

Influence of aging on bond strength of artificial teeth to denture base acrylic resins

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Aim: The aim of this study was to evaluate the bond strength of artificial teeth to different types of denture base resins when submitted to thermomechanical cycling (TMC). **Methods:** Sixty artificial mandibular first molars (Trilux, Vipi) were randomly divided into 3 groups according to denture base acrylic resins (Vipi Wave, Vipi Cril, and Vipi Cril Plus, Vipi). The teeth were fixed onto self-polymerizing acrylic resin bars (0.5 cm² cross-section x 2 cm height), and the set was included in a metal flask using dental stone/silicone. After the dental stone was set, the bar was removed, and the denture base resin was packed and processed according to the group studied (Vipi Wave: 180 W/20 minutes + 540W/5 minutes; Vipi Cril and Vipi Cril Plus: Water bath at 74°C for 9h). After polymerization, the samples were divided into 2 groups (n=10), according to the TMC treatment received (simulation of 5 years of mastication or not). The samples were submitted to tensile bond strength test (1 mm/min), and the data (MPa) were statistically analyzed (2-way ANOVA, Bonferroni, $\alpha=0.05$). The fracture interfaces were evaluated using a stereomicroscope (50x). **Results:** The bond strength results showed no statistically significant difference ($p>0.05$) between the resins studied. TMC was significant ($p<0.05$), demonstrating lower values for the bond strength of artificial teeth to Vipi Cril Plus. The predominant fracture type was cohesive in resin. **Conclusions:** It was concluded that there is no difference in bond strength between artificial teeth and the resins used for denture base. However, TMC decreases the bond strength values of artificial teeth and crosslink thermo-polymerizable acrylic resin.

Keywords: Cyclic loading. Acrylic resins. Denture, complete. Bond Strength.

Introduction

Complete dentures have a positive effect on the quality of life of patients, not only for provides esthetics, but also function, once edentulism harms masticatory efficiency, the concentration of nutrients required by the body and the maintenance of the individual's intermaxillary relationship¹, regardless in conventional or implant supported prostheses.

The dental material most used for fabrication of denture bases and tooth over the last 60 years has been acrylic resin, due to its low cost and easy processing^{2,3}. Unfortunately, dental prostheses are subject to failures and the debonding of artificial teeth accounts for approximately 22% to 30% of the repairs carried out^{4,5}.

Previous studies reported that the main causes of prosthetic failures are: tooth position in the alveolar ridge, incorrect occlusion, incorrect processing, different methods of preparation, contamination of the surfaces between the artificial tooth and denture base, and excessive forces during mastication^{1,4,5}.

Considering that artificial teeth are essential parts of dentures, the bond between the teeth and denture base resin must be adequate, because this factor increases the strength and durability of the dental prosthesis⁶, but the debonding of denture teeth may become a greater clinical problem and increases laboratory costs⁷. The use of acrylic artificial teeth is preferable than other materials as ceramic teeth, due to the possibility of a chemical bond to the denture base resin by polymethyl methacrylate (PMMA) that is copolymerized with the cross-linking substances⁸.

Methods that may be used to increase the artificial tooth bond to the denture base resin include performing mechanical retentions, wear on the denture base surface⁹, and chemical treatment with monomer¹⁰, solvent, PMMA or silanization^{6,7}.

Studies^{2,7,11} conducted about the bond strength of artificial teeth and denture base regarding the effect of static compression or tensile loads^{12,13} and thermalcycling². However, the dynamic forces of mastication, the influence of fatigue loads and thermomechanical on the bond strength of artificial teeth, have not been considered or limited^{14,15}. Accelerated aging conditions can indicate a performance degradation of the materials and bonding interface involved¹⁶. So, thermomechanical cycling can be used to simulate the oral condition and to evaluate the durability of the bond between the materials¹⁷.

Therefore, the aim of this study was to evaluate the influence of thermomechanical cycling on the bond strength of artificial teeth to different types of denture base resins. The study hypothesis was that the type of denture base resin and the thermomechanical cycling would not influence the bond strength of the artificial teeth to resins.

Material and Methods

Sixty artificial mandibular first molars and 3 thermoactivated acrylic resins for denture base were selected (Table 1).

Table 1. Acrylic resins for denture base used in the study and their respective characteristics.

Material	Manufacturer	Composition	Processing Method	Polymerization Method (recommended by manufacturer)
Vipi Wave Microwave polymerized resin	VIPI Ind. Com. Exp. Imp. De Produtos Odontológicos Ltda, Pirassununga, SP, Brazil	Powder: Polymethylmethacrylate, Benzoyl Peroxide, Biocompatible Pigments; Liquid: Methylmethacrylate, EDMA, Inhibitor	Pressing	Microwave oven 180 W for 20 min/540 W for 5 min
Vipi Cril Plus Heat-polymerized crosslinked resin		Powder: Polymethylmethacrylate, Benzoyl Peroxide, Biocompatible Pigments; Liquid: Methylmethacrylate, Inhibitor fluorescent, EDMA		Water bath 74°C for 9h
Vipi Cril Heat-polymerized resin		Powder: Polymethyl methacrylate, Benzoyl Peroxide, Biocompatible pigments; Liquid: Methylmethacrylate, inhibitor, EDMA		Water bath 74°C for 9h

EDMA – Ethylenedimethacrylate

Sample Preparation

Rectangular bars (cross-section of 0.5 cm² x 2.0 cm height) were prepared with self-cured acrylic resin (Vipi Flash, Vipi Dental Products, Pirassununga, SP, Brazil), according to methodology adapted from Consani et al.¹⁸ (2012). Acrylic artificial teeth were fixed on the bars with soft wax (Wilson, Polidental Ind&Com. Ltda, Cotia, SP, Brazil). The tooth-wax bar set was included in dental stone (Gesso Pedra Creme, Gesso-RIO, Rio Claro, SP, Brazil) proportioned and mixed according to the manufacturer's instructions and included in a metal flask (MAC - Artigos Odontologicos e Protese Ltda., Sao Paulo, SP, Brazil).

Before hardening, five rectangular wax bars (1.5 x 3.5 x 0.5 cm) were included on the dental stone. After the dental stone hardening, the wax bars were removed and the stone molds were filled with laboratory silicone putty (Zetalabor, Zhermack, Rovigo, Italy). The artificial teeth were partially included into the silicone layer (Figure 1A), and then covered with another layer of silicone (Figure 1B). After dental stone insulation with petroleum jelly, the flask was filled with dental stone.

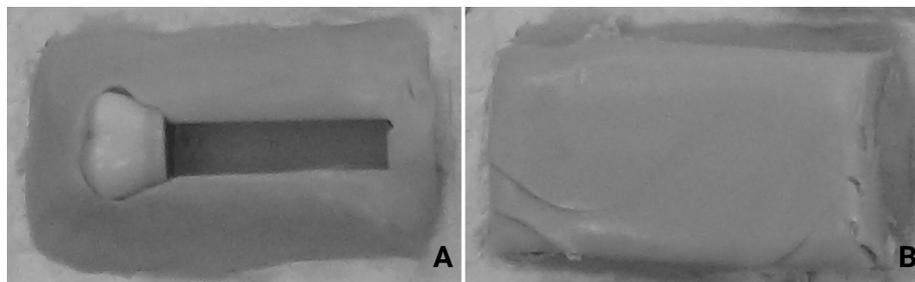


Figure 1. Initial preparation of samples. A) The artificial tooth was put into the silicone layer. B) Another layer of silicone covered the tooth. After stone set, the acrylic resin was included on the hole in silicon

Once the dental stone had set, the flask was opened. The wax bars were removed and the wax residues on the ridge lap surface was removed with tap water. To improve the bond strength of the teeth to base resin, mechanical retentions were made in the surface of the ridge laps using a tungsten carbide bur (# 6, KG Carbide; KG Sorensen, Cotia, SP, Brazil) at low speed of rotation (N270, Dabi Atlante, Ribeirao Preto, SP, Brazil). The operator used one bur for each ten teeth. After cleaning with compressed air, the mechanical retentions were etched with methyl methacrylate monomer¹⁹.

Inclusion of Denture Base Acrylic Resins

The teeth were randomly separated into three groups according to the denture resin used as the base. Specimens (Figure 2) were made with the tooth ridge lap surface attached to the acrylic resin, which was proportioned and manipulated according to the manufacturer's instructions. After inclusion, the flasks were submitted to 750 kgf load hydraulic pressure to remove resin excesses and, after, to 1000 kgf load for approximately 20 minutes. The flasks were polymerized as described in Table 1.

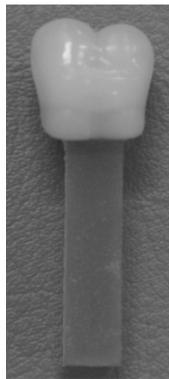


Figure 2. Sample prepared.

Twenty-four hours after polymerization, the specimens were deflasked after flask cooling at room temperature. Before testing, the resin bars were finished with abrasive stones, and the specimens stored in distilled water at 37°C for 7 days, to release the internal stress.

Thermomechanical Cycling (TMC)

The specimens of each group were divided into two subgroups (n=10) according to the treatment performed; with or without thermomechanical cycling (TMC). Specimens that were not submitted to TMC (control group) were immediately tested after stored in water for 7 days.

Prior to the TMC, the specimens were fixed into rigid PVC rings (16 mm height x 21 mm in diameter) using putty silicone, and a parallelometer to verify if the specimens were perpendicular to the horizontal plane. The TMC (ER 37000; ERIOS, SP,

Brazil) was performed at 1,200,000 cycles, with a load of 98 N (10 kg), and frequency of 2 Hz/s. A rounded tip with 6- mm in diameter was used as antagonist. The frequency used corresponds to 2 chewing movements per second²⁰, which simulated 5 years of chewing²¹.

Bond Strength Test

After cycling, the specimens were fitted to a device with two adjustable clips: one adapted to the portion adjacent to the tooth, simulating a hook; and the other fixed to the end of the bar. The specimens were submitted to the bond strength test (Mechanical Test Machine, Emic - 1L-2000, Sao Jose dos Pinhais, PR, Brazil) with a tensile load speed of 1 mm/min. The bond strength values were recorded in MPa. The bonding area was 25 mm² and the strength (MPa) was calculated by dividing the maximum force applied before fracture (N) by the area (mm²).

Statistical Analysis

The values of bond strength (MPa) were analyzed using 2-way ANOVA, and Bonferoni's test at a significance level of 5% (Software GraphPad Prism 4.0®, GraphPad Software, Inc., La Jolla, CA, USA).

Fracture Pattern Analysis

The fracture patterns were analyzed with a stereomicroscope (Keyence Brazil, Sao Paulo, SP, Brazil) at 50x magnification, and classified as: A) adhesive - when there was debonding between resin and tooth; B) cohesive - in the tooth or in the resin; C) mixed - adhesive and cohesive fractures.

Results

Bond Strength

The mean values of bond strength (MPa) of the artificial teeth to the denture base resins are described in Table 2. None of the specimens failed during TMC test.

Table 2. Comparison of bond strength mean values (MPa) (\pm standard deviations) of artificial teeth to denture base resins as a function of the thermomechanical cycling (TMC)

	Vipi Wave	Vipi Cril Plus	Vipi Cril
Control	16.27 (\pm 7.4) ^{aA}	21.52 (\pm 8.8) ^{aA}	17.60 (6.2) ^{aA}
With TMC	12.13 (\pm 5.6) ^{aA}	12.75 (\pm 5.5) ^{aB}	10.70 (3.4) ^{aA}

Different letters, lowercase in line and uppercase in column, indicate statistically significant difference ($p < 0.05$).

When the resins were compared, there was no statistical difference ($p > 0.05$) in the bond strength. There was significant reduction ($p < 0.05$) in the bond strength values for the Vipi Cril Plus resin, and no effect ($p > 0.05$) on the other studied acrylic resins when submitted to TMC. There was no interaction between the factors ($p = 0.5062$).

Fracture Type Analysis

Figure 3 presents the fracture mode for each group. The cohesive fracture in the resin was predominant in the specimens with and without TMC. The control group for microwaved resin presented the same occurrence for mixed fractures (50%). The Vipi Cril Plus resin presented twice the mixed fracture on the group submitted to TMC (20%) when compared with the group with no cycling (10%).

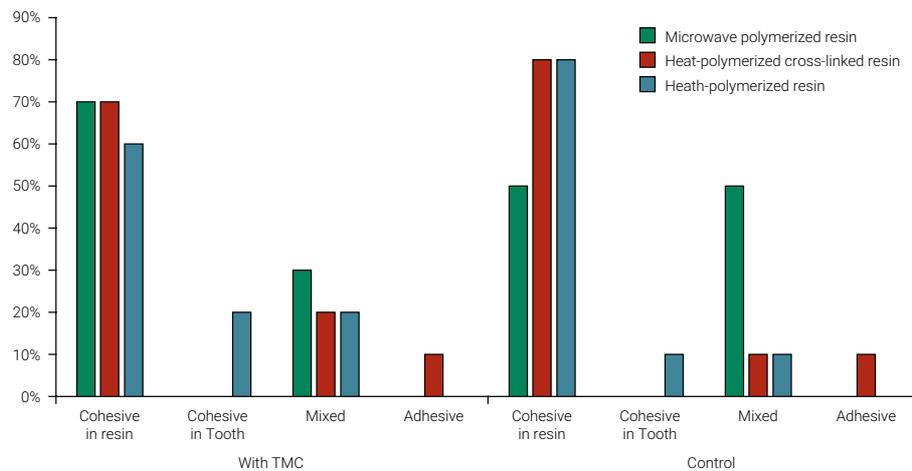


Figure 3. Distribution, in percentage, of the fracture types for each group. (TMC = Thermomechanical cycling)

Discussion

The aim of this study was to evaluate the tooth/resin bonding after TMC. The study hypothesis was that the type of denture base resin and the thermomechanical cycling would not influence the bond strength of the artificial teeth to resins. The results showed that there was no difference in the bond strength when the resins were compared. However, TMC reduced the bond strength of the artificial teeth to the Vipi Cril Plus resin, which allowed the hypotheses to be rejected.

The reduction in bond strength values for the Vipi Cril Plus resin after TMC may be explained by the degradation of the interface of the ridge lap/resin bond, as the mechanical stress associated with thermal changes can induce crack propagation through bonded interface²², explaining the lower bond strength found in this group.

However, the bond strength depends on the level of penetration of the monomer that plasticizes the surface and diffuses into the tooth acrylic resin¹³. The TMC cycles could change the ratio of monomer inter-penetration the denture tooth resulting in less strength of polymer networks formed^{23,24}.

On the other hand, no influence of TMC was observed on the bond strength values between ridge laps and the other studied resins. This can be attributed to the lower levels of residual monomer verified in these resins²⁵. Beside this, the water sorption

and thermal expansion coefficient are different and inherent to each material²⁶. Based on this, the diffusion of water molecules at the interface between the artificial tooth and acrylic resin²⁷ and different thermal expansion coefficients of the resins may result in differences in the bonding ability.

The TMC was used in this study because it can simulate intraoral conditions more closely. The heating–cooling process associated to simulated chewing can result in repeated expansion and contraction of the tooth and acrylic resin, stressing the bonding area, producing fatigue of the denture tooth/ridge laps interface, and decreasing the bond strength.

All groups and resins presented a higher prevalence of the cohesive fractures in the resin bars irrespective of submission to TMC test. This can be explained by the ridge laps mechanical retentions, which were able to improve the retentiveness.

The thermomechanical cycling is a suitable method for simulation of degradation of bond strength because the mechanical stress can induce crack propagation through bonded interfaces and the thermal changes can speed up this process²⁸. However, there is no evidence that bonding failures in clinical practice occur as a result of thermomechanical stress and whether failures occur because of leakage in one or another layer in the bonded structure, which must be dependent on the glass transition temperatures of the bonded material²⁸.

This study has several limitations. One is that it is not possible to know the exact difference in composition of the heat-polymerized and cross-linked heat-polymerized resin due to the lack of available manufacturer's information. Further study is needed of the chemical changes in the bonding surface between the resin and ridge laps surface. To overcome the limitations of in vitro tests, the bonding between denture teeth and acrylic resins should be evaluated using different methods.

It was concluded that there is no difference in bond strength between artificial teeth and the resins used for denture base. However, TMC decreases the bond strength values of artificial teeth and crosslink thermo-polymerizable acrylic resin.

List of abbreviations:

TMC – Thermomechanical cycling

PMMA – Polymethyl methacrylate

PVC – Polyvinyl chloride

Conflict of Interest Disclosure

All authors deny any financial and personal relationships with other people or organizations that could inappropriately influence the study.

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