Original Article

Effect of potentially chromogenic beverages on shear bond strength of acrylic denture teeth to heat-polymerized denture base resins

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Abstract

Background: Detachment of denture acrylic resin artificial teeth from denture base resin is one of the most common problems presented by denture wearers. Purpose: This study investigated the shear bond strength (SBS) and fracture type of bonding interface of two commercial acrylic teeth (Vipi Dent Plus e Biolux) to two denture base resins (Vipi Cril e Lucitone 550) after immersion in potentially chromogenic beverages (coffee, cola soft drink, and red wine) or control solution (distilled water).

Materials and Methods: Maxillary central incisor acrylic teeth were placed at 45° to denture base resin and submitted to short polymerization cycle according to manufacturers. Specimens were divided according to the combination tooth/resin/solution ($n = 8$) and submitted to bond strength tests in a universal testing machine MTS-810 (0.5 mm/min). Subsequently, fracture area was analyzed by stereomicroscope at a magnification of ×10 and categorized into adhesive, cohesive, or mixed failure.

Results: The bond strength of teeth/denture base resins interface was not significantly affected by tested solutions ($P > 0.087$), except for Biolux teeth immersed in coffee ($P < 0.01$). In all conditions, the Vipi Dent Plus teeth showed higher bond strength to Lucitone and Vipi Cril resins when compared to Biolux teeth ($P < 0.003$). All specimens' failure modes were cohesive.

Conclusions: The SBS of acrylic teeth to denture base resins was not generally influenced by immersion in the tested staining beverages.

Key Words: Acrylic resin, bond strength, coloring agents, tooth artificial

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INTRODUCTION

Since 1940 acrylic resin artificial teeth are used as denture teeth because of their similar characteristics and chemical bond with denture base resins.[1,2] However, a detachment of artificial teeth seems to be the main reason of dentures' repair, reaching up to 1/3 of maintenance

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made in these prostheses, usually in the anterior portion of the denture.[3-7]

Dentures are commonly in contact with saliva or immersed in water or cleansing solutions.[7-10] Hence, dentures may undergo sorption of liquid such as saliva, cleansing solutions and food within the polymer (absorption), and solubility.[8-11] The absorbed water can act like a plasticizer and lower the bond between acrylic teeth and the base resins.[7,12] Therefore, if denture's teeth and base resin can absorb water, they would be able to absorb other liquids, such as potentially chromogenic beverages.

The absorption and adsorption of beverages can lead to polymer outer discoloration because of the mild penetration and reaction of these materials to coloring agents due to plaque accumulation and surface degradation.[13,14]

Natural and artificial colorants are commonly found in human diet foods. Studies demonstrate that beverages like coffee are chromogenic.[15,16] It has also been suggested that alcohol drinks such as wine promote softening and degradation of the material's polymeric surface.[17,18] Moreover, low pH of acidic beverages like cola drinks can also damage the integrity of these materials.[19,20] Therefore, in addition to staining, certain foods have an influence in other acrylic resin characteristics and might as well interfere on denture base/tooth bonding interface.

Although studies that evaluated bond strength of acrylic teeth and base resins after prolonged immersion in water or after thermal cycling are found in the literature,[21-23] there are no researches on the effects of immersion in staining beverages on bonded interface. Thus, this study aimed to evaluate the shear bond strength (SBS) of two commercial acrylic teeth and two commercial brands of denture base heat-cured resin after immersion in three potentially chromogenic beverages.

MATERIALS AND METHODS

Specimen preparation

Two commercial acrylic resin artificial teeth (Vipi Dent Plus, Dental Vipi Ltda., Pirassununga, SP, Brazil and Biolux, Dental Vipi Ltda., Pirassununga, SP, Brazil) and two commercial brands of denture base resin (Lucitone 550, Dentsply Ind. E Com. Ltda., Petrópolis, RJ, Brazil and Vipi Cril, Dental Vipi Ltda., Pirassununga, SP, Brazil) were used to manufacture the specimens. Japanese standards for acrylic teeth (JIST 6506, 1989)[24] were followed and a maxillary incisor acrylic tooth was placed at 45° in a round cardboard container (12.7 mm × 20 mm) filled with modeling wax. Wax blocks patterns were made and conventional casting was used. Before inserting in the gypsum mold, the denture resin dough manipulated following manufacturers' instructions, the bonding surface of the tooth was pretreated with methyl-methacrylate (MMA) for 180s.[6,25,26] Denture base resins were polymerized in a water bath according to manufacturers' instructions as well (73°C for 90 min and 100°C for 30 min for Lucitone; and 70°C for 30 min and 100°C for 90 min for Vipi Cril). After deflasking, specimens were immersed in distilled water at 37°C for 48 h for residual monomer release. Thirty-two specimens were made for each tooth/base resin combination.

Solutions preparation

The coffee solution was prepared by adding 2.4 g of instant coffee (Nescafé Tradicão, Nestlé Brazil Ltda., Araras, São Paulo, Brazil) to 200 mL of boiling distilled water. Specimens were immersed only after complete bench cooling of the coffee solution. Red wine (Vinho Tinto Seco Campo Largo, Vinícula Campo Largo, Campo Largo, Paraná, Brazil) was obtained from 750 mL bottles, and cola soft drink (The Coca-Cola Company, Curitiba, Paraná, Brazil) was obtained from 600 mL containers.[18] Distilled water was the control group solution. Specimens were randomly divided according to acrylic teeth/denture base resins combinations ($n = 8$) and individually immersed in dark vials with 200 mL of tested solutions. Specimens were stored in the vials for 30 days at 37°C to simulate 2.5 years of daily intake of the beverages.[18,27-29] Solutions were stirred once a day and weekly replaced. Coffee solutions were prepared immediately before weekly replacing, and red wine and soft drink solutions were substituted by solutions in newly opened containers.[13,16]

Shear bond strength test

After 30 days of storage, specimens were tested by a SBS machine (810, MTS System Corporation, Minnesota, USA) with a loading force at a crosshead speed of 0.5 mm/min until failure[2,30] SBS values were calculated using the formula σ (MPa) = F (N)/A (mm^2), where F is the maximum breakout force and A is the adhesive area.[31] Fracture surfaces were analyzed by stereomicroscope (Carl Zeiss, Jena, Alemanha) at ×10 of magnification and categorized into adhesive failure that denotes total separation at the interface between teeth and denture base resin, to cohesive failure that denotes a full brake in the denture base resin or artificial tooth, or to mixed failure that denotes both.

Statistical analysis

The data for SBS test were analyzed by using Kruskal–Wallis test (α =0.05). Previously, a Kolmogorov–Smirnov test was carried out to check for homogeneity of data. Failure mode analyses were done by percentage.

RESULTS

SBS mean and standard deviations for all combinations of acrylic teeth/denture base resins and immersion solutions used are summarized in Table 1.

Biolux teeth bonded to either denture resins presented lower SBS values when compared do Vipi Dent Plus teeth combinations ($P < 0.003$). Analysis of data also revealed there was no significant variation in SBS of Biolux teeth bonded to both denture resins when immersed in water (control), cola, or red wine ($P > 0.087$). However, when immersed in coffee, Biolux teeth showed a decrease in SBS values when bonded to Lucitone ($P < 0.01$). In addition, Vipi Dent Plus teeth bonded to both denture resins indicated no significant difference ($P < 0.01$) in SBS after immersion in all solutions ($P = 0.223$). Furthermore, visual analysis of the fractures showed that all specimens, including control, resulted in cohesive failure (100%).

DISCUSSION

Denture teeth detachment is one of the most common problems presented by denture wearers.[2] A number of researches on this subject can be pointed out in the pertinent literature but none of them, at the best of our knowledge, correlates potentially chromogenic beverages and bond strength between acrylic teeth and denture base acrylic resin.

When artificial acrylic teeth are exposed to the oral cavity, they will be in contact with saliva, beverages, and cleaning agents, and such materials are prone to the absorption and adsorption processes.[8-11] It has been shown that certain kinds of foods that are routinely ingested in a human diet can promote discoloration, surface degradation, and changes in other properties of the polymers.[13,14] Therefore, this study aimed at investigating the SBS of two different commercial acrylic teeth bonded to two different brands of denture base[18] resins after immersion in staining beverages. The aqueous solutions used in this study can be absorbed and adsorbed by the teeth, acting as plasticizers.[7,12] It is known that the composition, pH, and polarity of the liquid medium to which the polymers are subjected, as well as the immersion time, are factors that can change its solubility and cause polymer degradation.[13,14] In the present investigation, beverages with natural dyes were used: Red wine, which contains anthocyanin from grape; coffee, which has caramel coloring; and orange juice, which contains annatto. From this, we supposed that the presence of these dyes in beverages probably would have an additional effect on the SBS of artificial teeth bonded to denture base resins in relation to water. However, SBS of teeth/denture base resins interface was not significantly affected by tested solutions, except for Biolux teeth immersed in coffee.

Table 1: Shear bond strength (MPa) mean±standard deviations of the study groups

Solutions	Teeth/resin Mean±SD			
	Biolux/ Lucitone	Biolux/ Vipi Cril	Vipi Dent Plus/Lucitone	Vipi Dent Plus/Vipi Cril
Distilled water	9.66±1.40^{Aa}	9.44±1.66^{Aa}	15.09±1.89^{Ab}	14.97±2.97^{Ab}
Coffee	8.40±1.52^{Ba}	8.79±1.81^{Aa}	14.48±1.83^{Ab}	15.58±2.57^{Ab}
Cola soft drink	9.61±1.28^{Aa}	8.96±0.85^{Aa}	15.75±3.18^{Ab}	15.06±3.26^{Ab}
Red wine	8.93±1.22^{Aa}	9.82±1.97^{Aa}	15.38±2.57^{Ab}	15.19±2.64^{Ab}

SBS mean and SD followed by a distinct capital letter in columns and lower case letter in rows are statistically different ($P<0.05$). SBS: Shear bond strength, SD: Standard deviation

Although different bond strength evaluation methods are described by the international specification, shear seems to have a greater clinical relevance by simulating forces on teeth lingual surfaces and therefore used as the main method by several of authors.[2,5,6,23,25,32,33] Evaluating different artificial teeth bonded to the same acrylic resin, it can be assumed that the differences in the results are due to the different types of acrylic teeth used in this study. Acrylic resin artificial teeth are composed basically of poly-MMA beads and pigments immersed in a polymeric matrix with cross-linking agents. The chemical bond between teeth and denture base resins results from the propagation of MMA monomer into the artificial tooth.[34-36] Afterward, a network is made around the polymer beads by the monomer and the cross-linking agent.[37] Cross-linking agents are added to denture acrylic teeth to improve strength and resistance to wear and to prevent discoloration and crazing.[38]

In our study, Vipi Dent Plus teeth presented greater SBS results than Biolux teeth in all situations. These results can be explained by the characteristics of the teeth's material. According to the manufacturer, both teeth have in its composition dimethacrylate of polymerized ethylene glycol which is a cross-linking agent. However, Biolux teeth have high molecular weight polymers that provide the possibility of higher content of cross-linking agents and the presence of the double cross-linking system[39,40] forming a fully interpenetrate polymer chain while Vipi Dent forms only a linear polymer chain.[41] It seems to be well established that as the cross-linking content of the tooth increases the bonding between it and denture base resins decreases.[2,7,42,43] This happens due to the enhanced surface features of the high cross-linking acrylic teeth that jeopardize permeation of the denture base resin monomer, forming a weaker interwoven polymer network.

Biolux teeth when combined with Vipi Cril denture resin showed less resistance after immersion in coffee, which was not observed for Vipi Dent Plus teeth. There are no studies up to the present time that evaluate bond strength between acrylic teeth and denture base resins after immersion in potentially

staining solutions. Thus, only indirect comparisons between other studies and ours can be established. Ruyter *et al*.[44] stated that the polarity degree of the staining agent defines the penetration degree into resin's bulk. The less polar beverages, such as coffee, can penetrate easier and join the polymer matrix.[45] Several authors observed color modification in acrylic resins after prolonged immersion in coffee.[46,47] It was also shown that coffee causes a significant change in color stability of acrylic resin artificial tooth.[16,45] The polymers' surface degradation caused by coffee may be related to its affinity with these materials and to adsorption and absorption of its colorants, particularly of the yellow one.[27,48] The tannic acid present in solutions like tea and coffee can also promote this surface alteration.[27,46,49] Khan *et al*.[49] reported that extended immersion in tea solution worsened the features of light-curing acrylic resin denture base, such as water absorption, flexural strength, and hardness. Therefore, the bond strength reduction perceived on Biolux teeth after immersion in coffee solution in the present study can be attributed to the solution's low polarity, its high affinity to the polymer, and the presence of yellow dye and tannic acid in its composition.

In our investigation, the failure modes were cohesive for all specimens, consistent to the results of similar studies.[21,23,50] However, Akin *et al*.[31] reported 93% of adhesive failures, when evaluating acrylic tooth bonded to denture base resin. This outcome may be due to the lack of tooth bonding surface treatment in this study. In our study, the tooth ridge lap was treated with MMA monomer that is proven to increase SBS and lead to most reliable results, regarding failure modes.[21,35,51] Cohesive failures happen more often than adhesive failures when the bond interfaces are not contaminated.[52]

Overall, this study suggests that potentially chromogenic beverages commonly consumed in daily diet do not cause significant changes in the bond strength between acrylic artificial teeth and heat-polymerized resins used in this study. Moreover, acrylic teeth with higher molecular weight and cross-linking agents have weaker bond compared to those with a lower content of molecular weight and cross-linking agents. However, artificial teeth may undergo several other events that could not be assessed within this study's *in vitro* methodology. In clinical use, acrylic resin artificial teeth can have their surface features influenced by various dynamic conditions, such as quantity and quality of saliva, cleansing procedures, type of feeding (consistency of food), intake frequency of coloring and/or acidic foods, parafunctional habits, accidents/trauma, antagonist teeth, occlusal condition, and among many others. In addition, other aspects are proven to reduce bonding between acrylic teeth and denture base resin, such as contamination in the tooth-denture base resin interface and difference in the structure of the two materials due to their different processing routes.[2,7,53] Furthermore, only two brands of acrylic teeth, two brands of denture heat-polymerized resin, and three types of potentially chromogenic beverages were tested given the many types commercially available. Therefore, the results of this study should be interpreted with caution.

CONCLUSIONS

Within the limits of the study, the following conclusions were drawn:

- SBS between Vipi Dent Plus teeth and Vipi Cril and Lucitone base resins were higher when compared to Biolux teeth bonded to both base resins, regardless of immersion solution
- Staining beverages did not show the impact on SBS in all combinations of teeth/denture base resin, except for Biolux/Lucitone after immersion in coffee solution.

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Conflicts of interest

There are no conflicts of interest.

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