Original Research

Shear Bond Strength of Acrylic Denture Teeth to PMMA and Polyamide Denture Base Materials

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Abstract

Introduction: Detachment of denture teeth from denture base is one of the most common reasons for costly denture repairs .This study aimed at evaluating the bond strength of an acrylic denture tooth to polyamide injection-molded thermoplastic denture base material compared with three conventional polymethylmethacrylate (PMMA) denture base resins.
Materials and Method: A total of 40 acrylic denture molar teeth were randomly allocated into four groups (n=10) of heat-polymerized (HP), Auto-polymerized (AP), Injection molded (IM) and Polyamide thermoplastic (PT). All denture base/acrylic teeth combinations underwent 5000 thermal cycles (5-55˚C).Samples were subjected to shear bond strength test by a universal testing machine with a 1 mm/min crosshead speed .Data were analyzed using ANOVA and Tukey’s tests(α=0.05). **Results:** Mean ±SD of shear bond strength values were (MPa) 4.82±1.21, 4.52±1.67, 3.7±0.84 and 4.13±2.21 for groups HP, AP, IM and PT respectively. No significant difference was found among the experimental groups (P=0.429). **Conclusion:** Polyamide thermoplastic denture base resin was similar to conventional PMMA denture base materials in terms of bond strength to artificial denture teeth.

Keywords:bond strength, Polyamide, flexible dentures, denture base materials.

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Introduction

Polymethylmethacrylate (PMMA) has long been the most popular material for denture fabrication because of it's advantages such as simple-processing technique, low-cost of fabrication, easy repair and adequate esthetic properties (1, 2). However, polymerization shrinkage, low flexural strength and fatigue resistance as well as residual monomer content are the main limitations of this material (3, 4). These shortcomings can lead to denture base fracture, allergic reactions and improper seating of denture in undercut areas.

Recently, thermoplastic resin materials commonly known as flexible dentures have been marketed (5, 6). Polyamide, a type of nylon, is a class of thermoplastic material that is widely used as a denture base material. The most prominent advantages of polyamides are higher elasticity, toxicological safety and use of heat-molding instead of chemical polymerization to control polymerization shrinkage and related deformation (7, 8).

Detachment of denture teeth from the base is one of the most frequent reasons for denture repair (9, 10). The range of failure resulting from denture teeth dislodgment is reported to be from 25% to 33% (11, 10). According to Huggett *et al*, about 30% of all denture repairs are related to detached artificial teeth (12).

The mechanism of bond between PMMA/MMA (methyl methacrylate) denture base and denture teeth is based on an interpenetrating network or covalent bond (13). Polyamide is a chemical-resistant material with high crystalline characteristics which makes it difficult to bond to self-curing PMMA resin(14 , 15).Moreover, polyamide denture base resin cannot be chemically bonded to artificial teeth; i.e, the bond of polyamide denture base material to denture teeth relies solely on macro-mechanical retention .

Denture teeth are likely to detach from thermoplastic denture base, particularly in cases with insufficient clearance with opposing teeth (5). Singh *et al*; reported 22.2% debonding of denture teeth after 18 months in flexible dentures (16).

Scientific literature lacks important information regarding bond strength of acrylic denture teeth to thermoplastic denture base resin. Thus, the aim of this study was to compare the bond strength of acrylic denture teeth to polyamide injection-molded thermoplastic denture base material with three conventional PMMA denture base resin materials including heat-polymerized, Auto-polymerized and injection molded. The null hypothesis was that there is no difference in bond strength among these four denture base materials.

Materials and Methods

The specimens were composed of denture base resin cylinders bonded to the ridge-lap surface of acrylic denture teeth. According to the study of Schneider et al, a sample size of 10 was determined to provide 99% confidence and 95% power for detecting a difference between groups (17). A total of 40 maxillary first molar acrylic denture teeth (IvoclarVivadent, Schaan, Liechtenstein) were selected. Each denture tooth was embedded in auto-polymerized PMMA acrylic resin. The ridge-lap surface of each embedded tooth was displayed using 600 grit silicon carbide paper. 40 Wax patterns with a circular opening (7 mm diameter × 10mm length) were obtained from a hollow aluminum cylinder to standardize the dimensions of denture base resin cylinders. The wax patterns were manually positioned and fused on the ridge-lap surface of denture teeth by using molten wax (figure 1). The embedded teeth and attached (fused) wax patterns were then randomly allocated into 4 groups (n=10) according to the employed denture base resin.

Figure 1: A single specimen tested in the study
C: Specimens subjected to bond strength testing in a universal testing machine

Heat-polymerized PMMA (HP): The embedded tooth/wax pattern sets were invested in denture flasks by using dental stone .The sample was surrounded by putty impression material to facilitate removal of processed samples from the flask .When the dental stone set, the flask was opened and the wax pattern carefully removed. The heat-polymerized PMMA denture base resin (Triplex;IvoclarVivadent, Schaan, Liechtenstein) was then packed into the flask, trial-packed and processed according to the manufacturer's instruction. After polymerization, the flask was bench cooled at room temperature overnight.

Auto- polymerized PMMA (AA): In this group, the wax pattern of each sample was covered by putty impression material. Then, the wax pattern attached to the embedded teeth was carefully removed. Auto-polymerized acrylic resin (ProBaseCold; IvoclarVivadent, Schaan, Liechtenstein) was packed into the mold. The sample was placed in a pressure cooker at 6 bar (40ºC) according to the manufacturer's instruction. After polymerization of the acrylic resin, the putty impression material was cut and removed.

Injection molded PMMA (IM): The embedded tooth/wax pattern sets were invested in special plastic flasks by using agar material. After agar was set, the flask was opened and the wax pattern was carefully removed. Having assembled the flask to its precise position, injection molded denture base resin was poured in it's middle hole until the acrylic resin came up through the three other holes. Polymerization was accomplished at 60°C and a pressure of 2 bars for 25 minutes in a pressure cooker, according to the manufacturer's instruction (Major.SkelMoncalieri (TO); Italy).The samples were then bench cooled at room temperature.

Polyamide thermoplastic (PT): A 10-gauge waxed sprue former was attached to the wax pattern of each sample at the center of the circular opening. The samples were then invested in a special flask. After dewaxing and deflasking, the diatoric (small-size mechanical undercut) was made by grinding into the ridge-lap of the embedded teeth with a round bur (310 204 001 001-031; Jota, Rüthi, Switzerland) with dimensions of 1×2 mm using magnification loupes (2.5×).Then, the molten polyamide thermoplastic denture material (Valplast;Valplast International Corp, , NY, USA) was injected in the mold according to the manufacturer's instruction.

All polymerized samples were stored in distilled water at 37ºC for 24 hours .After water storage; the specimens were thermocycled between 5◦C and 55◦C for 5000 cycles. The samples were then subjected to shear load by using a universal testing machine (STM20; Santam, Tehran, Iran) with a crosshead of 1 mm/min and a 50 kg load cell (figure 1-c). A bi-chisel apparatus was used to direct the parallel shearing force as close to the denture tooth/denture base resin interface as possible.

The force at fracture point was recorded and the shear bond strength values were calculated by the following formula: S=F/A, where S is shear stress (MPa), F is force at fracture point (N) and A is bonded area (mm^2).The mean shear bond strength values were statistically analyzed using one-way ANOVA.

Results

Mean shear bond strength values and standard deviation (±SD) of HP, AP, IM and PT groups were (MPa) 4.82±1.21, 4.52±1.67, 3.7±0.84 and 4.13±2.21, respectively (Table1).One-way ANOVA test revealed no significant difference in bond strength between the study groups (P=0.429) (table 1). Nevertheless, the highest and lowest mean bond strength values were observed in group AP and PT, respectively.

Table 1. Mean ± standard deviation (SD) shear bond strength values (MPa) of experimental groups

Denture base materials	N	Mean±SD	*P* value*
Polyamide injection-molded (PT)	10	3.7± 0.84	0.429
Pure- type PMMA(PU)	10	4.13±2.21	
self- cured PMMA(SC)	10	4.82±1.21	
Heat-cured PMMA(HC)	10	4.52±1.67	

*One-way ANOVA

Discussion

According to the results of this study, the null hypothesis stating that there is no difference in shear bond strength of denture teeth to the four experimented denture base resins was accepted.

Debonding of denture teeth from thermoplastic denture base resin is a major problem because there is no chemical bond between them. This is a disadvantage for thermoplastic denture base resin compared to PMMA denture base materials. Nonetheless, in the present study, there were no significant difference in mean shear strength values between PT and other experimental groups.

This finding is partially in contradiction with literature that found insufficient bond strength between polyamide denture base material and auto-polymerized acrylic resin (15,18,19). Obtaining bond strength comparable to those with PMMA resin might have been related to the issue that in the current study gross and deep macro mechanical retention has been used to provide bonding of denture teeth to polyamide denture base resin. While in studies on bond strength of polyamide to acrylic resin, bonding mechanism was only based on chemical interactions. Nevertheless, long-term durability of mechanical bond is questionable, since mixed failure was not observed in any of the PT specimens.

This finding can also be attributed to the fact that insertion of macro-mechanical retention is expected to be of higher influence on shear bond strength compared to tensile bond strength testing (13). Therefore, significant difference might have been obtained between PT and other study groups if tensile bond strength test had been applied instead. It is speculated that using macro-mechanical retention has been able to compensate for lack of chemical bond.

According to the ISO 22112 standard for artificial teeth for dental prostheses, tensile bond strength test is recommended for assessment of the bond of synthetic polymer teeth to acrylic denture base resins (20). However, thermoplastic denture base materials do not conform to this ISO instruction due to different mechanical properties. It is noteworthy to mention that in many investigations shear test has been used to evaluate the bond strength of auto-polymerized resin to thermoplastic denture base materials (15, 18, 21, 22).

Bonding of polyamide denture base material to auto-polymerizing repair resin is exceedingly difficult due to the high crystalline characteristics of polyamide that makes reaction with chemical etchant and primers of auto-polymerizing repair resins quite difficult. However, it was demonstrated that surface treatment with silica coating and 4- META/MMA-TBB resin and acetic acid improved bond strength of polyamide denture base material to auto-polymerizing repair resin (15, 18, 22). It is unknown whether surface pretreatment improves bond strength of artificial denture teeth to polyamide material.

Injection molded denture base materials are actually auto-polymerizing resins with a polymerization temperature below 65º C. Many previous studies have demonstrated stronger bond strength between denture teeth and heat-polymerized PMMA resins compared to auto-polymerized resins (23,24,25). In contrast, Robinson *et al* reported higher failure strengths for injection molded resin in comparison to heat-processed acrylic denture base resin. In their study, the ridge lap portion of denture teeth was embedded in denture base resin. In this study, no statistically significant difference was observed between heat and injection molded denture base resins (classified as auto polymerizing resins) in bond strength to denture teeth. In order to achieve a suitable bond between denture teeth and denture base resins, a sufficient amount of free monomer content is required to allow penetration and incorporation into existing polymer chains of denture teeth. According to the results of this study, it can speculated that injection molded resins provide a sufficient amount of free monomer content. Such controversial results might be attributed to the difference in mechanical properties of the artificial teeth, thermocycling regime, the applied load and even more compatibility between the employed materials. According to Colebeck*et al* (26) bond strength improves when denture teeth and denture base resins from the same manufacturer are used.

Thermocycling and cyclic loading are important factors in simulating oral environment. In the current study, thermocycling was performed at 5000 cycles between 5 and 55 º C, since it is widely accepted as a standard procedure for artificial ageing. Nonetheless, the samples were not treated with cyclic loading which restricts the portability of the results to clinical situations. The bond strength was also evaluated without embedding the ridge lap portion of denture teeth in denture base resin. Despite this limitation, because of the standardization of experimental setup, the obtained results can be valuable to predict the material's behavior under in *vivo* condition.

Studies have used shear, tensile, compressive or peel tests to evaluate the bond strength between denture teeth and denture base materials (13). It is speculated that the force applied to denture teeth is a combination of tensile and shear forces. However, it is hardly feasible to simulate 1:1 in an *in vitro* experiment.

Although such *in vitro* studies could be helpful to predict the outcomes of clinical application, further *in vivo* investigations are needed to affirm the bond strength of polyamide denture base resin to denture teeth. Further *in vitro* studies on evaluation of bond strength of polyamide denture base materials to denture teeth are recommended using tensile test/applying cyclic load. Additionally, the effect of surface treatment on bond strength may also be studied and compared to the current data.

Conclusion

Within the limitations of this study, it can be concluded that polyamide thermoplastic denture base resin was similar to conventional PMMA denture base materials in terms of bond strength to artificial denture teeth.

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