized groups failed cohesively within the artificial tooth. While the light cured 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 artificial teeth 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: Artificial teeth, visible light cured denture base, shear bond.

INTRODUCTION
One of the advantages of using acrylic teeth over 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 physical 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 interfere with the contact between the polymerizing denture base and the denture tooth, thereby adversely affecting the bond strength. The 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 base 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 thermocycling(6).

Solvent wetting 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 bond strength was related to the high degree of cross linking of the acrylic teeth. Cross linking of the acrylic teeth were done to improve the properties of the resin 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. In addition the IPN teeth had significantly lower bond strength to heat cured resin than regular plastic teeth. The bond between (VLC) resin and both types of teeth were consistently low, less than 12% of the strength of heat cure resin to plastic teeth(9), also heat cured resin had the highest transverse bond strength to regular plastic teeth, IPN teeth and multi-lithic in that order. Bonding of the teeth to auto-polymerizing resin was the same order but with significantly lower strength. The bond strength of all teeth to visible light cured resin was again consistently low(10).

Thermocycling 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. The range of temperature used in thermocycling had an upper limit being 45-60°C and lower limit 4-15°C, these ranges were based on changes in temperature that are within normal extremes in the oral cavity and that induce an opening between the tooth and restoration(11).

Thermocycling was used to more closely simulate the oral conditions. This treatment theoretically allowed for repeated expansion and contraction of the tooth and denture base components. There by stressing the bond. The secondary benefit of thermocycling 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 denture bases: conventional water bath and visible light cured after application of different surface treatment materials: [acetone (dimethylketone)], thinner (turpentine) and diatoric preparation or a combination of both for acrylic teeth and [acidic etching (hydrofluoric acid)] and diatoric preparation or a combination of both for porcelain teeth and the effect of thermocycling [aging] with artificial saliva on that bond.

MATERIALS AND METHOD

Bond strength
Representative makes of conventional artificial teeth (acrylic, Florident) and (porcelain, Ivoclar vivadent) were chosen to be bonded to two types of denture bases: heat and visible light cured denture bases. A total of 120 acrylic teeth and 80 porcelain teeth were used in the study. All denture teeth were maxillary central incisors.

For each denture base, 60 acrylic and 40 porcelain teeth were waxed onto the beveled surface of a rectangular wax block, (figure 1).

Figure 1: Acrylic and porcelain teeth attached to waxed blocks.

The slope of the beveled surface aligned each artificial tooth such that the long axis of the tooth was at 45 degrees from the base of the wax block as shown in (figure 2). The denture teeth were flaked and the wax was eliminated with running hot water.

Figure 2: The configuration of the specimen.

Surface treatments
The ridge lap surfaces of the artificial teeth were treated with chemical solvent (acetone and thinner for acrylic teeth) and (hydrofluoric acid for porcelain teeth) or were prepared by diatoric or a combination of both, (figure 3).

Figure 3: Acrylic and porcelain teeth undergo surface treatment.

The diatoric was prepared by cutting a groove (2mm width and 3mm depth) mesio-distally drilled into the ridge lap surface of each artificial tooth with an inverted cone bur, (figure 4).

Figure 4: Diatoric preparation.
The artificial teeth from both types did not undergo any surface treatment and thus were used as controls. Photomicroscope pictures were taken to the surface of the teeth prior to and after the application of surface treatments and also after failures.

The denture resins were packed in flask for heat and in glass mould for light cured resin according to the manufacturer’s directions. The specimens were de-flasked upon the completion of the resin processing. All specimens were stored at 37°C for 7 days in artificial saliva before the shear test. Then half of the specimens were tested by using instron machine. The other half of the specimens were thermocycled between 5°C and 55°C in 60-second cycle for 3 days or 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, (figure 5).

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

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

**RESULTS**

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

**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). Diatoric preparation significantly improved the bond strength of artificial teeth(P<0.001). The application of acetone and thinner to acrylic teeth and hydrofluoric acid to porcelain teeth significantly improved the bond strength. On the other hand the combination of diatoric preparation with the chemical surface treatment gives the highest bond strength of these teeth to both denture bases before and after thermocycling (P<0.001).

**Effect of curing techniques:**

T-test of the comparison showed that the heat cured denture base generally possessed significantly higher shear bond strength than the light cured denture base.

**Effect of thermocycling:**

T-test of the comparison showed that the thermocycling had little significant effects on the bond of acrylic teeth to heat cured denture base especially in the combined chemical and mechanical surface treatments(P>0.05), while it possessed high significant effect on the shear bond strength of the light cured denture base bonded to both acrylic and porcelain teeth (P<0.001). The results of the study were illustrated in the following figures.
DISCUSSION

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

Effect of surface treatments:

The placement of groove significantly improved the bond strength of artificial teeth, with the use of acetone and thinner for acrylic teeth and hydrofluoric acid for porcelain teeth achieving even higher shear bond strength. The benefit of using diatoric may be explained by two mechanisms: first, the diatoric increases the surface area on the artificial teeth available for the polymerizing denture base to interact with. Second, the diatoric of the denture base resin embedded in the artificial tooth creates a path of resistance to fracture in a direction different from the tooth – denture base interface. This mechanically strengthen the bond between the artificial tooth and the denture base.

Acetone and thinner are strong solvents. They facilitate 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.

Acetone dissolve away the microdebris and smooth out the surface and produced sponge like structure and increase the number of active sites and then there will be physical interaction (Vander Waal Forces), although these forces...
provide a good bond strength but did not produce chemical cross-linking reaction\(^{(14)}\).

Thinner is a strong solvent since its chemical composition from multiple solvents could dissolve the polymer in an amount more than acetone\(^{(15)}\).

Hydrofluoric acid or other acids creates retentive channels which optimize the micromechanical bond between the ceramic and the resin\(^{(16)}\).

### Effect of curing technique:

Light cured 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 exhibited by these materials\(^{(17)}\). The mismatch of polymer structure between artificial tooth and denture base when VLC resin is used does not provide the same free monomer transfer as is found in heat cured resin\(^{(18)}\). 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\(^{(19)}\).

Also, the long curing cycle of heat cured acrylic resin compared with the short curing cycle of light cured resin lead to produce a material with high molecular weight and strong bonds between the polymer chains\(^{(20)}\).

### Effect of thermocycling:

Acrylic teeth and the acrylic resin denture base have nearly the same coefficient of thermal expansion\((80-81 \times 10^{-6}^\circ C)\) therefore, this similarity reduced the chance for the creation of thermal stress, so the bond strength was not affected by such thermal fluctuation\(^{(21)}\). 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\(^{(22)}\).

Diatonic preparation leads to creation of voids also solvent treatments (acetone and 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\(^{(12)}\). Moreover, since thermocycling cause hydration of the specimens, so the material absorbed water and this had a damaging effect on the bonding. The water may percolate 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\(^{(23)}\).

Mechanical and chemical surface treatments of acrylic resin enhanced the resistance to debonding forces because of thermal cycling\(^{(24)}\).

As a composite, the VLC denture base resin is more brittle than the \((\text{poly methyl methacrylate})\) of heat cured denture base. VLC resin was possibly more susceptible to partial cracks during finishing and polishing procedures on the lathe machine, then the additional stress of thermocycling may have propagated the cracks to total fractures seen in most of VLC specimens\(^{(4,18)}\).

Thermocycling had no effect on bond strength of porcelain teeth to heat cured 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\(^{(25)}\).

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 \((80 \times 10^{-6}^\circ C)\) and \((6.6 \times 10^{-6}^\circ C)\) respectively. Significant thermal stresses were anticipated to be induced at the porcelain teeth / denture base junction during thermocycling. Therefore, repeated expansion and contraction at the bonding sites play vital role in lowering the bond strength of porcelain teeth to denture base\(^{(26)}\).

### REFERENCES

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