self CDE 2 HOURS CREDIT instruction

Effect of toothbrushes and denture brushes on heat-polymerized acrylic resins

Karina Matthes de Freitas Pontes, DDS, MS, PhD ▪ Janaína Câncio de Holanda, DDS, MS ▪ Cristiane Sa Roriz Fonteles, DDS, MS, PhD
Cassio de Barros Pontes, DDS, MS, PhD ▪ Cláudia Helena Lovato da Silva, DDS, MS, PhD ▪ Helena de Freitas Oliveira Paranhos, DDS, MS, PhD

It is important to choose an appropriate brush for denture cleaning to prevent damage to the surface properties of prosthetic devices. The purpose of this study was to evaluate the abrasiveness of toothbrushes and denture brushes on boiled and microwave-processed acrylic resins. Specimens of 4 resin brands were prepared (n = 30). Five brands of brushes (n = 6) were used in a toothbrushing machine, first for 17,800 strokes and then for an additional 35,600 strokes (total of 53,400), at a load of 200 g. An analytical balance and a profilometer were used to assess the weight and surface roughness, respectively, before and after 17,800 and 53,400 strokes. Analysis of variance and Tukey tests were used for data analysis ($\alpha = 0.05$). Weight loss increased with time, while surface roughness remained the same. There were no statistically significant differences among toothbrushes and denture brushes in the resulting weight loss (17,800 strokes, 1.83 mg; 53,400 strokes, 3.78 mg) or surface roughness (17,800 or 53,400 strokes, 0.14 µm). The weight loss values after 53,400 brush strokes indicated that Clássico (2.28 mg) and VIPI Wave (2.75 mg) presented significantly greater abrasion resistance than Lucitone 550 (3.36 mg) and Onda-Cryl (2.85 mg) ($P < 0.05$). The type of brush and the polymerization method did not influence resin wear after brushing.

Received: June 9, 2014
Accepted: November 3, 2014

Key words: acrylic resins, denture bases, denture wear

Optimal denture cleaning is essential to the prevention of disease among edentulous patients, since some oral and systemic infections may originate from colonized inner surfaces of complete dentures.[1-7] Denture surfaces commonly accumulate biofilm, and studies have shown a link between biofilm accumulation and denture stomatitis.[8-13] Many denture wearers use a toothbrush, dentifrice, and water to mechanically remove debris, but this economical and simple technique, although effective, can result in wear of the denture base and relining materials.[14-19] The use of nonabrasive pastes and specific brushes has been recommended for cleaning of complete dentures, but in some countries these products are not always available.[20-22] Another standard recommendation consists of the use of a soft-bristle brush with warm soap or water, but the relationship between bristle hardness and the degree of abrasion produced is controversial.[7,9,15,21,23-25]

Brushing of acrylic resin denture bases may cause loss of mass, loss of surface polish, surface roughness, and a loss of surface detail that impacts denture adaptation.[26] Biofilm formation is facilitated by flaws in the acrylic resin surface.[27-29] It has been reported that a surface roughness of 0.2 µm is the threshold for bacterial adhesion, but the acceptable weight loss of acrylic resins remains unknown.[30] A number of factors influence the degree of surface abrasion that results from toothbrushing, including the abrasiveness of the dentifrice; the stiffness of the bristles; the technique, frequency, and force of toothbrushing; and the hardness of the denture base material.[26] Some researchers have emphasized the influence of the bristle tips in the magnitude of abrasion, while others have highlighted the influence of the types of bristles holding the toothpaste.[15,31] To control for these variables, many studies use brushing with water to determine the action of the brushes on the substrates.

Abrasion of oral tissues and restorative materials, especially restorative composite resins, by toothbrushing and dentifrices has been extensively reported in the literature.[32-34] In the field of complete dentures, although many other comparative studies show dentifrice abrasion on various types of acrylic resin, limited information is available regarding the abrasiveness of toothbrush and denture brush bristles on these materials.[17,35-41] It seems important to evaluate not only the influence of toothbrushing with water on abrasive wear and surface roughness of acrylic resins but also the abrasion resistance of different types of acrylic resin. The purpose of this study was to evaluate the weight loss and surface roughness of 4 commercially available heat-polymerized acrylic resins (boiled and microwave processed) after brushing with 5 different toothbrushes and denture brushes. The hypothesis tested was that different resins and toothbrushes or denture brushes influence weight loss and surface roughness after brushing.

Materials and methods

Study design

Four different brands of acrylic resins were selected to be used in the present study, rendering 4 groups (n = 30) of specimens. Each resin group was subdivided into 5 subgroups (n = 6), and a different toothbrush brand was assigned to each subgroup. The selected brushes included Oral-B Indicator Soft (Procter & Gamble); Johnson REACH Professional Soft (Johnson & Johnson); Johnson REACH Professional Medium (Johnson & Johnson); Prótese BITUFO (Hypermarcas S/A); and Medic Denture (Condor SA).

The geometries of bristle tips of the different brushes were observed, at 20× magnification, with a profilometer (Nikon, Nippon Kogaku KK). The bristle tips were classified according to the categories described by Silverstone & Featherstone, as modified by Jung et al.[42,43]

Specimen preparation

For this experiment, 120 rectangular specimens (90 × 30 × 4 mm) were made using boiled (Clássico, Clássico Artigos Odontológicos, Ltda; Lucitone 550,

Table 1. Analysis of variance table for weight loss.

Source	SS	*df*	MS	*F* value	Significance
T	228.5394	1	228.5394	232.00	$P < 0.05$
B	10.8326	4	2.7082	2.75	NS
R	34.9979	3	11.6660	11.84	$P < 0.05$
T × B × R	7.8843	12	0.6570	0.67	NS
Residuals	197.0164	200	0.9851		
Total variation	575.0148	239			

Abbreviations: B, brushes; *df*, degrees of freedom; NS, not significant; R, acrylic resins; MS, mean square; SS, sum of squares; T, number of strokes.

Table 2. Weight loss (mg) of acrylic resins after 53,400 brush strokes.

Acrylic resin	Mean	SD
Lucitone 550	3.36[a]	1.28
Clássico	2.28[c]	0.68
VIPI Wave	2.75[bc]	0.66
Onda-Cryl	2.85[b]	0.76

Means with different superscript letters are significantly different ($P < 0.05$).

DENTSPLY International) and microwave-processed (Onda-Cryl, Clássico Artigos Odontológicos, Ltda; VIPI Wave, VIPI Produtos Odontológicos) heat-polymerized acrylic resins. All specimens were manufactured using a polymethyl methacrylate matrix. The matrix was flasked in type III and IV dental stone (Herodent Soli-Rock, Vigodent SA Indústria e Comércio) within appropriate flasks (metallic for conventional polymerization and plastic for microwave polymerization). After the gypsum was completely set, the matrix was removed, the acrylic resin was packed, and the flasks were placed in a polymerizing unit. The resins were processed following their manufacturer's instructions. For microwave-cured acrylic resins, the plastic flasks were placed in a microwave oven (Brastemp Clean, Whirlpool Latin America).

All flasks were bench cooled for 2 hours, subsequently removed, and ground with progressively smoother aluminum oxide papers (320, 400, and 600 grit) in a horizontal polisher (APL-4, Arotec SA). A brush wheel (TMP-200, Equilam Indústria e Comércio) with pumice slurry and a felt cone with chalk powder (Branco-Rio, OAB-ME) were used for mechanical polishing. All of the specimens were exposed to the same procedures, and each mechanical polishing step was performed for 1 minute on each surface.

The polished specimens were stored in distilled water at 37°C for 7 days, rinsed in running water, and then placed in an ultrasonic bath with distilled water and 1% of detergent for 1 minute.The specimens were dried with absorbent paper until all visible moisture disappeared. After 1 minute, the initial weight (mass [m_1]) in milligrams was obtained with the aid of an analytical electronic scale with a sensitivity of 0.1 mg (Mettler-Toledo LLC). Roughness measurements were taken with a profilometer (Surftest SJ-201P, Mitutoyo America Corporation), calibrated at a specimen length of 0.8 mm, indentation of 4.0 mm, speed of 0.5 mm/s, and resolution of 0.01 µm. The initial surface roughness (Ra_1) in microns was measured on specimens at 3 predetermined areas to establish a mean measurement for each specimen.

Brushing assays

The specimens were submitted to brushing assays in accordance with the recommendations of the International Organization for Standardization.[44] The toothbrushing procedure involved a mechanical cross-brushing machine (Pepsodent, Precision Shop, University of São Paulo) in which 6 specimens could be brushed simultaneously at a load of 200 g. The brushing was performed with distilled water only, at 23°C (SD, 3°C). All specimens were subjected to 17,800 strokes, measured (weight and surface roughness), and then subjected to an additional 35,600 strokes. The total of 53,400 strokes correspond to 3 years of manual brushing.[18,37] Brushes were replaced with new ones at each interval of 17,800 strokes.

Weight loss and surface roughness calculations

The gravimetric method was employed to calculate weight loss as $Lm_1 = m_1 - m_2$ and $Lm_2 = m_1 - m_3$, where m_1 is the initial mass, m_2 is the mass after 17,800 brush strokes, and m_3 is the mass after 53,400 brush strokes. Surface roughness analysis was conducted by comparing the initial Ra values (Ra_1) and the values obtained after 17,800 (Ra_2) and 53,400 (Ra_3) brush strokes.

Statistical analysis

Normality of the data was tested with a chi-square test. The weight loss and surface roughness variables showed normal and homogenous distribution. Therefore, 3-way analysis of variance (ANOVA) was used for comparisons among variation factors (number of brush strokes, tooth and denture brushes, and acrylic resins). When differences were identified, the Tukey test was applied as a post hoc test ($\alpha = 0.05$). Weight loss and surface roughness data were reported as mean and standard deviation of the mean.

Results

Comparisons among groups showed a statistically significant difference ($P < 0.05$) between weight loss after 17,800 (mean for all groups, 1.83 mg; SD, 0.60 mg) and 53,400 strokes (mean for all groups, 3.78 mg; SD, 0.90 mg), demonstrating an important increase in wear on the acrylic resins with brushing time (Table 1). In addition, resistance to abrasion also differed significantly among acrylic resin brands, although there were no differences among the brushes tested. Lucitone 550 was less abrasion resistant than all other resins. Clássico was the most resistant, followed by VIPI Wave and Onda-Cryl (Table 2).

Table 3. Analysis of variance table for mean surface roughness.

Source	SS	*df*	MS	*F* value	Significance
T	0.0063	2	0.0032	2.20	NS
B	0.0024	4	0.0006	0.42	NS
R	0.2672	3	0.0891	62.06	$P < 0.05$
T × B × R	0.0061	24	0.0003	0.18	NS
Residuals	0.4305	300	0.0014		
Total variation	0.8111	359			

Abbreviations: B, brushes; *df*, degrees of freedom; NS, not significant; R, acrylic resins; MS, mean square; SS, sum of squares; T, number of strokes.

Table 4. Surface roughness (µm) of acrylic resins after 53,400 brush strokes.

Acrylic resin	Mean	SD
Lucitone 550	0.09[a]	0.03
Clássico	0.13[b]	0.04
VIPI Wave	0.14[b]	0.03
Onda-Cryl	0.17[c]	0.04

Means with different superscript letters are significantly different ($P < 0.05$).

Surface roughness of the specimens differed significantly ($P < 0.05$) among resins (Table 3). These significant differences were related to the initial surface roughness of each resin before brushing (Table 4). The initial roughness values (0.14 µm) were not significantly changed after the abrasion assays (17,800 or 53,400 brush strokes), regardless of the toothbrush or denture brush used.

Discussion

The present study tested weight loss and surface roughness, which are adequate parameters to determine abrasion caused by brushing.[18,24,26,32] The variation factors were the number of brush strokes (17,800 and 53,400), 4 brands of acrylic resins (boiled and microwave cured), and 5 brands of brushes, including toothbrushes and denture brushes. To evaluate the abrasiveness caused by brush bristles on various brands of acrylic resins, distilled water was chosen instead of a dentifrice to avoid interference of its abrasive agents and possible chemical influence on the substrate and to prevent variations in its retention by the different bristles.[15,24] Studies that assess the abrasiveness caused by brushes alone are rare, especially comparisons of toothbrushes against brushes designed specifically for dentures.

Most studies that test abrasion caused by brushing employ dentifrices, with the intent of evaluating only the substrates and not the brushes.[32,35] There is significant variation in the results of those studies due to the use of various types of dentifrices, with distinctive abrasive particles in different concentrations, making comparisons to the present data a challenge. The present work aimed to isolate the action of brushes by analyzing different types of bristles and the influence of these factors on the wear resistance of various brands of acrylic resin. The purpose was to test the hypothesis that specific denture brushes were more abrasive than toothbrushes considered soft. The bristle tips of all the toothbrushes and denture brushes in the present study were considered unacceptable, according to the classification proposed by Silverstone & Featherstone and modified by Jung et al.[42,43]

Most in vitro studies found in the literature use 20,000-100,000 brushing cycles, which simulate from 1-5 years of manual brushing.[18,37] The present study chose to simulate the abrasion generated during the first 12 (17,800 cycles) and 36 months (53,400 cycles) of denture brushing. Since dentures should be replaced every 5-7 years, simulations held in the present study were equivalent to half the period that a patient should use the same denture.

The weight loss of specimens increased from an average of 1.83 (SD, 0.6) mg, or 0.02%, after 17,800 brush strokes to 3.78 (SD, 0.9) mg, or 0.03%, after 53,400 strokes. This increment was statistically significant ($P < 0.05$), indicating that brushing associated with distilled water can produce some level of abrasion. However, this weight loss is minimal when compared to the weight loss observed in the presence of dentifrices. Richmond et al demonstrated a weight loss of 300-500 mg on denture base polymers after 20,000 brushing cycles in the presence of toothpaste.[26] However, they reported no weight loss following 50,000 brushing cycles without toothpaste. Other studies have also shown that brushing in association with water produces minimum wear on different substrates.[15,17,35] To the authors' knowledge, no previous studies have compared the abrasiveness of different types of brushes in the absence of dentifrices.

In the results of this study the different toothbrushes and denture brushes tested did not differ in their abrasiveness. This lack of difference was observed in weight loss and surface roughness, reinforcing the evidence that toothbrushes and denture brushes alone do not threaten the integrity of acrylic resins, regardless of the level of bristle hardness. Brushing with water alone did not alter surface roughness of the specimens, maintaining the values below 0.2 µm, previously reported as the critical value of surface roughness for bacterial adhesion.[30] Therefore, importance should be given to the substances used with toothbrushes and denture brushes and to their ability to provide appropriate denture cleaning, given that many surveys have shown the influence of cleaning materials, mainly dentifrices, on the roughness of different dental materials. Dyer et al found a roughness range of 3.15-4.26 µm on acrylics submitted to 20,000 brushing cycles with toothpaste.[15] Richmond et al observed roughness of 1.36-9.43 µm on acrylic resins after 100,000 brushing cycles.[26] Oliveira et al found roughness of 0.88 µm on acrylic resins after 30,000 brushing cycles.[36]

In the present study, weight loss differed among the brands of acrylic resins that were tested. Lucitone 550 showed the lowest abrasion resistance and presented the highest weight loss values, while Clássico was the material that best resisted the abrasive effects of brushing, generating the lowest weight loss. The microwave-cured resins, VIPI Wave and Onda-Cryl, showed intermediate values for weight loss. Before brushing, Lucitone 550 proved to be smoothest (0.09 μm), while Onda-Cryl showed the greatest roughness (0.17 μm). None of the resins presented significant alterations in roughness after 17,800 or 53,400 brushing cycles. Such results suggest that in the present study the curing method was not a determinant of abrasion resistance, which is consistent with the findings reported by Lai et al.[29] Nevertheless, some researchers have stated that factors such as time, temperature, and manner of polymerization can influence the properties of the acrylic resins.[18] There is a consensus that precise procedures for manufacturing a denture base, including the appropriate finishing and polishing phases, are essential for optimizing their physical properties.

More studies are needed to validate concepts related to the selection of brushes and cleaning materials that do not damage the physical properties of complete and partial dentures. An increase in the number of brushing cycles, simulating the total time of denture use, must be considered when these variables are investigated. Tests associating specific denture brushes and toothbrushes with dentifrices would serve to demonstrate the effects of the bristles in holding the dentifrice and on their surface contact with the substrate. In Brazil and other countries, the lack of specific commercial products for cleaning dentures may hamper recommendations by dentists, who still have many questions about the advantages and disadvantages of each method. Therefore, studies about available, effective, nondamaging methods for cleaning dentures are needed.

Conclusion

Within the limitations of the present study, the following could be concluded:

1. Soft and medium toothbrushes and denture brushes showed equivalent abrasiveness on boiled or microwave-cured acrylic resins.
2. Acrylic resins expressed wear resistance in the following order: Clássico (conventional) resin demonstrated the highest wear resistance (ie, least weight loss), followed by VIPI Wave (microwave), Onda-Cryl (microwave), and Lucitone 550 (conventional).

Author information

Dr K.M.F. Pontes is a professor, Department of Restorative Dentistry, Faculty of Pharmacy, Dentistry and Nursing, Federal University of Ceará, Fortaleza, Brazil, where Dr Holanda is a master's student, Postgraduate Program in Dentistry, and Dr Fonteles is a professor, Department of Clinical Dentistry. Dr C.B. Pontes is a professor, Implantology and Dental Prosthesis Specialization Course, Cearense Academy of Dentistry, Fortaleza, Brazil. Drs Silva and Paranhos are professors, Department of Dental Materials and Prosthesis, School of Dentistry of Ribeirão Preto, São Paulo University, Brazil.

Disclaimer

The authors have no financial, economic, commercial, or professional interests related to topics presented in this article.

References

1. Nikawa H, Hamada T, Yamashiro H, Kumagai HA. Review of in vitro and in vivo methods to evaluate the efficacy of denture cleansers. *Int J Prosthodont.* 1999; 12(2):153-159.
2. Gornitsky M, Paradis I, Landaverde G, Mallo AM, Velly AM. A clinical and microbiological evaluation of denture cleansers for geriatric patients in long term care institutions. *J Can Dent Assoc.* 2002;68(1):39-45.
3. Sumi Y, Miura H, Sunakawa M, Michiwaki Y, Sakagami N. Colonization of denture plaque by respiratory pathogens in dependent elderly. *Gerodontology.* 2002; 19(1):25-29.
4. Senpuku H, Sogame A, Inoshita E, Tsuha Y, Miyazaki H, Hanada N. Systemic diseases in association with microbial species in oral biofilm from elderly requiring care. *Gerodontology.* 2003;49(5):301-309.
5. Sumi Y, Kagami H, Ohtsuka Y, Kakinoki Y, Haruguchi Y, Miyamoto H. High correlation between the bacterial species in denture plaque and pharyngeal microflora. *Gerodontology.* 2003;20(2):84-87.
6. Shay K. Denture hygiene: a review and update. *J Contemp Dent Pract.* 2000;1(2):28-41.
7. Salles AE, Macedo LD, Fernandes RA, Silva-Lovato CH, Paranhos Hde F. Comparative analysis of biofilm levels in complete upper and lower dentures after brushing associated with specific denture paste and neutral soap. *Gerodontology.* 2007;24(4):217-223.
8. Keng SB, Lim M. Denture plaque distribution and effectiveness of a perborate-containing denture cleanser. *Quintessence Int.* 1996;24(5):341-345.
9. Paranhos Hde F, da Silva CH, Venezian GV, Macedo LD, de Souza RF. Distribution of biofilm on internal and external surfaces of upper complete dentures: the effect of hygiene instruction. *Gerodontology.* 2007;24(3):162-168.
10. Barbeau J, Séguin J, Goulet JP, et al. Reassessing the presence of *Candida albicans* in denture related stomatitis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2003;95(1):51-59.
11. Coelho CM, Souza YT, Daré AM. Denture-related oral mucosal lesions in a Brazilian school of dentistry. *J Oral Rehabil.* 2004;31(2):135-139.
12. Webb BC, Thomas CJ, Harty DW, Willcox MD. Effectiveness of two methods of denture sterilization. *J Oral Rehabil.* 1998;25(6):416-423.
13. Dhir G, Berzins DW, Dhuru VB, Periathamby AR, Dentino A. Physical properties of denture base resins potentially resistant to *Candida* adhesion. *J Prosthodont.* 2007;16(6):465-472.
14. Harrison A, Jagger DC. An in vitro investigation of the abrasive qualities of a selection of denture-cleaning pastes on poly(methyl methacrylate) denture base material. *Prim Dent Care.* 1997;4(1):21-24.
15. Dyer D, MacDonald E, Newcombe RG, Scratcher C, Ley F, Addy M. Abrasion and stain removal by different manual toothbrushes and brush actions: studies in vitro. *J Clin Periodontol.* 2001;28(2):121-127.
16. Purnaveja S, Fletcher AM, Ritchie GM, Amin WM, Moradians S, Dodd AW. Compatibility of denture cleansers with some new self-curing denture base materials. *Biomaterials.* 1982;3(4):251-252.
17. de Freitas KM, Paranhos Hde F. Weight loss of five commercially available denture teeth after toothbrushing with three different dentifrices. *J Appl Oral Sci.* 2006;14(4):242-246.
18. Haselden CA, Hobkirk JA, Pearson GJ, Davies EH. A comparison between the wear resistance of three types of denture resin to three different dentifrices. *J Oral Rehabil.* 1998;25(5):335-339.
19. Harrison Z, Johnson A, Douglas CW. An in vitro study into the effect of a limited range of denture cleaners on surface roughness and removal of *Candida albicans* from conventional heat-cured acrylic resin denture base material. *J Oral Rehabil.* 2004;31(5): 460-467.
20. Paranhos Hde F, Panzeri H, Lara EH, Candido RC, Ito IY. Capacity of denture plaque/biofilm removal and antimicrobial action of a new denture paste. *Braz Dent J.* 2000;11(2):97-104.
21. Andrucioli MC, de Macedo LD, Panzeri H, Lara EH, Paranhos Hde F. Comparison of two pastes for the removal of biofilm from dentures and palatal lesions in patients with atrophic chronic candidiasis. *Braz Dent J.* 2004;15(3):220-224.
22. Fernandes RAG, Silva-Lovato CH, Paranhos Hde F, Ito IY. Efficacy of three denture brushes on biofilm removal from complete dentures. *J Appl Oral Sci.* 2007; 15(1):39-45.
23. Pipko DJ, El-Sadeek M. An in vitro investigation of abrasion and staining of dental resins. *J Dent Res.* 1972;51(3):689-705.
24. Wictorin L. Effect of toothbrushing on acrylic resin veneering material, 1: a study of abrasion in vitro. *Sven Tandlak Tidskr.* 1971;64(4):247-254.
25. 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(5):453-459.

26. Richmond R, Macfarlane TV, McCord JF. An evaluation of the surface changes in PMMA biomaterial formulations as a result of toothbrush/dentifrice abrasion. *Dent Mater.* 2004;20(2):124-132.
27. Quirynen M, Marechal M, Busscher HJ, Weerkamp AH, Darius PL, van Steenberghe D. The influence of surface free energy and surface roughness on early plaque formation. An in vivo study in man. *J Clin Periodontol.* 1990;17(3):138-144.
28. Bollen CML, Lambrechts P, Quirynen M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. *Dent Mater.* 1997;13(4):258-269.
29. Lai CP, Tsai MH, Chen M, Chang HS, Tay HH. Morphology and properties of denture acrylic resins cured by microwave energy and conventional water bath. *Dent Mater.* 2004;20(2):133-141.
30. Yap AU, Wu SS, Chelvan S, Tan ES. Effect of hygiene maintenance procedures on surface roughness of composite restoratives. *Oper Dent.* 2005;30(1):99-104.
31. Silverstone LM, Featherstone MJ. Examination of the end rounding pattern of toothbrush bristles using scanning electron microscopy: a comparison of eight toothbrush types. *Gerodontics.* 1988;4(2):45-62.
32. Takeuchi CY, Orbegoso Flores VH, Palma Dibb RG, Panzeri H, Lara EHG, Dinelli W. Assessing the surface roughness of a posterior resin composite: effect of surface sealing. *Oper Dent.* 2003;28(3):281-286.
33. Wang L, Garcia FC, Amarante de Araújo P, Franco EB, Mondelli RF. Wear resistance of packable resin composites after simulated toothbrushing test. *J Esthet Restor Dent.* 2004;16(5):303-314.
34. Schemehorn BR, Moore MH, Putt MS. Abrasion, polishing, and stain removal characteristics of various commercial dentifrices in vitro. *J Clin Dent.* 2011;22(1):11-18.
35. Prakki A, Cilli R, de Araújo PA, Navarro MF, Mondelli J, Mondelli RF. Effect of toothbrushing abrasion on weight and surface roughness of pH-cycled resin cements and indirect restorative materials. *Quintessence Int.* 2007;38(9):e544-e554.
36. Oliveira LV, Mesquita MF, Henriques GE, Consani RL, Fragoso WS. Effect of polishing technique and brushing on surface roughness of acrylic resins. *J Prosthodont.* 2008;17(4):308-311.
37. Freitas-Pontes KM, Silva-Lovato CH, Paranhos HF. Mass loss of four commercially available heat-polymerized acrylic resins after toothbrushing with three different dentifrices. *J Appl Oral Sci.* 2009;17(2):116-121.
38. Liljeborg A, Tellefsen G, Johannsen G. The use of a profilometer for both quantitative and qualitative measurements of toothpaste abrasivity. *Int J Dent Hyg.* 2010;8(3):237-243.
39. Pisani MX, Bruhn JP, Paranhos HF, Silva-Lovato CH, de Souza RF, Panzeri H. Evaluation of the abrasiveness of dentifrices for complete dentures. *J Prosthodont.* 2010;19(5):369-373.
40. Machado AL, Giampaolo ET, Vergani CE, Pavarina AC, Salles Dda S, Jorge JH. Weight loss and changes in surface roughness of denture base and reline materials after simulated toothbrushing in vitro. *Gerodontology.* 2012;29(2):e121-e127.
41. Lira AF, Consani RL, Mesquita MF, Nóbilo MA, Henriques GE. Effect of toothbrushing, chemical disinfection and thermocycling procedures on the surface microroughness of denture base acrylic resins. *Gerodontology.* 2012;29(2):e891-e897.
42. Silverstone LM, Featherstone MJ. Examination of the end rounding pattern of toothbrush bristles using scanning electron microscopy: a comparison of eight toothbrush types. *Gerodontics.* 1988;4(2):45-62.
43. Jung M, Koçkapan C, Wetzel WE. Bristle end rounding of manual toothbrushes and reproducibility of end rounding classification. *Am J Dent.* 2003;16(5):299-304.
44. International Organization for Standardization (ISO). *ISO/TS 14569-1, Dental Materials—Guidance on Testing of Wear Resistance—Part 1: Wear by Toothbrushing.* Geneva: ISO; 1996.