The Role of Surface Treatments on the Bond between Acrylic Denture Base and Teeth

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The aim of this study was to compare the bond strength between acrylic denture base and teeth subjected to 6 surface treatments. Ninety-six specimens were made with poly(methylmethacrylate) teeth bonded to a microwave-polymerized acrylic denture base material. The specimens were distributed into 6 groups (n=16) according to surface treatments: CT - no treatment (control); MN - methylmethacrylate monomer etching; AO - 50-µm-particle aluminum oxide air abrasion; BR - glaze removal with a round bur; ST - surface grinding with an aluminum oxide abrasive stone; group CV - cavity preparation (diatorics). The control and surface-treated groups were subjected to a compressive load at 45º angle to the long axis of the teeth. Data were analyzed by one-way ANOVA, followed by Scheffé's test ($p<0.05$). Bond strength means and (SD) in kgf for groups were: CT: 18.19 (7.14), MN: 18.34 (5.28), AO: 23.82 (5.40), BR: 23.30 (4.79), ST: 25.39 (7.80) and CV: 17.48 (7.17). There was statistically significant difference ($p=0.037997$) only between ST and CV. In conclusion, ridge lap surface grinding with an aluminum oxide abrasive stone provided the highest bond strength, though it differed significantly only when compared to diatorics. The other surface treatments provided similar bond between the acrylic denture base and teeth.

Key Words: artificial teeth, acrylic resins, tooth-resin bond, ridge lap treatment.

INTRODUCTION

The bond strength of different denture teeth to their denture bases can be high enough to cause tooth fracture without debonding (1). If the bond between the parts resists until the materials fail, the bond will have fulfilled its functional requirements (2). Nevertheless, bond failures between plastic teeth and heat-polymerized denture base resins can occur (3), and remain a major problem in prosthodontic practice (4). The bond between acrylic denture teeth and denture base materials remains unreliable, inconsistent and unpredictable (2,5). Previous surveys report that 26% to 33% of denture repairs are due to debonded teeth (6,7), frequently causing distress and cost for the patients (6).

The following causes of tooth debonding are well known: excessive stress, fatigue, insufficient tooth cleaning during denture base acrylic resin placement, wax and tinfoil substitute contamination, defective properties of materials (8-10) and inappropriate heat-polymerizing technique (11).

Many factors have been investigated as to their influence on the bond strength between artificial teeth and denture base, such as ageing, ridge lap grinding, bonding agents, solvents or monomer-polymer solution application, surface grooving, tooth material, cross-linking agent concentration, denture base material, separating medium, impurities or wax contamination, thermocycling, microwave polymerization and polymerization temperature rise (1-4,8,11-19). The American Dental Association (A.D.A.) specification #15 defines standards concerning synthetic resin teeth, including the minimum bond strength between artificial teeth and denture base materials and a bond test method (20).

Most experimental tests use flat and ground tooth surfaces bonded to denture base, or the original ridge lap area of the teeth without any denture base material coverage

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in proximal, buccal and lingual surfaces (1,3,4,7,9,12-16). These conditions are not realistic and, moreover, the applied load direction is often different from clinical conditions. The aim of this study was to evaluate the influence of surface treatments on the ridge lap area of poly(methylmethacrylate) (PMMA) acrylic denture teeth on their bond strength to a microwave-polymerized PMMA denture base material. The null hypothesis tested was that surface treatment on the ridge lap area of acrylic denture teeth influences their bond strength to the denture base material.

MATERIAL AND METHODS

Acrylic Resin Pattern for Specimen Standardization

Two PMMA maxillary central incisors (one left and one right) with no cross-linking or filler particles (model A14 and 1C shade; Ivoclar Vivadent, Schaan, Liechtenstein) were used to form 2 acrylic dies for specimen standardization. A line was drawn surrounding the cervical area, 1 mm above the bottom (ridge lap base) of the teeth. A drawing compass (Mod. 9000; Trident S/A, Itaipui, SP, Brazil) and a digital caliper accurate to the nearest 0.01 mm (727 Series; Starrett Ind. Com. Ltda., Itu, SP, Brazil) were used to draw the lines. The teeth were placed on a cone of wax (Pink Wax #7; Epoxiglass Chemical Products Ind. Com. Ltda., São Paulo, SP, Brazil) supported by a PVC tube 1 cm high and 1.87 cm diameter. The long axis of the teeth was perpendicular to the PVC tube bottom. Each tooth was gently embedded in wax until it reached the line previously drawn. The angle between wax surface and teeth long axis was established in 45 degrees all around the cervical area with a stainless steel spatula. Each set (tooth, wax cone and PVC tube) was embedded in a microwave polymerization flask (Vipi-STG; Dental Vipi Ltda., Pirassununga, SP, Brazil). Routine procedure was used to wax removal. Denture base material (Vipi Wave, Dental Vipi Ltda.) was handled in a glass vessel, and left for 20 min to reach dough stage. The moulds were filled with denture base material and pressed under 1,200 kgf for 2 h in a hydraulic press (VH; Midas Dental Products Ltda., Araraquara, SP, Brazil), and heat-polymerized in a domestic microwave oven (CMS180; Consul, São Paulo, SP, Brazil) for 20 min at 80 watts followed by 5 min at 400 W. After cooling at room temperature, the models were deflasked, finished, and inspected at ×5 magnification with a magnifying glass (TGB-390, Tasco Sales Inc., Hong Kong) for any inaccuracy near the teeth.

Artificial Tooth Cleaning

Ninety-six PMMA maxillary central incisors (48 left and 48 right teeth) were removed from the wax plates and residual wax was cleaned with dry cotton. The teeth were then cleaned with a wax remover (Remox; Dental Vipi Ltda.) and rinsed in boiling water for 10 s in order to ensure complete wax removal.

Inclusion in Polyvinyl Siloxane Moulds

Six moulds of polyvinyl siloxane putty material (Express; 3M/ESPE, St. Paul, MN, USA) were made over each PMMA model (left and right). These moulds were flasked in microwave flask (Vipi) with type II dental stone. Each flask provided 6 specimens, one *per* group, according to the same tooth side. After stone setting under 500 kgf for 1 h in a hydraulic press (VH), the flasks were opened and all stone surfaces were coated with sodium alginate tinfoil substitute (Vipi-Film; Dental Vipi Ltda.).

Surface Treatments of the Acrylic Denture Teeth

The 96 artificial teeth were divided into 6 groups, according to the following surface treatments: CT - no treatment (control); MN - the tooth bases were etched twice with a methylmethacrylate monomer 10 min before acrylic resin packing and just before packing; AO - surface treatment with 50-μm-particle aluminum oxide air abrasion (Bio-Art; São Carlos, SP, Brazil) with 4.9 kgf/cm^2 air pressure at 1 cm distance, for 10 s; BR - ridge lap glaze removal with a 2.3-mm-diameter #8 round bur (KG Sorensen, Barueri, SP, Brazil) at low speed; ST - ridge lap glaze removal with an aluminum oxide abrasive stone (Schelble Burs; Petrópolis, RJ, Brazil); CV - a diatoric cavity (2 mm deep x 2.3 mm diameter) was prepared with #8 round bur (KG Sorensen) at low speed. Each tooth of the CV group was placed in a polyvinyl siloxane putty material custom support, attached to a milling machine (1000 N; Bio-Art, São Carlos, SP, Brazil), in order to provide cavities with standardized sizes and positions.

Specimen Preparation

Six teeth from the same side were embedded into each flask. Only the ridge lap base and a 1 mm high cervical area were left exposed. The teeth received ridge lap treatments before insertion in the moulds, except for CT, which received no treatment, and MN, in which the monomer was applied after insertion of the teeth in the mould. The denture base material (Vipi Wave) was handled, pressed and heat-polymerized as previously described. After flask cooling at room temperature, the specimens were deflasked and labeled. Finishing was made with sandpaper discs, and the specimens were examined with a ×5 magnification glass. Any inaccuracy in denture base material near the teeth was removed with sandpaper discs.

This process was repeated 8 times for the right tooth flask and 8 times for the left tooth flask. The specimens were stored in distilled water at room temperature for 7 days.

Bond Strength Testing and Statistical Analysis

In order to measure the bond strength between the artificial teeth and the denture base material, the specimens were fixed to a 45° angulated metal split support (Fig. 1), attached to the test machine (Instron 4444; Instron Corp., Canton, MA, USA). A compressive load was applied on the incisal line by means of a cylindrical pin, at a 45° angle, with a crosshead speed of 0.5 mm/min until fracture. The recorded ultimate failure load in Newtons (N) was converted into kgf. The bond surface was not calculated due to the complexity of curve and irregular shape of original teeth's ridge lap and cervical area. Resulting data were analyzed statistically by one-way ANOVA followed by Scheffé's test (α=0.05).

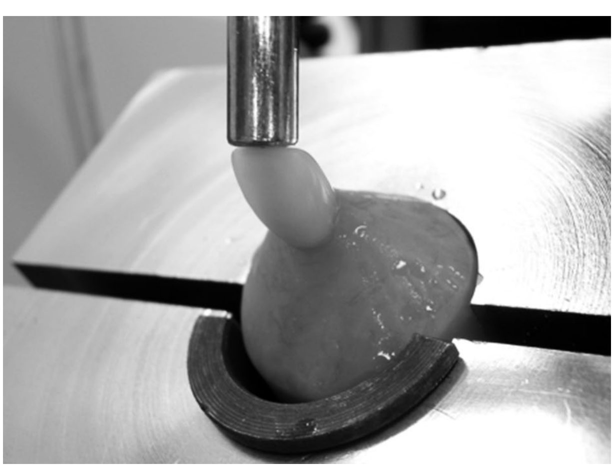

Figure 1. Oblique view of specimen fixed to a 45° angulated metal split support, subjected to the compressive strength test.

The failure modes were assessed with a magnifying glass (×5 magnification), according to the following classification: 1) Adhesive - when the separation occurred at the tooth/denture base interface; 2) Cohesive in PMMA denture base - when the denture base material remained bonded to the dislodged teeth, covering it completely; 3) Cohesive in the tooth - when total tooth base remained bonded to the denture base; 4) Cohesive in the tooth associated with cohesive in the denture base; and 5) Mixed - when significant areas of adhesive and cohesive failures occurred simultaneously.

Six extra teeth received the surface treatments applied to the experimental groups and were prepared for scanning electron microscopy in order to verify the resulting ridge lap surface patterns with illustrative purposes. These specimens were coated with a 300 Å golden layer (Bal-Tec SCD 005, Bal-tec Co., USA) and were examined with a scanning electron microscope (Phillips SEM XL30, Phillips, Eindhoven, Netherlands) operating in a range of 10 kV and 20 kV.

RESULTS

Table 1 and Figure 2 present the mean load (kgf) required for specimen bond to failure. There was statistically significant difference only between ST and CV (p=0.037997). The null hypothesis that surface treatment on the ridge lap area of acrylic denture teeth influences their bond strength to the denture base material was partially rejected, since only ST and CV means (extreme means) differed significantly from each other, and were statistically similar to intermediary means, obtained in the other groups (CT, MN, AO and BR).

Regarding the failure modes, only cohesive failures in the tooth associated with cohesive in the denture base (n=89), and mixed failures (n=7) occurred.

DISCUSSION

Factors affecting bond strength between plastic teeth and denture base have been investigated with different testing methods and the resulting data have been used to suggest technical procedures that enhance this bonding. However, few studies apply methods with load direction (2,4,12,16) and specimen design (2) similar to clinical conditions, producing data that may not be clinically representative. Lab research on bonding between artificial teeth and denture base usually employs testing methods with only one original or modified tooth surface contacting the denture base material. The most common surface is ridge lap base with no cervical coverage (1,3,4,7,12-16). The A.D.A specification #15 test is an example of method with no cervical coverage (20). This may not be the most realistic clinical condition, which is why the present study used an alternative method.

Cervical coverage of artificial teeth by denture base material in bond strength tests may be an inconvenience because the study variable (e.g.: surface treatment) may suffer the interference of mechanical retention. Nevertheless, it is important to ratify that partial covering of cervical surface of teeth ("neck") is a common practice, and occurs in most of the complete and partial dentures because of technical and esthetic reasons. Moreover, according to the findings of a pilot study conducted by our research group, cervical coverage of plastic teeth enhances the bond strength between acrylic denture teeth and base material, possibly reducing the significance of other variables already known, like surface treatment and wax contamination.

The lack of significant difference among the mean values of groups CT, MN, AO, ST, CV and BR (except between ST and CV) suggests that the influence of surface treatments may be minimized by mechanical retention resulting from tooth cervical coverage. However, it is important to emphasize that failure mode analysis showed that mechanical retention due to cervical coverage was not the only factor responsible for bond strength. All specimens, even those with mixed failure, had some regions of cohesive failure in the tooth and/or

Table 1. Bond strength mean values (kgf) and standard deviations between the acrylic teeth and the denture base material.

Group	Mean (SD)
CT	18.19 ab (±7.14)
MN	18.34 ab (±5.28)
AO	23.82 ab (±5.40)
BR	23.30 ab (±4.79)
ST	25.39 a (±7.80)
CV	17.48 b (±7.17)

CT: no treatment (control); MN - methylmethacrylate monomer etching; AO: 50-µm-particle aluminum oxide air abrasion; BR: glaze removal with a round bur; ST: surface grinding with an aluminum oxide abrasive stone; CV: cavity preparation (diatorics). Different letters indicate statistically significant difference (Scheffé, $p>0.05$).

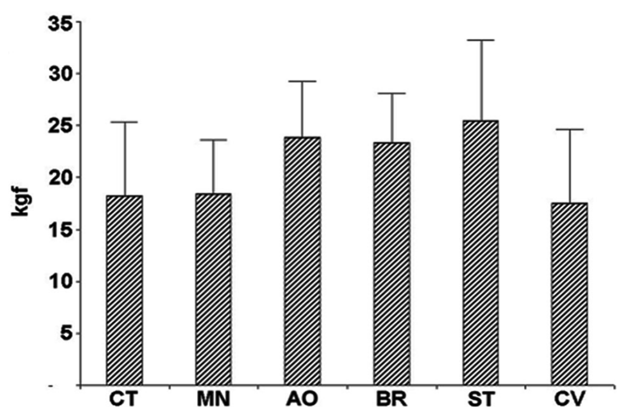

Figure 2. Mean bond strengths recorded in the groups.

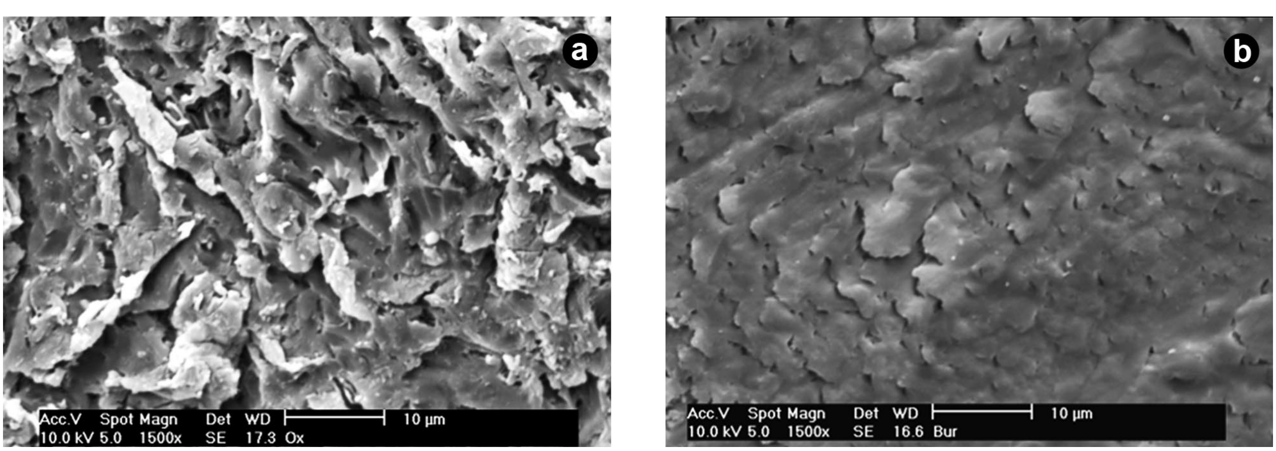

Figure 3. SEM micrographs of tooth surface after 50-µm-aluminum oxide air abrasion (A) and glaze removal with #8 round bur (B).

denture base material, with material remnants bonded to non-retentive ridge lap areas.

Tooth base roughening with cutting or abrasive rotary instruments or aluminum oxide air abrasion provided slightly higher bond strength values than those achieved without surface modification, or with cavity preparation or monomer etching, though without statistical significance. As far as bond strength is concerned and considering the unavoidable clinical cervical coverage, in principle, choosing CT, MN, BR or AO is apparently indifferent. These results are similar to those of previous studies (8,12,15,16) and contrary to others (4,14). Differences may be due to the materials and methodology employed. However, it is likely that roughened surfaces provide a wider contact area with denture base resin and greater micromechanical retention, justifying the slightly higher bond strength tendency in these groups.

SEM analysis showed that surface treatment with aluminum oxide air abrasion (Fig. 3-A), round bur (Fig. 3-B) or abrasive stone (Fig. 4-A) resulted in higher surface roughness compared to no treatment (Fig. 4-B) and monomer etching (Fig. 4-C). The teeth treated with diatorics showed rough surface inside the cavity (Fig. 4-D).

The worst results of this study occurred in CV (cavity) group. It may be a consequence of non-treated surfaces tendency to lower bond strength associated with lower cohesive strength of denture base material, which had failured cohesively in all CV specimens, keeping diatorics filled with denture base resin. Also, it is possible that the sharpness of the cavity borders collaborates to stress concentration, thus, leading base material to failure in this area. High impact denture

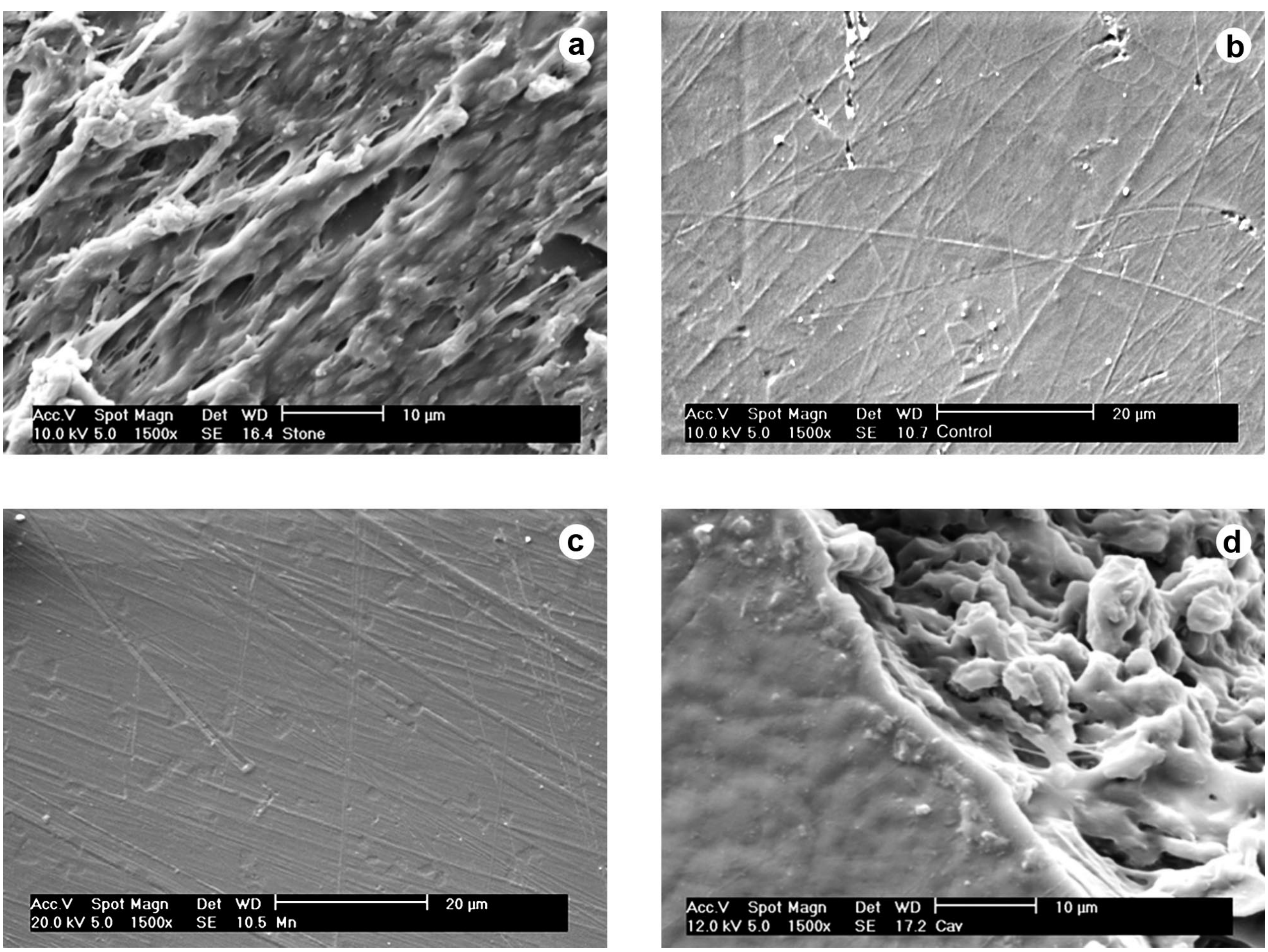

Figure 4. Images obtained in the SEM analysis after surface treatment. A) SEM micrograph of tooth surface after glaze removal with aluminum oxide abrasive stone; B) SEM micrograph of original (non-treated) tooth surface; C) SEM micrograph of monomer treated tooth surface; D) SEM micrograph of tooth surface treated with diatorics. The left side of image shows the original surface; at right, the inner surface of cavity.

resins might provide different results.

The tensile loads used in many artificial tooth bond strength studies are not representative of real conditions either. The expulsive anatomic shape of anterior teeth and the direction of occlusal forces make the occurrence of significant tensile forces over these teeth unlikely. On the other hand, shear and compressive loads are much more plausible clinically, especially the angulated load applied by the authors. Similar load direction has previously been used by other researchers (2,4,12,16,17).

The proposed method can be further investigated using different denture base materials, tooth brands and materials, surface treatments, polymerizing parameters, thermocycling, and alimentary chemical solvents, among other variables not evaluated in this study.

Within the limits of this study, it may be concluded that regarding bond strength between acrylic teeth and denture base material, significant differences were found only between the surface treatments diatorics (worst results) and roughening with an aluminum oxide stone (best results). The groups treated with round bur, abrasive stone or air abrasion showed numerically higher bond strength than the other groups, but without statistical significance. After tooth debonding, most failures were cohesive in the teeth (buccal portion) associated with cohesive in the denture base material (palatal portion).

RESUMO

Este estudo comparou a resistência de união entre base de prótese e dentes de resina acrílica submetidos a 6 tratamentos de superfície. Noventa e seis espécimes foram feitos com dentes de poli(metilmetacrilato) unidos a uma resina para base de prótese polimerizada por energia de microondas. Os espécimes foram distribuídos em seis grupos (n=16) de acordo com o tratamento de superfície: CT – controle, superfície não alterada; MN – aplicação de monômero de metilmetacrilato; OA – jateamento com partículas de óxido de alumínio de 50 µm; BR – remoção do brilho superficial com broca esférica; PE – asperização com pedra abrasiva de óxido de alumínio e; CV – confecção de cavidade. Os grupos foram submetidos a uma carga compressiva em ângulo de 45 graus com o longo eixo dos dentes. Os resultados foram analisados por meio da ANOVA de um fator, seguido do teste de Scheffé ($p<0,05$). As médias de resistência (kgf) dos grupos foram: CT: 18,19 (7,14), MN: 18,34 (5,28), OA: 23,82 (5,40), BR: 23,30 (4,79), PE: 25,39 (7,80) e CV: 17,48 (7,17). Houve diferença estatisticamente significante apenas entre os grupos PE e CV ($p=0,037997$). Pode-se concluir que a asperização da base do dente com pedra abrasiva proporcionou a maior resistência de união, embora com diferença estatisticamente significante apenas em relação à confecção de uma cavidade na base do dente. Os demais tratamentos de superfície proporcionaram valores sem diferenças estatisticamente significativas.

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