International Journal of Adhesion & Adhesives 44 (2013) 180–183

Contents lists available at SciVerse ScienceDirect

International Journal of Adhesion & Adhesives

journal homepage: www.elsevier.com/locate/ijadhadh

Effect of immersion cleansers on the bond strength between a denture base resin and acrylic resin teeth

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ARTICLE INFO

Article history:
Accepted 8 February 2013
Available online 6 March 2013

Keywords:
Structural acrylics
Fracture mechanics
Lap-shear
Interfaces

ABSTRACT

The aim of the present study was to assess the shear bond strength between a heat-polymerized denture base resin and acrylic resin teeth after immersion in different denture cleansers by simulating a 180-day use. Two acrylic teeth (Biotone, Biotone IPN, Dentsply Ind. e Com., Rio de Janeiro, RJ, Brazil) were chosen for bonding to a heat-polymerized denture base resin (Lucitone 550- Dentsply Ind. e Com., Rio de Janeiro, RJ, Brazil). Eighty specimens were produced and divided into eight groups ($n=10$) according to their experimental condition (distilled water, 2% chlorhexidine digluconate, 1% sodium hypochlorite and Corega Tabs). Shear bond strength tests (MPa) were performed with a universal testing machine at a crosshead speed of 0.5 mm/min. Data were analyzed by two-way analysis of variance (ANOVA) and Student-Newman–Keuls' multiple comparisons post hoc analysis ($\alpha=.05$). The shear bond strength results revealed statistically significant differences between the groups. For the Biotone IPN tooth, significantly lower shear bond strength values were found for the group immersed in sodium-perborate solution (4.48 ± 2.18 MPa) than for the group immersed in distilled water (control group) (10.83 ± 1.84 MPa). For Biotone, significantly higher bond strength values (10.04 ± 3.28 MPa) were found for the group immersed in Corega Tabs than for the control group (5.45 ± 2.93 MPa). The immersion in denture cleanser solutions was more detrimental to the conventional acrylic denture tooth (Biotone) than to the highly cross-linked denture tooth (Biotone IPN). However, this effect was not observed for the groups immersed in Corega Tabs solution, regardless of the type of denture tooth.

1. Introduction

Denture care is essential for the greater longevity of the prosthesis and the maintenance of a healthy oral mucosa. A lack of denture hygiene can cause a proliferation of microorganisms on the denture surface and the development of oral infections, [1] since denture materials may act as reservoirs for microorganisms and have the potential to support biofilm formation [2].

In an attempt to prevent this condition and improve the quality of life of denture wearers, hygiene instructions should be emphasized to the patients by dental professionals. The most common method of denture cleaning is the mechanical method associated with detergent, soap or dentifrice [3,4]. However, many elderly patients cannot effectively brush their dentures because of advanced senility or debilitating diseases. [4]

An alternative approach to solve this problem could be the use of chemical cleansers associated to mechanical methods [1,5] of denture cleaning. These denture cleanser solutions include sodium hypochlorite, chlorhexidine, alkaline peroxides, enzymes and diluted acids [6]. The immersion of dentures in sodium hypochlorite solutions has been indicated [5,7] and is effective in reducing *Candida albicans* in patients with denture stomatitis [8]. Chlorhexidine has been shown to be effective by inhibiting the proliferation of a broad spectrum of microorganisms, including *C. albicans* and Gram-positive bacteria [7]. It has been reported that effervescent tabs (alkaline peroxide solutions) do not exhibit satisfactory antimicrobial activity, but must be useful in association with mechanical cleaning [7].

Denture cleaning by immersion in chemical solutions should not cause deleterious effect to the denture materials [4,6,9] and should not affect the bond strength between acrylic teeth and denture base resins. Debonding acrylic teeth from denture base resins remains a common clinical problem in prosthodontic practice. [10]

Different types of acrylic denture teeth have been introduced with claims of increased abrasion resistance, improved esthetics and more convenient curing methods [11]. A conventional acrylic denture tooth is essentially composed of polymethyl methacrylate (PMMA) beads and color pigments in a polymer matrix, whereas a cross-linked resin denture tooth contains an Interpenetrating Polymer Network (IPN), described as the outer layer of the polymer

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http://dx.doi.org/10.1016/j.ijadhadh.2013.02.011

beads into which the monomers of the matrix have diffused during the processing of the tooth [12]. A number of factors may affect the bond strength between artificial acrylic teeth and denture base resins. These include the action of the water and the degree of cross-linking in the polymer [10,12,13]. Thus, the nature of the acrylic resin polymer tooth and the immersion of dentures in an aqueous medium, such as a cleansing agent, should be investigated. However, there are no records of the effects of the immersion of dentures in denture cleansers and the type of acrylic denture tooth on the bond strength between acrylic teeth and denture base resins.

The aim of the present study was to assess the shear bond strength between a heat-polymerized denture base resin and acrylic resin teeth after successive cleansing protocols of immersion in different denture cleansers, simulating a 180-day use. The null hypothesis tested was that neither the immersion in denture cleansers nor the type of acrylic denture tooth would have an effect on the shear bond strength between a denture base resin and acrylic denture teeth.

2. Materials and methods

2.1. Experimental design

A conventional acrylic resin denture tooth (Biotone, Dentsply Ind. e Com., Rio de Janeiro, RJ, Brazil) and a cross-linked resin denture tooth (Biotone IPN—Interpenetrating Polymer Network, Dentsply) were chosen for bonding to a denture base resin (Lucitone 550—Dentsply Ind. e Com., Rio de Janeiro, RJ, Brazil). Eight experimental groups ($n=10$) were formed according to each acrylic resin denture tooth (Biotone or Biotone IPN)/denture cleanser immersion solution (2% chlorhexidine digluconate, 1% sodium hypochlorite, Corega Tabs or distilled water—control) combination.

2.2. Specimen fabrication

The specimens were composed of denture base resin cylinders (5.0 mm diameter × 2.5 mm length) bonded to the ridge-lap surface of the acrylic denture teeth (Fig. 1). All of the acrylic resin denture teeth were maxillary molars. The specimen fabrication was performed as described in previous studies [14,15]. The ridge-lap surfaces of the denture teeth were reduced using 320-, 400-, and 600-grit silicon carbide paper (Norton, Saint-Gobain Abrasivos Ltd., Vinhedo, SP, Brazil) in a polishing machine (Arotec Ind. e Com. Ltd., Cotia, SP, Brazil) at 300 rpm. This was done to obtain a flat surface for bonding to the denture base resin. Each denture tooth was embedded in autopolymerizing polymer

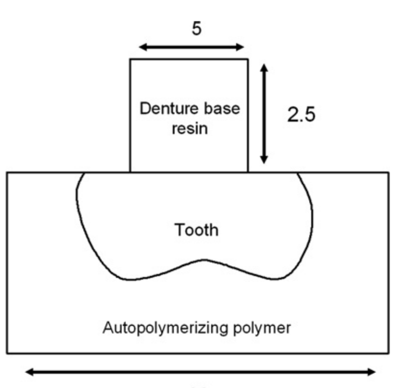

Fig. 1. Schematic drawing of the specimen with the dimensions in millimeters [15].

(poly)methyl methacrylate (PMMA) (Jet, Artigos Odontológicos Clássico Ltd., Sao Paulo, SP, Brazil) using an embedding machine (Arotec Ind. e Com. Ltd., Cotia, SP, Brazil). The ridge-lap surface of the embedded tooth was then polished with 600-grit silicon carbide paper. Silicone patterns (Zetalabor/Indurent—Zhermack, Badia Polesine, Rovigo, Italy), with a circular opening (5.0 mm diameter × 2.5 mm length), were obtained from a stainless steel mold to standardize the dimensions of the denture base resin cylinders. Cyanoacrylate glue (Super Bonder, Loctite Henkel Ltd., Diadema, SP, Brazil) was applied to the silicone pattern PMMA/polymer interface so that the silicone pattern opening position coincided with the prepared ridge-lap surface. The circular opening of the silicone pattern was then sealed with a small amount of silicone before proceeding. The embedded tooth and the silicone pattern were then placed in denture flasks using dental stone (Herodent, Vigodent S.A. Ind. Com., Rio de Janeiro, Brazil). After the dental stone was set, the flask was opened and the silicone was carefully removed from the silicone pattern circular opening. The heat-polymerized denture base resin (Lucitone 550) was mixed, packed and processed according to the manufacturer's instructions and polymerized in an automatic polymerization water tank (Solab Equipamentos para Laboratórios Ltda., Piracicaba, SP, Brazil). The temperature and time used were 73 °C for 90 min, followed by 30 min at 100 °C. These procedures were carried out to simulate the usual laboratorial procedures for denture fabrication. After polymerization, each flask was bench cooled at room temperature overnight. The specimens were carefully deflasked, cleaned, and stored in distilled water at 37 °C for 50 ± 2 h before the immersion procedure [16].

2.3. Immersion procedure

The present study simulated immersion in different denture cleansers for 180 days. The time needed to simulate the 180 day-period was based on a previous report [4]. The effervescent solution (Corega Tabs, Stafford Miller Ind., Rio de Janeiro, RJ, Brazil) was prepared according to the manufacturer's instructions, by adding one tablet to 200 mL of warm tap water (40 °C). The specimens were submitted to thirty immersion cycles daily (5 min each) over a period of 6 days, simulating a 180-day use [4]. After each cycle, the soaking solution was discarded and the specimens were thoroughly washed in running water. These specimens were stored in distilled water at room temperature (23 ± 2 °C) when the immersion cycles were not carried out in the effervescent denture cleanser solution [4,17].

For the groups immersed in 200 mL of 2% chlorhexidine digluconate, 1% sodium hypochlorite, or distilled water (control group), the total immersion period was 15 h to simulate the same 5 min of daily immersion for 180 days before the shear bond strength tests.

2.4. Shear bond strength test

A universal testing machine (EMIC-DL 3000, EMIC Ltd., Curitiba, PR, Brazil) was used at a crosshead speed of 0.5 mm/min. The maximum stress (MPa) required to shear the denture base resin off the acrylic tooth was considered as the shear bond strength [14,15]. The data were analyzed by two-way analysis of variance (ANOVA) and Student-Newman–Keuls' multiple comparisons post hoc analysis ($\alpha = .05$).

3. Results

The two-way ANOVA detected significant differences in the factor acrylic denture tooth ($p < .001$) and in the interaction of the

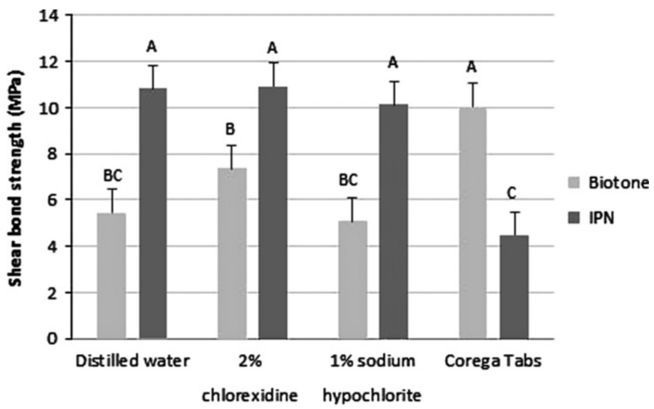

Fig. 2. Means and standard deviations of shear bond strength for the groups. Similar capital letters denote no significant differences between the groups (Student-Newman–Keuls test, $\alpha = .05$).

acrylic denture tooth with the denture cleansers ($p < .001$). No significant differences were found for the factor denture cleansers ($p = .062$).

For the Biotone tooth, further analysis with the Student-Newman–Keuls test revealed significantly higher bond strength values (10.04 ± 3.28 MPa) for the group immersed in sodium-perborate based solution (Corega Tabs) than for the groups immersed in distilled water (control group) (5.45 ± 2.93 MPa), chlorhexidine (7.36 ± 2.47 MPa) and hypochlorite (5.09 ± 1.85 MPa), whereas these groups exhibited statistically similar results between each other. For the Biotone IPN tooth, significantly lower shear bond strength values were found for the group immersed in sodium-perborate solution (4.48 ± 2.18 MPa) than for the control (10.83 ± 1.84 MPa), chlorhexidine (10.93 ± 1.73 MPa) and hypochlorite (10.12 ± 1.50 MPa) groups, whereas these groups exhibited statistically similar results between each other. Fig. 2 illustrates the results of the effect of the type of acrylic denture tooth and the immersion in denture cleansers on the shear bond strength between a denture base resin and acrylic denture teeth.

By analyzing the effect of the type of artificial tooth on the shear bond strength, the results of the present study indicate that for all the denture cleansers solutions assessed, the type of tooth significantly influenced the variable studied since the values of bond strength were statistically different within the same immersion solution.

4. Discussion

Based on the results of the present study, the null hypothesis was rejected. The type of acrylic tooth and immersion in denture cleanser factors influenced the shear bond strength between denture base resin and different acrylic denture teeth.

Several studies have investigated the effects of denture cleansers on the physical and mechanical properties of denture base resins. However, there are very few studies that used acrylic denture teeth [18–20].

Acrylic resin polymer teeth are chemically capable of bonding to denture base polymers [21]. According to Vallittu et al., [12] the bond between acrylic denture teeth and denture base resins at the interface is dependent on the swelling of monomers from the denture base polymer into the polymer matrix of the denture tooth. The same authors stated that the higher bond strength at the interface acrylic denture tooth/ denture base can be explained by the higher diffusion of monomers from the denture base into the polymer tooth, with an increasing polymerization temperature. This diffusion rate of monomers is also dependent on the polymeric structure of the polymer tooth [12].

It has been stated that conventional acrylic resin teeth usually provide an improved bond to denture base resins when compared to highly cross-linked teeth [5,22,23]. Suzuki et al. [24] explained that the addition of cross-linking agents reduces the amount of free polymer chains in an artificial tooth, which considerably decreases the interaction with the denture base resin.

However, the results of the present study showed that, in general, the groups of IPN teeth exhibited higher shear bond strength values, with the exception of the groups immersed in perborate. According to Vallittu et al., [12] the cross-linked polymer matrix of a proprietary tooth is usually not evenly distributed in the tooth structure. Therefore, it could be hypothesized that the improved bonding results obtained for the groups of IPN teeth are related to the lesser cross-linked structure at the interface, facilitating the bonding between the polymer tooth and the denture base. In addition, these results could be explained by the lower water absorption into the bulk of the material. According to Pisani et al., [20] artificial teeth containing cross-linking agents promote a decrease in fluid diffusion to the polymer because of their inseparable polymeric chains. This explanation is similar to that provided by Arima et al., [25] who observed that the addition of cross-linking agents to acrylic resin reduced the absorption of water into this material.

On the other hand, conventional acrylic resin teeth have a higher amount of free polymer chains than cross-linked teeth. This could facilitate the diffusion of water into this type of tooth and could possibly explain the low bond strength values obtained for the Biotone groups. According to previous studies, [14,26–29] the water molecules absorbed by the resin act as plasticizers [20,29]. This could detrimentally affect the bond strength between acrylic denture teeth and denture base resins at the bonding interface. [26,27].

In studying the effects of the immersion of acrylic resins in denture cleanser solutions, the chemical affinity of these polymers with water must be considered. Acrylic resin absorbs water by a diffusion mechanism [30]. Factors such as the acrylic resin composition, the presence of residual monomer after polymerization and the type of solution in which the material is immersed can influence the absorption of water [25,28,29,31]. Nevertheless, according to Arikan et al., [31] the chemical nature of the polymer and the distribution of its molecules, as well as their geometrical arrangement, influence the water absorption.

The low values of bond strength observed for the group of IPN teeth immersed in sodium-perborate solution could be explained by the fact that these compounds, when dissolved in water, readily decompose to form an alkaline peroxide solution. This peroxide solution releases oxygen, enabling a mechanical cleaning action caused by the oxygen bubbles produced during the reaction of the effervescent product [3]. This could affect the bond strength.

Despite this mechanical cleaning action, which could affect the bond strength between an acrylic denture tooth and denture base resin, the immersion in perborate was not deleterious to the conventional acrylic denture tooth (Biotone). This could be explained by the composition of this type of acrylic tooth, which exhibits a higher amount of free polymer chains. This would optimize the bond strength between an acrylic denture tooth and denture base resin.

Failure analysis was not included in the present study and this can be considered as a limitation of this study. It is a preliminary report regarding the effects of the immersion of dentures in denture cleansers on the bond strength between acrylic teeth and denture base resins. Further studies are suggested to assess the nature of failure between different types of acrylic teeth and denture base resins submitted to immersion in denture cleansers.

Furthermore, other combinations of materials and immersion periods are suggested so that new results can contribute to an improved clinical performance.

5. Conclusion

In general, immersion in denture cleanser solutions was more detrimental to the conventional acrylic denture tooth (Biotone) than to the highly cross-linked denture tooth (Biotone IPN). Immersion in sodium-perborate solution had a deleterious effect on the Biotone IPN tooth but achieved good results for the Biotone tooth.

Acknowledgments

The authors would like to thank Professor Raphael Freitas de Souza of Ribeirão Preto Dental School in the University of São Paulo (USP) for his assistance with the statistical analysis and FAPESP for financial support (Grant no. 2011/18031-4).

References

[1] Paranhos HFO, Silva-Lovato CH, Souza RF, Cruz PC, Freitas KM, Peracini A. Effects of mechanical and chemical methods on denture biofilm accumulation. J Oral Rehabil 2007;34:606–12.
[2] Radford DR, Sweet SP, Challacombe SJ, Walter JD. Adherence of *Candida albicans* to denture-base materials with different surface finishes. J Dent 1998;26:577–83.
[3] Jagger DC, Harrison A. Denture cleansing-the best approach. Br Dent J 1995;178:413–7.
[4] Peracini A, Davi LR, de Queiroz Ribeiro N, Souza RF, Lovato da Silva CH, Paranhos HFO. Effect of denture cleansers on physical properties of heat-polymerized acrylic resin. J Prosthodont Res 2010;54:78–83.
[5] Barnabé W, de Mendonça Neto T, Pimenta FC, Pegoraro LF, Scolaro JM. Efficacy of sodium hypochlorite and coconut soap used as disinfecting agents in the reduction of denture stomatitis, *Streptococcus mutans* and *Candida albicans*. J Oral Rehabil 2004;31:453–9.
[6] Felipucci DN, Davi LR, Paranhos HF, Bezzon OL, Silva RF, Pagnano VO. Effect of different cleansers on the surface of removable partial denture. Braz Dent J 2011;22:392–7.
[7] da Silva FC, Kimpara ET, Mancini MN, Balducci I, Jorge AO, Koga-Ito CY. Effectiveness of six different disinfectants on removing five microbial species and effects on the topographic characteristics of acrylic resin. J Prosthodont 2008;17:627–33.
[8] Moore TC, Smith DE, Kenny GE. Sanitization of dentures by several denture hygiene methods. J Prosthet Dent 1984;52:158–63.
[9] Polyzois G, Niarchou A, Ntala P, Pantopoulos A, Frangou M. The effect of immersion cleansers on gloss, colour and sorption of acetal denture base material. Gerodontology 2012 March 20. [Epub ahead of print].
[10] Patil SB, Naveen BH, Patil NP. Bonding acrylic teeth to acrylic resin denture bases: a review. Gerodontology 2006;32:131–9.
[11] Kawara M, Carter JM, Ogle RE, Johnson RR. Bonding of plastic teeth to denture base resins. J Prosthet Dent 1991;66:566–71.
[12] Vallittu PK, Ruyter IE, Nat R. The swelling phenomenon of acrylic resin polymer teeth at the interface with denture base polymers. J Prosthet Dent 1997;78:194–9.
[13] Pisani MX, Silva-Lovato CH, Malheiros-Segundo AL, Macedo AP, Paranhos HF. Bond strength and degree of infiltration between acrylic resin denture liner after immersion in effervescent denture cleanser. J Prosthodont 2009;18: 123–9.
[14] Marra J, de Souza RF, Barbosa DB, Pero AC, Compagnoni MA. Evaluation of the bond strength of denture base resins to acrylic resin teeth: effect of thermocycling. J Prosthodont 2009;18:438–43.
[15] Marra J, Paleari AG, Pero AC, Souza RF, Barbosa DB, Compagnoni MA. Effect of methyl methacrylate monomer on bond strength of denture base resin to acrylic teeth. Int J Adhes Adhes 2009;29:391–5.
[16] American Dental Association, Revised American Dental Association Specification n.12 for denture base polymers, J. Am. Dent. Assoc. 90 (1975) 451–8.
[17] Paranhos HFO, Davi LR, Peracini A, Soares RB, Lovato CH, Souza RF. Comparison of physical and mechanical properties of microwave-polymerized acrylic resin after disinfection in sodium hypochlorite solutions. Braz Dent J 2009;20:331–5.
[18] Campanha NH, Pavarina AC, Jorge JH, Vergani CE, Machado AL, Giampaolo ET. The effect of long-term disinfection procedures on hardness property of resin denture teeth. Gerodontology 2012;29:571–6.
[19] Pavarina AC, Vergani CE, Machado AL, Giampaolo ET, Teraoka MT. The effect of disinfectant solutions on the hardness of acrylic resin denture teeth. J Oral Rehabil 2003;30:749–52.
[20] Pisani MX, Macedo AP, Paranhos HFO, Silva CH. Effect of experimental *Ricinus communis* solution for denture cleaning on the properties of acrylic resin teeth. Braz Dent J 2012;23:15–21.
[21] Clancy JM, Boyer DB. Comparative bond strengths of light-cured, heat-cured and autopolymerizing denture resins to denture teeth. J Prosthet Dent 1989;61:457–62.
[22] Chai J, Takahashi Y, Takahashi T, Habu T. Bonding durability of conventional resinous denture teeth and highly crosslinked denture teeth to a pour-type denture base resin. Int J Prosthodont 2000;13:112–6.
[23] Takahashi Y, Chai J, Takahashi T, Habu T. Bond strength of denture teeth to denture base resins. Int J Prosthodont 2000;13:59–65.
[24] Suzuki S, Sakoh M, Shiba A. Adhesive bonding of denture base resins to plastic denture teeth. J Biomed Mater Res 1990;24:1091–103.
[25] Arima T, Murata H, Hamada. T. The effects of cross-linking agents on the water sorption and solubility characteristics of denture base resin. J Oral Rehabil 1996;23:476–80.
[26] Aydin AK, Terzioðlu H, Akinay AE, Ulubayram K, Hasirci N. Bond strength and failure analysis of lining materials to denture resin. Dent Mater 1999;15: 211–8.
[27] Cucci AL, Rached RN, Giampaolo ET, Vergani CE. Tensile bond strengths of hard chairside reline resins as influenced by water storage. J Oral Rehabil 1999;26:631–4.
[28] Pero AC, Marra J, Paleari AG, de Souza RF, Ruvolo-Filho A, Compagnoni MA. Reliability of a method for evaluating porosity in denture base resins. Gerodontology 2011;28:127–33.
[29] Takahashi Y, Chai J, Kawaguchi M. Effect of water sorption on the resistance to plastic deformation of a denture base material relined with four different denture reline materials. Int J Prosthodont 1998;11:49–54.
[30] Anusavice KJ. Phillips' science of dental materials. 10th ed. Pennsylvania: Saunders; 1996.
[31] Arikan A, Ozkan YK, Arda T, Akalin. B. An in vitro investigation of water sorption and solubility of two acetal denture base materials, Eur. J. Prosthodont Restor Dent 2005;13:119–22.