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ORIGINAL RESEARCH

Effect of Surface Treatments and Adhesive Materials on the Shear Bond Strength of Artificial Denture Teeth to Denture Base Resins

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ABSTRACT

Aim: The purpose of the current study was intended to evaluate the effect of different surface modifications and different adhesive materials on the shear bond strength of artificial teeth to heat-polymerized and thermoplastic denture base materials using different repair techniques.

Materials and methods: Forty cross-linked artificial teeth used to construct different types of acrylic based denture prosthesis were selected to be bonded to two types of denture base materials, heat-polymerized acrylic resin denture base material, and thermoplastic acrylic resin denture base material. The specimens were divided into four subgroups according to the repair technique and adhesive material used. The base surfaces of all acrylic teeth then were moistened with monomer prior to bonding to the denture base specimens. Then, the specimens were tested using Universal Testing Machine for shear bond strength. The results were analyzed by using two-way analysis of variance (ANOVA) statistical analysis and multiple comparison tests, $\alpha \leq 0.05$.

Results: The effect of the types of denture base materials *vs* the surface conditioning methods displayed a statistically significant difference.

Conclusion: This study concluded that monomer surface treatment of the bonded surface of artificial denture teeth and the use of cyanoacrylate adhesive followed by additional microwave polymerization displayed better shear bond strength when compared with other repair techniques.

Clinical significance: Artificial teeth debonding from their denture bases is a common complication in dental practice. The current study evaluates different repairing techniques. Within the limitation of this study, the use of cyanoacrylate adhesive in combination with microwave polymerization is one of the best techniques of repairing denture teeth debonding.

Keywords: Artificial tooth, Bonding, Denture base resin, Shear strength and surface treatment.

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INTRODUCTION

Polymers are considered as biomaterials that have multiple uses in the medical and industrial fields. Proper understanding of the different biomaterial characteristics of polymers facilitates their application in dentistry. Physical, mechanical, and biological properties of polymeric material are extremely important when considering using them in the oral cavity.[1]

Today, one of the most widely used materials in prosthetic dentistry is polymethyl methacrylate (PMMA) because their acceptable properties allow for several clinical dental applications. On the contrary, they have multiple disadvantages, such as dimension changes during polymerization, potential for porosities, and relatively poor mechanical resistance. It has been considered the material of choice to construct denture bases and artificial teeth. Heat-polymerized resins and artificial acrylic teeth are the most common materials used in the prosthodontic clinics for the fabrication of partial or complete dentures.[2,3]

Adequate bonding of acrylic resin artificial teeth to the denture base resins has a great influence on the success of the dental prosthesis. However, detachment of the acrylic resins artificial teeth from the denture base resins is still one of the most frequently occurring prosthetic complications, especially in implant-supported and -retained prosthesis, due to increased chewing capacity.[4]

The mode of bond failure between denture artificial teeth and denture base could be adhesive or cohesive. If debonding occurs without any remnant of the denture base material remaining attached to the bonding surface of the artificial teeth, then the mode of failure is considered adhesive, while cohesive failure occurs when some remnant of the denture base material remains firmly attached to the bonding surface of the artificial teeth after debonding.[5,6]

Several studies have been conducted in an attempt to enhance the bonding strength of acrylic resin artificial teeth to denture base resins by mechanical, chemical means, or combination of both techniques. Different chemical materials were used as surface treatment agents prior to bonding which includes liquid monomers, nonpolymerizable solvents, dissolved PMMA, and adhesives. Previous studies displayed that the use of adhesive materials can potentially increase the bond strength between acrylic resins artificial teeth and denture base materials.[7-11]

Recently, thermoplastic denture base resins were introduced to the dental market. In comparison with the conventional acrylic denture base resins, PMMA, thermoplastic materials have the advantages of increased flexibility, enhanced flexural strength, lightweight, no residual free monomer, and improved esthetics.[12,13] One of these materials' disadvantage is weaker bond strength to artificial teeth because the bond is mainly mechanical.[5,14]

Previous surveys reported that 26 to 33% of denture repairs are the result of deboned teeth, which cause distress and increased cost for patients. The purpose of the present study was to evaluate the effect of different surface treatments and adhesive materials on the shear bond strength of acrylic resins artificial teeth to heat-polymerized and thermoplastic denture base resins using different repair techniques.

MATERIALS AND METHODS

Forty acrylic resins artificial cross-linked mandibular premolar teeth (Acrostone Co., UK) were bonded to two different types of denture base materials: heat-polymerized acrylic resins (Acrostone Co, UK) and thermoplastic acrylic resin Breflex polyamide (Bredent, Gmbh, Co. K.G. Senden, Germany). The specimens were divided into two groups, I and II, each with 20 specimens.

Preparation of Denture Base Resin Specimens

Forty cylindrical wax specimens (Dental Wax, Lordell Trading, Australia) of 20 mm height and 15 mm diameter were prepared in split metallic mold for each denture base material specimen.

Group I: Twenty heat-polymerized PMMA denture base specimens were fabricated by using compression molding technique. The cylindrical wax specimens of this group were invested in stone mold in dental flask, dewaxed, packed, and processed in heat-polymerized PMMA according to the manufacturer's instructions. Heat-polymerized specimens were processed for 9 hours at 74°C and bench-cooled for 1 hour prior to deflasking. Then, the specimens were finished and polished.

Group II: It included 20 thermoplastic acrylic resin specimens. The wax specimens were invested in a stone mold in an injection-molding flask. The wax was eliminated and then the molten thermoplastic material was injected according to the manufacturer's instructions. An injection-molding machine was used with the metallic cartridges containing thermoplastic grains that were heated to plasticize the resin at an injection pressure of 720 to 750 kPa, 220°C for 15 min. Once the processing was completed, the flask was allowed to bench cool and the specimens then were finished and polished.

Preparation of tooth ridge lap surface: The base surfaces of all acrylic teeth were polished using silicon carbide papers with grits of 600 and 1,000 under cooling.

All the base surface of the teeth was moistened with monomer before bonding to the denture base specimens. The teeth adhered to the previously cured denture base specimens of groups I and II are presented in Figure 1.

Subgrouping and Surface Conditioning

The acrylic cylindrical denture base specimens of each groups I and II were divided into four subgroups, each with five according to the surface conditioning of the ridge lap as presented in Table 1. The ridge lap area was painted with fingertip brush.

Subgroups I1 and II1: Surface conditioning of the ridge lap area of acrylic denture with acrylic adhesive

Fig. 1: Acrylic cylindrical denture base specimens with acrylic premolar teeth after surface conditioning treatment

Table 1: The grouping and the subgrouping

Grouping	*Subgrouping* *Surface conditioning method* *Subgroups I1 and II1* *10 specimens*	*Subgroups I2 and II2* *10 specimens*	*Subgroups I3 and II3* *10 specimens*	*Subgroups I4 and II4* *10 specimens*
Group I (20 specimens) Heat-cured PMMA denture base (compression molding technique) Group II (20 specimens) Thermoplastic acrylic resin denture base (injection molding technique)	Surface conditioning of the ridge lap area of acrylic denture tooth with acrylic adhesive (cyanoacrylate) cured in the microwave oven for 2 minutes at 500 W	Surface conditioning of the ridge lap area of acrylic denture tooth with acrylic adhesive (cyanoacrylate) only without microwave curing	Surface conditioning of the ridge lap area of acrylic denture tooth with (auto-polymerized) acrylic resin cured in the microwave oven for 2 minutes at 500 W	Surface conditioning of the ridge lap area of acrylic denture tooth with (auto-polymerized) acrylic resin only and left at room temperature for 1 hour without microwave curing

cyanoacrylate, Super Bonder Gel, Loctite, and then the tooth was bonded to the denture base and polymerized in microwave oven for 2 minutes at 500 W.

Subgroups I2 and II2: Surface conditioning of the ridge lap area of acrylic denture tooth with acrylic adhesive cyanoacrylate only, without microwave polymerization, then the tooth was bonded to the denture base and left at room temperature.

Subgroups I3 and II3: Surface conditioning of the ridge lap area of acrylic denture tooth with auto-polymerized acrylic resin, then the tooth was bonded to the denture base and polymerized in the microwave oven for 2 minutes at 500 W.

Subgroups I4 and II4: Surface conditioning of the ridge lap area of acrylic denture tooth with auto-polymerized acrylic resin only, then the tooth bonded to the denture base was left at room temperature for 1 hour without microwave polymerization.

Method of Bonding Procedure

The denture base resin and tooth specimens were aligned in a customized positioning device to allow for a standardized location and size of the bonding surfaces throughout the experiment. A repair material was used/mixed according to the manufacturer's instructions and applied on the bonding surface of the denture base material. Then, the artificial tooth specimen was seated over the joining surface with a static load of 250 gm for 5 minutes. When auto-polymerizing, acrylic resins were used as a repair material, and the specimens were polymerized in a pressure pot under a pressure of 30 psi at 106°F ± 2°F (41°C ± 1°C) for 15 minutes. The specimens were removed, dried, and then were ready for shear bond testing.

All the specimens were stored in distilled water for 24 hours at 37°C after processing and then followed by thermocycling between 5°C and 55°C, for 600 cycles and 30 seconds dwell time.

Shear Bond Strength Test

The prepared specimens were subjected to load testing using Universal Testing Machine (Canton Industries, Florida, USA). A cross-head speed of 5 mm/min was used for shear bond strength test. Load was applied till ultimate fracture occurred as shown in Figure 2.

The fracture load was recorded and shear bond strength was calculated using the following formula: Fracture load in N/surface area in mm^2. Shear bond strength (N/mm^2) = F (N)/A(mm^2). The resulting bond strengths were recorded and statistically analyzed for each group.

Statistical Analysis

The collected data were statistically analyzed using Statistical Package for the Social Sciences, version 21 software. Means and standard deviations were determined for each group, and two-way ANOVA test was used for analysis. It was followed by Tukey *post hoc* test for comparison of testing among the groups. Also, analysis of the

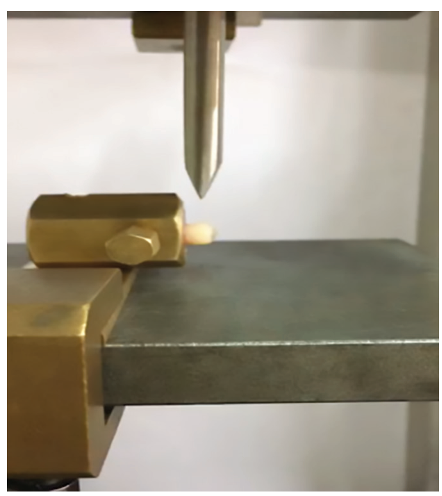

Fig. 2: The bonded tooth subjected to shear strength using universal testing machine

Table 2: The shear bond strength of heat-polymerized PMMA (group I) and thermoplastic acrylic denture base resin (group II) after different surface conditioning

Grouping	*Bonds of subgroup (1–4)*				*f-value*	*p-value*
Group I: Heat-polymerized acrylic resin denture base (mean ± SD)	I1 (n = 5) 522.4 ± 113.5	I2 (n = 5) 409.7 ± 99.7	I3 (n = 5) 446.7 ± 110.4	I4 (n = 5) 409.1 ± 74.3	1.400	0.279
Group II: Thermoplastic denture base resin (Breflex) (mean ± SD)	II1 (n = 5) 498.8 ± 61.3	II2 (n = 5) 355.5 ± 65.8	II3 (n = 5) 234.6 ± 106.8	II4 (n = 5) 175.5 ± 67.6	17.007*	<0.001*

SD: Standard deviation; F-values and p-values for ANOVA test, *Statistically significant at $p \leq 0.05$

Table 3: Comparison of shear bond strength between the two groups and the subgroups after surface conditioning

Surface conditioning methods	*Subgrouping*	*Mean ± SD*	*t-value*	*p-value*
Acrylic adhesive cyanoacrylate cured in the microwave oven for 2 minutes	I1	522.4 ± 113.5	0.409	0.697
	II1	498.8 ± 61.3		
Acrylic adhesive cyanoacrylate without microwave curing	I2	409.7 ± 99.7	1.015	0.340
	II2	355.5 ± 65.8		
Auto-polymerized acrylic resin cured in the microwave oven for 2 minutes	I3	446.7 ± 110.4	3.089*	0.015*
	II3	234.6 ± 106.8		
Auto-polymerized acrylic resin cured without microwave	I4	409.1 ± 74.3	5.200*	0.001*
	II4	175.5 ± 67.6		

t-values and p-values for Student's t-test for comparing between the two subgroups. *Statistically significant at $p \leq 0.05$

factors affecting the bond strength and the interaction among them was done using two-way ANOVA.

RESULTS

Table 2 represents the mean value of shear bond strength of subgroups I1, I2, I3, and I4. Two-way ANOVA test was used for comparison among the subgroups. It revealed no statistical significance in the shear bond strength.

The shear bond strength among subgroups I1, I2, I3, and I4 is displayed in Table 2. Comparison between the subgroups revealed statistical significance at 5% level ($F = 17.007$).

Table 3 represents the comparison among the subgroups. Student's t-test was used for the comparison; it presented no statistically significant difference in shear bond strength between subgroups I1 and II1 and subgroups I2 and II2. However, a statistically significant difference was observed between subgroups I3 and II3 and subgroups I4 and II4 ($t = 3.089$ and 5.200) at 5% level respectively.

Table 4 reveals a statistically significant difference in the shear bond strength between the two different denture base resins, groups I and II, $F = 21.222$ and the different surface condition methods, $F = 10.856$ respectively. The effect of the types of denture base resin *vs* the surface conditioning methods displayed a statistically significant difference, $F = 3.565$.

Table 4: Two-way ANOVA for analysis of the factors affecting the shear bond strength

Factors	*f-value*	*p-value*
Types of denture base resins (I and II)	21.222*	<0.001*
Surface conditioning methods	10.856*	<0.001*
Types of denture base resins *vs* surface conditioning methods	3.565*	0.025*

F-values and p-values for two-way ANOVA test; *Statistically significant at $p \leq 0.05$

DISCUSSION

One of the most clinical complications in prosthetic dentistry is deboning of acrylic resin artificial teeth from the denture base.[15] The shear bond strength test was selected in the current study because it is considered one of the fundamental mechanical properties that is believed to govern the strength of such material.[16]

Heat-polymerized denture base resins and thermoplastic denture base resins were chosen in this study because the type of denture base material may affect the bond strength of the acrylic resins artificial teeth.[17] Bonding acrylic resins artificial teeth to heat-polymerized acrylic resins denture base material is purely chemical,[18-20] while bonding acrylic resins artificial teeth to thermoplastic denture base material Breflex is considered purely mechanical.[14]

Surface conditioning of the ridge lap area of the tooth was used in an attempt to enhance the bond strength of the acrylic resins artificial teeth to denture base resins because it facilitates the diffusion of polymerizable materials from the denture base and improves the formation of a more extensive interwoven polymer network.[7] Cyanoacrylate adhesive was used because it has widespread use in dentistry and medicine, especially as tissue adhesives and sealing material. It has been proven that cyanoacrylate adhesives can perform sufficiently in a moisture environment.[21] Thermocycling testing was performed to simulate the intraoral conditions in which prosthesis could be subjected to different temperatures and forces during function.[22]

The results revealed that surface treatment of group A1 has the highest bond strength. This may be attributed to multiple factors. First, the increased surface energy created by the use of monomer as a surface conditioner, which enhanced the chemical bond between the acrylic resins artificial teeth and the heat-polymerized acrylic resins denture base material. Second, this result could be due to the similar chemical composition of the polymeric material of the denture base material and artificial acrylic teeth.[5,6] Third, the fact that monomer contains a great amount of cross-linking agent which contributed to the formation of interwoven polymer network.[5,6] Barbosa et al[24] study results are in favor of the present study results in which the use of monomer as a surface conditioner prior to bonding has a positive impact on the bond strength. On the contrary, Marra et al[20] study results displayed a significantly higher bond strength between acrylic artificial teeth to denture base materials after the use of monomer as a surface treatment only in one group. The results of the present study displayed that the use of microwave energy to polymerize the cyanoacrylate adhesives during repair has a great impact on the bond strength between acrylic resins artificial teeth and denture base materials. The microwave irradiation energy activates the decomposition of benzoyl peroxide components of the monomer that results in free radical formation and initiation of the polymerization process.[23,24] Also in these systems, the power of the microwave and time of exposure and the rate of polymerization can be regulated to control.[25] The mechanism of repair, when using auto-polymerizing acrylic resins to attach acrylic resins artificial teeth to acrylic resins denture base material, starts with the monomer content of the auto-polymerizing repair material that dissolves the surface layer of PMMA contents of the artificial teeth that provide free double bonds that may copolymerize with the PMMA of the denture base resins which result in the formation of a durable secondary semi-interpenetrating polymer network structure.[5,26-28] This may explain the high bond strength value that was obtained when using auto-polymerizing resin as the repair material only in subgroup A3, with the additional polymerization in the microwave for 2 minutes. The result of Patil et al[25] study is in favor of the present study in which the use of microwave energy polymerization enhances the flexural strength values of the resins.

The increased value of bond strength in group II1 that used thermoplastic denture base and surface treating with cyanoacrylate polymerized in the microwave oven for only 2 minutes may be explained by the effect of wetting of the ridge lap area of diatoric teeth with monomer. The diatoric teeth increased the surface area of the artificial acrylic teeth for the polymerizing denture base to interact with and at the same time, the diatoric of the denture base resin embedded in the artificial tooth created a path of resistance to fracture in a direction different from the tooth–denture base interface.[29] The decreased bond strength in other subgroups II2, II3, and II4 may be due to the difference in the nature of the chemical composition of Breflex polyamide-based polymer and self-polymerizing methylmethacrylate repair material that is mean mismatch of polymer structure between artificial tooth and denture base materials. These results are similar to the study of Meng et al[18] where they concluded that the use of diatoric recess in conjunction with adhesives prior to repair process has a significant enhancement of the bond strength between the artificial acrylic teeth and denture bases.

The interaction between the different denture base materials and the methods of surface conditioning was statistically significant which displayed improvement in the bond strength of PMMA values.

CONCLUSION

With the limitation of this study, treatment of the ridge lap surface of acrylic resins artificial teeth by monomer and the use of cyanoacrylate adhesive followed by additional polymerization in microwave oven significantly improved their bond strengths to the denture base materials.

Poor bond strength was observed when using autopolymerized resin as a repair material for thermoplastic resin Breflex denture base material.

The use of cyanoacrylate adhesive in combination with microwave polymerization as a repair technique displayed better shear bond strength values than other methods.

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