EFFECT OF SURFACE TREATMENTS ON THE BOND STRENGTH OF DIFFERENT RESIN TEETH TO COMPLETE DENTURE BASE MATERIAL

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ABSTRACT

Although different commercial brands of artificial teeth are available in the market, debonding from the denture base is still an issue when rehabilitating edentulous patients with conventional or implant-supported complete dentures. The purpose of this study was to investigate the effect of surface treatments on the bond strength of four artificial teeth brands to a denture base material polymerized by microwave energy. Forty anterior artificial teeth of each brand (Biolux®, Trilux®, Biotone IPN®, and Vipi Dent Plus®) were bonded to denture base material (VipiWave®). Before processing, groups of ten specimens of each brand received surface treatment: control, monomer application (MA), air abrasion (AA) or diatoric cavity (DC). After processing, a blinded examiner conducted the bond test by applying load to the specimens (0.5 mm/min, to 45°). Data were analyzed by one-way ANOVA followed by Tukey's test ($\alpha = 0.05$). Biolux® teeth have stronger bonding to denture base than Trilux® ($p < 0.05$) in control group; higher bond values than Biotone IPN® ($p < 0.05$) in MA group; and higher bond strength than Vipi Dent Plus® and Trilux® ($p < 0.01$) in DC group; AA had no differential effect for any of the brands. With regard to the effect of the surface treatments on bond strength within groups of commercial brand, statistical analysis revealed no difference among them. According to results in general, Biolux® teeth had the strongest bonding to the denture base material polymerized by microwave energy. Results may assist dentists in selecting denture teeth from the standpoint of shear bond strength.

Key words: *Artificial teeth, Acrylic resins, Surface properties.*

INFLUÊNCIA DO TRATAMENTO DE SUPERFÍCIE EM DENTES ARTIFICIAIS NA RESISTÊNCIA DE UNIÃO EM BASES DE PRÓTESES TOTAIS CONFECCIONADAS EM RESINAS ACRILICAS TERMOPOLIMERIZÁVEIS POR ENERGIA DE MICROONDAS

RESUMO

Diferentes marcas comerciais e tipos de dentes artificiais estão disponíveis no mercado, entretanto o descolamento do dente artificial à base da prótese ainda é um problema em reabilitações com próteses totais convencionais e implanto-suportada. O objetivo deste estudo foi verificar o efeito de diferentes tratamentos de superfície em quatro marcas de dentes artificiais e sua influência na resistência de união a base de prótese confeccionada em resina acrílica termopolimerizavel por energia de microondas. Foram utilizados quarenta dentes artificiais anteriores de quatro marcas comerciais (Biolux®, Trilux®, Biotone IPN® e Vipi Dent Plus®) distribuídos aleatoriamente em 4 grupos (n=10) de acordo com o tratamento de superfície utilizado: controle (sem tratamento), aplicação de monômero (MA), abrasão a ar (AA) ou cavidade com broca (DC). Após os tratamentos de superfície as amostras receberam procedimentos de inclusão e polimerização usualmente utilizados para resinas acrílicas ativadas por energia de microondas (VipiWave®). Após o processamento, foi realizado o ensaio de resistência de união (microcisalhamento), em equipamentos para ensaios universais. Os resultados foram analisados estatisticamente (ANOVA e Tukey, $\alpha = 0,05$). Os resultados evidenciaram que os dentes Biolux ® apresentam forte resistência de união a base da prótese de Trilux® ($p < 0,05$) no grupo controle; no grupo MA o maiores valores foi da marca Biotone IPN® ($p < 0,05$); no grupo DC a maior resistência de união foram das marcas Vipi Dent Plus® e Trilux® ($p < 0,01$); O grupo AA não apresentou influencia para nenhuma marca de dente avaliada. Com base nos resultados obtidos, é possível concluir que não houve diferença estatística nos valores de resistência de união nas marcas avaliadas e que os tratamentos de superfície utilizados não aumentaram os valores de união para as marcas comerciais utilizadas.

Palavras-chave: *Dente artificial, Resina acrílica, Propriedades de superfície.*

INTRODUCTION

Although complete dentures cannot be considered a substitute for natural teeth, they have been, and remain, the staple treatment for edentulous patients,[1] and the use of complete dentures by edentulous patients is projected to increase over the next two decades because of an increase in life expectancy[2]. When conventional treatment is inadequate, mandibular two-implant overdentures offer a positive alternative[3].

Nonetheless, although these edentulous patients can be effectively rehabilitated with either conventional complete dentures or implant-supported complete dentures, debonding of acrylic teeth from the denture base, usually anterior teeth, continues to be a problem[4].

This detachment accounts for approximately 33% of complete dentures failures, and failure of acrylic denture tooth adherence has also been reported in implant-supported dentures[5]. Consequently, in the future, dentists will continue to face such situations frequently in their clinical practice, for both conventional- and implant-supported complete denture wearers.

Most attempts to improve the bond strength of denture teeth to the acrylic resin denture base involve chemical treatment or mechanical modification on the ridge lap surface of the denture tooth. Conflicting results have been reported with the use of monomer, air abrasion and the placement of a diatoric cavity.[6] Such contradictory results may be due to differences not only in methodology used and composition of the denture base acrylic resin, but also to differences inherent to manufacturing of the artificial teeth,[7] i.e., different commercial brands.

If these features were carefully evaluated, complete denture wearers would benefit by avoiding the need for repeated repairs or corrections of their dentures. Based on the fact that polymerization of acrylic resin using microwave energy is a cleaner and time-saving method[8] that has so far been shown to preserve the physical properties of conventional denture base resins,[9] the aim of this study was to investigate the effect of different surface treatments on the shear bond strength of four acrylic resin artificial teeth brands in complete dentures polymerized by microwave energy. The null hypothesis was that neither the surface treatments nor the different brands of artificial teeth would alter the shear bond strength between the acrylic resin polymerized by microwave energy and the artificial teeth.

Table 1: Artificial teeth used in this study.

Denture Teeth	Composition and Arrangement	Manufacturer
Biolux®	PMMA, EDMA, (CL)	Vipi Ind Com Ltd, Pirassununga, São Paulo, Brazil
Biotone IPN®	PMMA, (IPN)	Dentsply Ind e Com Ltd
Trilux®	PMMA, EDMA, (DCL)	Ruthibras Imp Exp Com de Mater Odontol Ltd, Pirassununga, São Paulo, Brazil
Vipi Dent Plus®	PMMA, EDMA, (CL)	Vipi Ind Com Ltd

PMMA, polymethyl methacrylate; EDMA, dimethacrylate of polymerized ethylene glycol; CL, cross-link; IPN, interpenetrating polymer networks; DCL, double cross-link

MATERIAL AND METHODS

Sample preparation

Four different brands of artificial teeth were evaluated (Table 1). For each brand, 40 left lateral incisors were prepared according to the method previously described by Cunningham & Benington[10].

Patterns were produced using one artificial tooth from each brand (Fig. 1a), each bonded to a brass collar containing a 5mm diameter reamed hole. A pre-formed brass tensile specimen was inserted into the tooth-collar assembly (Fig. 1b) and the whole set had one half sequentially invested in heavy body polyvinylsiloxane elastomeric impression material in a self-cured acrylic resin tray. Four trays, one for each of the artificial teeth brands tested, were invested in type III stone in the polyvinylchloride flask (PVC-F) base, so that their top surfaces were flush with the stone surface. The upper part of the PVC-F was adapted, filled with type III stone, and taken to a hydraulic press until the stone set (Fig. 1c).

After that, the PVC-F was opened, patterns were removed and four new artificial teeth, one of each brand, were randomly selected and placed in the sockets of the rubber moulds. All four artificial teeth received one of the four surface treatments: *control*, in which artificial teeth were left untreated; *monomer application (MA)*, where a drop of acrylic resin monomer was applied with small brush on the tooth surfaces; *air abrasion (AA)* with aluminum oxide with 4.9 kgf/cm^2 air pressure at 1 cm distance for 10 seconds[11]; and *diatoric cavity (DC)*, which was prepared before placing teeth in the rubber moulds, by placing them previously in a custom support made of polyvinylsiloxane putty material attached to a milling machine (1000N, Bio-Art, Sao Carlos, SP, Brazil) loaded with a #8 round bur (KG Sorensen), in order to provide cavities of standardized size (2 mm depth X 2.3 mm diameter) and position. All surface treatment groups contained ten artificial teeth from each brand.

Heat-cured acrylic resin (Vipi Wave, Dental Vipi, Pirassununga, SP, Brazil) was prepared following the manufacturer's instructions and packed into the cylin-

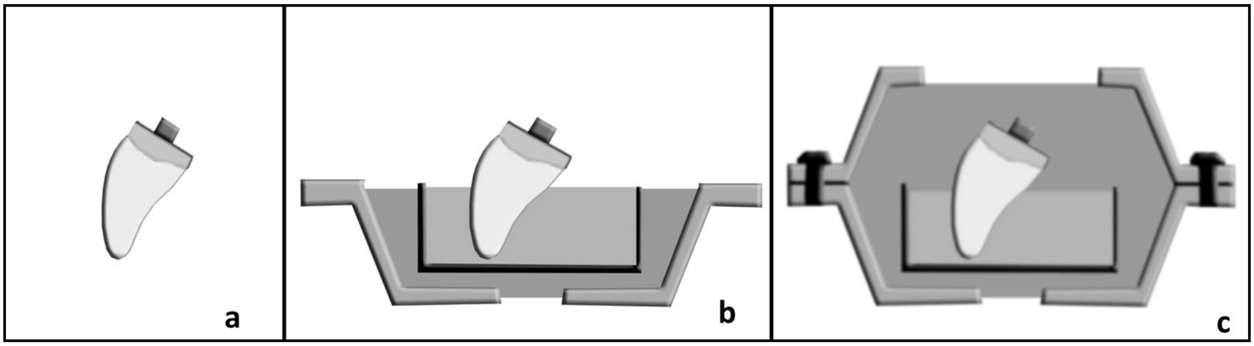

Fig. 1: Schematic representation of sample preparation. a) artificial tooth; b) inserted in an elastomer; c) invested in type III stone in the polyvinylchloride flask (PVC-F) base.

drical cavities of the mould. PVC-F was closed, placed in the hydraulic press (0.5 ton) for 5 minutes, and reopened in order to remove excess material. PVC-F was finally closed, and after pressing with 1.25 ton in hydraulic press for 15 minutes, it was screwed together and taken to the microwave oven (AW-42, BSH Continental Ltd, Sao Paulo, SP, Brazil) for polymerization according to the manufacturer's instructions.
After flask cooling at room temperature, the specimens were deflasked and finished with sandpaper discs. Any inaccuracy in denture base material near the teeth was removed with sandpaper discs.

Bond strength test and statistical analysis

To measure bond strength between artificial teeth and the denture base material, a blinded examiner fixed the specimens to a 45° angled metal split support, attached to the test machine (Instron 4444; Instron Corp., Canton, MA, USA). Load was applied on the incisal line by means of a cylindrical pin with a crosshead speed of 0.5 mm/min, until fracture. The recorded ultimate failure load in Newtons (N) was converted into kgf. Data were analyzed by one-way ANOVA followed by Tukey's test ($\alpha=0.05$).

RESULTS

When no surface treatment was applied on the artificial teeth (*control* group), Biolux® had higher bond strength values than Trilux® ($p<0.05$), while Biotone IPN® and Vipi Dent Plus® were not statistically different from either Biolux® or Biotone IPN®. Application of monomer (*MA* group) on the ridge lap area of the Biolux® teeth resulted in stronger artificial teeth-acrylic resin base bonding than in Biotone IPN® ($p<0.05$), and Vipi Dent Plus ® and Trilux® artificial teeth did not differ from either of them. With regard to artificial teeth that received air abrasion (*AA* group), there was no significant difference among the four brands. Finally, the placement of a diatoric cavity on the cervical base of the artificial teeth (*DC* group) revealed that bond strength of Biolux® teeth is higher than that of artificial teeth of both Vipi Dent Plus® and Trilux® ($p<0.01$); Biotone IPN® values were not statistically different for any of the three brands (Table 2).
In an attempt to identify which of the surface treatments would result in stronger artificial teeth-acrylic resin base bonding for each brand, shear bond strength values within commercial brand

Table 2: Shear bond strength mean values (kgf) and (standard deviations-SD) of artificial teeth submitted to different surface treatments.

Brands	Control	MA	AA	DC
Biolux®	33,84 (8,13) a*A	33,60 (8,15) a*A	30,48 (11,92) aA	34,95 (6,73) a†A
Trilux®	23,46 (8,84) b*A	22,48 (9,87) abA	22,84 (9,64) aA	23,46 (8,84) b†A
Biotone IPN®	25,53 (6,55) abA	22,03 (9,45) b*A	20,87 (9,61) aA	23,74 (5,07) bA
Vipi Dent Plus®	24,85 (5,95) abA	27,36 (9,48) abA	23,63 (6,12) aA	26,58 (8,36) a†A

Vertically, identical lowercaseletters denote no significant differences among groups. Horizontally, identical uppercase letters denote no significant differences among surface treatment groups. *$p<0.05$; †$p<0.01$; (ANOVA and Tukey test) groups was also tested, and revealed no statistically significant difference for any of the brands. Even when all shear bond strength values of each surface treatment were grouped, regardless of commercial brand, no surface treatment proved to be statistically better than any other (*data not shown*).

DISCUSSION

Given the demographic data on population ageing, the need to rehabilitate edentulous patients will remain considerable for many more decades. Thus, providing patients with complete dentures, whether conventional or implant-supported, will continue to be an important prosthodontic task[1].

Commercially, vast numbers of artificial teeth are available for prosthesis construction. However, there is little or no mention of bond strength of acrylic teeth to denture base resin by the manufacturers and studies evaluating the shear bond strength of different brands of artificial teeth attached to a microwave-polymerized denture base material are rare[5,12].

To the best of our knowledge, this is the first study investigating the effect of different surface treatments on shear bond strength of the commercial brands Biolux®, Trilux®, Biotone IPN® and Vipi Dent Plus® to an acrylic resin denture base material polymerized by microwave energy. Here we have found that, except when the pre-processing treatment was air abrasion with aluminum oxide particles, Biolux® teeth have stronger bonding to the acrylic resin base, whereas the surface treatments applied in this study had no effect on the shear bond strength of any of the brands of artificial teeth tested.

In order to explain the higher bonding values of Biolux® teeth, the chemical composition of the acrylic resins must considered. Resin denture teeth are primarily composed of PMMA and have been increasingly modified to improve their physical properties by using cross-link agents, different monomers and the addition of fillers[13]. Cross-linking agents are generally used to improve strength and crazing resistance, whilst lower bond strength values have been found than in conventional acrylic resin teeth, therefore, the ridge lap portion of the teeth is expected to be the least cross-linked, so as to facilitate bonding to the denture base resin[14]. Interpenetrating polymer network (IPN) resins, formed when a polymer network is crossed inside another network occupied by a second polymer, is a more recent resin modification aiming to produce denture teeth with better mechanical and physical properties[15].

Furthermore, the bonding of artificial tooth resin to denture base acrylic resin has been related to the ability of monomer to diffuse into the tooth resin, observed by the presence of swelling. The degree of swelling is related to the degree of cross-linking of a polymer. If a polymer is highly cross-linked, it has difficulty swelling in organic solvent[16].

Therefore, it is reasonable to understand that less cross-linked artificial teeth (Biolux®) have stronger bonding to the acrylic resin denture base than highly cross-linked teeth (Trilux® and Biotone IPN®). It is worth mentioning that Vipi Dent Plus®, which also has a lower degree of cross-linking agents, did not differ from Biolux®, regardless of the pre-processing surface treatment. Our results match those of previous studies, which also found that the more cross-link, the lower the bond strength between artificial teeth and the denture base[13,17].

Although incorporation of cross-linking agents to the PMMA matrix of artificial teeth is advisable in order to improve properties such as wear resistance[15,18], hardness[18] and flexural strength[19], which help increase prostheses longevity, bonding strength is significantly affected by the highly condensed matrix obtained, due to hampered diffusion of monomer through the artificial tooth/denture base resin interface[12].

With regard to the pre-processing surface treatments tested, the null hypothesis was accepted, meaning that none of them altered the shear bond strength between the artificial teeth and the acrylic resin denture base polymerized by microwave energy.

Application of monomer before packing the resin has been found to increase bond strength in a number of studies,[6,20-22] Although our results do not agree with these findings, it can be pointed that the lack of standardization of the waiting time before packing the resin in the groups that were submitted to monomer application is the strongest limitation of our study and is possibly responsible for this finding. A recent study has demonstrated that, in general, 60 seconds of monomer treatment resulted in higher bond strength than the 180-second treatment, probably due to higher monomer evaporation in the latter group, so that less MMA was available to react with the denture base resin.[6] Therefore, our lack of time-before-packing control can be considered to have affected the results.

Air abrasion is supposed to increase shear bond strength either by augmenting free surface energy of the newly abraded resin surface or by causing severe irregularities and undercuts in the ridge lap surface area, improving micromechanical retention.[5] Our results agree with others that did not find air abrasion with aluminum oxide particles to improve bond strength[21,23-25] and we propose that elevated free surface energy and the presence of micromechanical irregularities may difficult wettability of the ridge lap surface area, hampering adequate polymerization in the artificial teeth/acrylic resin denture base interface. Placement of a diatoric cavity in the cervical base of artificial teeth is another ridge lap modification that has been proposed, but we did not find it to improve shear bond strength. A recent study using a scanning electron microscope has found acrylic resin surface to be rough inside the cavity and the worst bond strength values in this group.[26] Presumably, wettability of the ridge lap surface is also impaired by the presence of the diatoric cavity, especially if we consider the sharpness of the cavity borders, which can help explain why this modification does not improve shear bond strength.

Although there are conflicting results in the matter of the effect of different surface treatments on the shear bond strength, they can be attributed to the large variety of experimental designs, measuring instruments and bond-testing methods used in the investigations.

Still, manufacturers frequently launch denture teeth made of new materials on the market, which are advertised as products with improved mechanical properties. The results of our study may assist dentists in selecting PMMA denture teeth from the standpoint of shear bond strength.

CONCLUSION

Within its limitations, this *in vitro* study permits to conclude that there was no difference in shear bond strength values of the brands evaluated and pre-processing treatment used, there is no improvement of the bond strength within groups of commercial brands involved.

ACKNOWLEDGMENT

The authors acknowledge Dental Vipi, Pirassununga, SP, Brazil, for providing the artificial teeth used in this experiment.

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