Effect of Denture Cleansers on the Surface Roughness and Hardness of a Microwave-Cured Acrylic Resin and Dental Alloys

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Purpose: This study evaluated the effect of denture cleansers on the surface hardness of a denture base resin, and on the surface roughness of the resin and Co-Cr and Ti-6Al-4V alloys.

Materials and Methods: Forty-eight disc-shaped specimens were fabricated of a microwave-cured acrylic resin, each having one of the alloys attached to its surface. The specimens were randomly divided into 6 groups, each consisting of 8 samples. Specimens were exposed to one of the three cleansing treatments (polident, manipulation pharmacy cleanser, and water) as follows. Group I: Co-Cr + polident; Group II: Co-Cr + manipulation; Group III: Co-Cr + water; Group IV: Ti-6Al-4V + polident; Group V: Ti-6Al-4V + manipulation; and Group VI: Ti-6Al-4V + water. Three exposures lasting 5 minutes each were conducted daily, and repeated after storage periods of 1, 14, and 29 days in artificial saliva at 37°C. Hardness and roughness measurements were undertaken immediately after specimen preparation (T0) and on the 1st (T1), 15th (T15), and 30th (T30) day following the beginning of storage. Three roughness and hardness evaluations were carried out for each sample and testing time, and mean values were calculated. Results were analyzed using ANOVA and linear regression.

Results: The Knoop hardness test demonstrated differences ($p < 0.05$) between Groups I and IV at T1 and T30 (14.30 ± 2.78; 14.06 ± 1.76) and between Groups II and V at T15 (16.99 ± 2.24). Significant differences ($p < 0.05$) in resin roughness (in μm) were observed between Groups I and IV at T15 and T30 (0.14 ± 0.06; 0.21 ± 0.38). With regard to Co-Cr, roughness data showed differences ($p < 0.05$) for all groups at T30 (Group I: 0.15 ± 0.07; Group II: 2.43 ± 0.66; Group III: 4.05 ± 1.03), for Group II at T1 (0.10 ± 0.03), and for Group I at T15 (0.15 ± 0.02). There were significant differences ($p < 0.05$) in titanium roughness for Group IV at T15 (0.12 ± 0.01) and T30 (0.11 ± 0.04).

Conclusions: Manipulated cleanser containing sodium perborate increased surface roughness and hardness, probably due to its incapacity to remove the pellicle formed on the acrylic resin and dental alloys.

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INDEX WORDS: microwave, acrylic resin, titanium, cobalt, cleanser

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THE REMOVAL of biofilm deposited on prosthesis surfaces is commonly accomplished by mechanical methods. Due to a patient's lack of motor coordination, such methods may be ineffective and thus demand alternative means such as chemical cleansing.[1,2] The efficacy of denture cleansers in dislodging food debris, biofilm, and tobacco stains from prosthodontic surfaces has been previously reported.[1-7]

Removable partial denture (RPD) frameworks are often fabricated from cobalt-chromium alloys (Co-Cr). Because these alloys can corrode or stain as a result of surface contact with the chlorine or oxygen present in some commercial cleansers,[8] RPD wearers must be instructed about the prudent selection of cleansing agents for their sanitization regime.

Cobalt alloys and titanium alloys, such as the titanium-aluminum-vanadium alloys (Ti-6Al-4V), have been used for RPD framework fabrication since the 1980s and have shown results comparable to those of Co-Cr alloys.[9] Moreover, because titanium-based alloys passivate more strongly than Co-Cr alloys do, they tend to corrode less noticeably.[10]

The use of microwave energy to polymerize acrylic resin denture base materials has been reported.[11-14] Acrylic resin cured with microwave energy demonstrates adequate physical properties,[15] even when used in the fabrication of metal-based RPDs.[16]

Although the use of microwave-cured acrylic resins is increasing, no studies have investigated the influence of prosthetic cleansers on the surface properties of these materials. Similarly, titanium-based alloys have not been sufficiently investigated to determine their resistance to corrosion in such cleanser solutions.

Therefore, this study aimed to evaluate the effect of 2 cleansers and water on the surface roughness and hardness of a microwave-cured acrylic denture base resin and on the surface roughness of Co-Cr and Ti-6Al-4V RPD alloys.

Materials and Methods

Forty-eight circular discs (30 mm in diameter × 4.0 mm thick) were fabricated using conventional gypsum molding technique and a microwave-cured acrylic resin (Onda-Cryl; Clássico Artigos Odontológicos Ltda., São Paulo, Brazil). Before packing the resin, a rectangular (30 mm × 10 mm × 2 mm) insert of a Co-Cr (Degussa; Frankfurt, Germany) or a Ti-6Al-4V (Brodene Dahl A/S; Oslo, Norway) alloy was centered in the bottom of each mold. Specimens were exposed to a microwave cycle of 3 minutes at 360 W, followed by 4 minutes rest, then 3 minutes at 810 W in a 900-W microwave oven (Continental AW-42; Manaus, Brazil). After processing, all specimens were ground with 360, 400, 600, and 1200-grit abrasive papers (Carbimet®; Buehler, Lake Bluff, IL) in a polishing machine (Arotec APL-4; São Paulo, Brazil) under refrigeration, followed by polishing cloths and 1-μm diamond suspension (Metadi® diamond suspension; Buehler, Lake Bluff, IL).

The specimens were randomly distributed into 6 groups, each consisting of 8 samples, according to the alloy type and cleansing treatments tested (Table 1). Immediately after finishing and polishing (time = T0), all specimens were tested for surface roughness and hardness. Hardness was assayed using a microhardness tester (Shimadzu HMV-2000; Shimadzu Corp., Kyoto, Japan) with a Knoop penetrator. Settings for load and penetration were 25 g and 5 seconds. Three penetrations were made on the acrylic surface of each specimen. The surface roughness was measured in micrometers in 3 different areas of each specimen by the use of a profilometer (Surfcorder SE 1700; Kozaka Industry, Kozaka, Japan) calibrated at sample length of 0.8 mm, 2.4 mm percussion of measure, and 0.5 mm/s. The mean roughness of each specimen surface was calculated.

Table 1. Group Division According to Alloys and Cleansers Used

Group	*Alloy*	*Cleanser*	*Code*
I	Co-Cr	Polident	PO
II	Co-Cr	Manipulation pharmacy	MA
III	Co-Cr	Water (control)	WA
IV	Ti-6Al-4V	Polident	PO
V	Ti-6Al-4V	Manipulation pharmacy	MA
VI	Ti-6Al-4V	Water (control)	WA

Subsequent to the T0 measurements, all specimens were stored in artificial saliva,[17] consisting of 0.220 g/L of calcium chloride, 1.07 g/L of sodium phosphate, 1.68 g/L of sodium bicarbonate, and 2 g/L of sodium azide 0.2% (NaN_3) at 37°C for 14 hours. After storage, all specimens were removed from the artificial saliva, and those from Groups I and IV were immersed in the commercial cleanser Polident (Group PO) (Block Drug Co; Jersey City, NJ) consisting of sodium perborate, potassium monopersulfate, proteolytic enzyme, detergent, and effervescent base. Specimens of Groups II and V were immersed in a proprietary pharmacy cleanser (Group MA) (Fórmula & Ação; São Paulo, Brazil) containing sodium perborate, sodium bicarbonate, sodium sulfate, and tartaric acid. Specimens of Groups III and VI were immersed in tap water (Group WA) and served as controls.

Both the cleansers' solutions were prepared by adding one tablet or sachet of each cleanser to 200 mL of tap water at 37°C. All immersions were of 5 minute duration.

After immersion in the respective solutions, each test specimen was washed in distilled water for 10 seconds, and put into artificial saliva for further 5 hours. The procedure of specimens being immersed in the cleansing solutions and later stored in artificial saliva for 5 hours was then repeated. Immediately after they had been immersed in the cleansing solutions and washed for the third time, a new Knoop hardness and surface roughness evaluation was carried out (T1), completing a 24-hour cycle (Fig 1). This cycle was performed with the intention of simulating the use of these cleansing agents thrice a day by the patient.

The Knoop hardness and surface roughness were once again evaluated after repeating this cycle for a

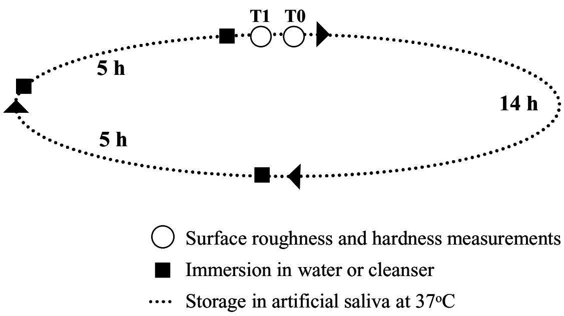

Figure 1. Immersing and storing protocol for T0 and T1.

further 14 (T15) and 29 days (T30), simulating the clinical use of these solutions for 15 and 30 days, respectively.

For each immersion, fresh solutions of both the denture cleansers were prepared and the artificial saliva was changed daily.

The results were subjected to two-way ANOVA and compared by means of Turkey's test. Linear and quadratic regression analysis was carried out to compare treatments longitudinally. All tests were performed with the confidence level set at 95% ($p < 0.5$).

Results

Hardness was significantly different ($p < 0.05$) between PO and WA at T1, between MA and both PO and WA treatments at T15, and between PO and the other treatments at T30 (Table 2). The specimens immersed in MA cleanser showed the highest hardness values for all periods of time.

The acrylic resin surface roughness values (Table 3) were not statistically different for any treatment at T0 and T1. In contrast, a statistically significant difference between PO and the other treatments ($p < 0.05$) at T15 and T30 was found. Longitudinal comparison of treatments showed that the surface roughness of specimens immersed in WA or MA was affected ($p < 0.05$) by extended periods of immersion. In contrast, no differences ($p > 0.05$) in surface roughness after prolonged immersions were detected for specimens immersed in PO (Fig 2).

Surface roughness results of the Co-Cr and Ti-6Al-4V alloys are presented in Table 4. MA and PO affected the Co-Cr alloy less than the other treatments at T1 and T15. For the Co-Cr alloy, a statistically significant difference was found among all groups at T30. For the Ti-6Al-4V alloy, a significant difference in surface roughness was detected between PO and the other treatment at T15 and T30 ($p < 0.05$) with the samples immersed in PO demonstrating the lowest roughness. Comparisons between alloys in each period of time showed significant differences within the control (WA) group at T0 and T30, exhibiting the highest and the lowest mean, respectively.

Linear and quadratic regressions showed that the results for treatments MA and WA differed ($p < 0.05$) over the extended periods of analysis (Figs 3 and 4).

During the experimental phase, visual inspection showed that a pellicle was formed on the acrylic resin, as well as on the alloy surfaces of the specimens immersed in MA and WA.

Discussion

The purpose of this study was to evaluate the effect of denture cleansing agents on the surface roughness and hardness of a microwave-cured acrylic resin and 2 alloys used for RPD frameworks. Specimens were submitted to 3 daily immersions in cleaning agents to simulate the prosthesis-cleaning routine followed by patients.

Acrylic resin hardness is closely related to the amount of plasticizer present in the material. Plasticizers solubilize when in contact with organic solvents or chlorine-containing solutions.[18] In this evaluation, the commercial cleanser resulted in the lowest hardness values in the microwave resin

Table 2. Mean and Standard Deviation (SD) of Knoop Hardness (Kg/mm^2) of the Microwave-Cured Acrylic Resin (n = 8) According to Treatments in Each Period of Time

	Time (Days)			
Treatments	*T0*	*T1*	*T15*	*T30*
WA	14.7 (2.40)[a]	15.5 (2.80)[a]	14.6 (2.37)[a]	16.7 (3.78)[b]
MA	15.3 (1.98)[a]	16.8 (2.93)[a,b]	17.0 (2.24)[b]	17.0 (3.75)[b]
PO	14.0 (2.70)[a]	14.3 (2.78)[b]	13.1 (1.81)[a]	14.1 (1.76)[a]

Note: Mean values followed by superscript letters are statistically different ($p < 0.05$).

Table 3. Mean and Standard Deviation (SD) for the Surface Roughness (μm) of the Microwave-Cured Acrylic Resin (n = 8) According to Treatments in Each Period of Time

	Time (Days)			
Treatments	*T0*	*T1*	*T15*	*T30*
WA	0.147 (0.070)^a	0.309 (0.194)^a	2.404 (0.940)^a	2.343 (1.018)^a
MA	0.146 (0.058)^a	0.245 (0.105)^a	2.064 (1.665)^a	2.037 (0.672)^a
PO	0.146 (0.072)^a	0.191 (0.147)^a	0.144 (0.062)^b	0.209 (0.383)^b

Note: Mean values followed by superscript letters are statistically different ($p < 0.05$).

(Table 2). In contrast, Pavarina et al[19] have investigated the effect of disinfectant solutions on the hardness of acrylic resin denture teeth and found no differences between immersion solutions. This could be explained by the different methods used in the 2 studies, because Pavarina et al. did not use artificial saliva as a storage condition.

The findings of this study may be clarified by chemical interactions among components of the acrylic resin and the cleansers (i.e., chlorine). Besides absorbing water when immersed in the aqueous solutions, the acrylic resin plasticizer may have been solubilized by the chlorine present in the commercial cleanser.[18]

All agents used in this study contain chlorine, a chemical that plays an important role in the cleansing process.[6] Comparing the hardness results of the acrylic resin immersed in the commercial or manipulated cleanser, a hypothesis for the superior hardness of the latter may be due to its greater chlorine content, thereby leading to an intense solubilization of the plasticizer and consequent improvement in hardness. Although no statistical differences were detected between the manipulated cleanser and water, the former showed higher mean values in all experimental periods (Table 2).

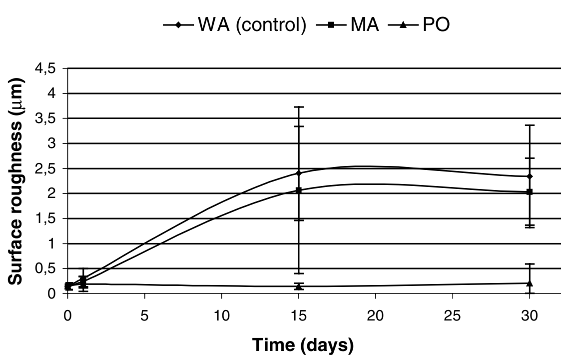

Figure 2. Average surface roughness (μm) of the acrylic resin over the periods of time.

In addition, during the experimental phase, a pellicle formed on both the acrylic and the alloy specimen surfaces treated with the manipulated cleanser and water. The high hardness values detected for these 2 groups may be due to the presence of this pellicle, probably formed by deposition of salivary constituents, such as calcium chloride and sodium phosphate salts,[20] and not removed by either the manipulated cleanser or water.

The tested manipulated cleanser contains sodium perborate, which does not liberate a volume of oxygen sufficient to remove debris deposited on the surface of prosthetic materials.[6] In contrast, specimens treated with the commercial cleanser showed a reduction in hardness values, possibly as a result of the hydrogen peroxide content in the product.[21] When hydrogen peroxide goes into aqueous solutions, oxygen is liberated, cleaning the acrylic surface of debris and stains.[6]

The roughness of the acrylic resin samples immersed in the commercial cleanser was constant and less than that of those treated with the manipulated cleanser and water (Table 3 and Fig 2). The oxygen dissociated from the hydrogen peroxide in the commercial cleanser may have dislodged the pellicle formed on the acrylic surface more effectively, thereby leading to lower surface roughness measurements. In contrast, because the manipulated cleanser and water did not remove this pellicle, those groups showed irregular and higher average roughness values.

Over the period of evaluation, the surface roughness of the Co-Cr alloy differed among the treatments at T1, where the lowest values were detected for the manipulated group. At T15, only minor average roughness was shown by the commercial cleanser. At T30, all groups differed among

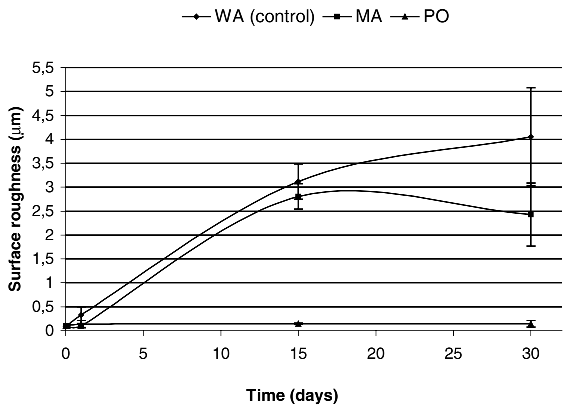

Figure 3. Average surface roughness (μm) of the Co-Cr alloy over the periods of time.

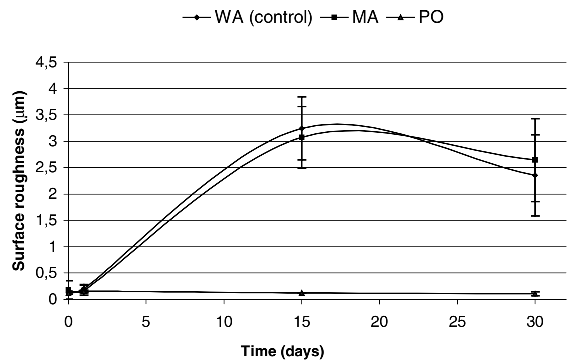

Figure 4. Average surface roughness (μm) of the Ti-6Al-4V alloy over the periods of time.

each other, with the commercial cleanser still showing the lowest roughness values (Table 4 and Fig 3). Similar to the acrylic resins, the Co-Cr alloy surfaces immersed in the commercial cleanser showed a generally lower roughness, probably due to the superior efficacy of this cleanser for removing the pellicle formed on the alloy surface. One could expect corrosion of the Co-Cr alloy as a result of immersion in a peroxide-containing cleanser[22] similar to the commercial one tested in this study; however, the presence of a chromium-oxide layer[8] in this alloy probably prevented further reactions of the underlying metal to the peroxide. The continuous increase in the roughness of the alloy immersed in the manipulated cleanser or water can be explained by the inability of these agents to remove the pellicle that accumulated on the alloy surface.

Similar to the Co-Cr alloy, the Ti-6Al-4V alloy showed lower roughness values at T15 and T30 (Table 4 and Fig 4) when immersed in the commercial cleanser, probably as a result of pellicle removal. Considering this same cleanser, the fact that the roughness of the titanium alloy was maintained and no pellicle was formed on its surface during the experimental phase emphasizes the ability of the alloy to passivate. In fact, more titanium-oxide passivity has been shown when compared to chromiumoxide.[8,10,23]

Comparisons between the Co-Cr and the Ti-6Al-4V alloys showed higher initial roughness values for the latter at T0 (Table 4). However, at T0, little pellicle had formed on the surface of the alloys; hence, the dissimilarity may be the result of the greater hardness and the consequent higher polishability[8] of the Co-Cr alloy. At T1 and T15, the alloys responded similarly to each immersion treatment and did not differ. In contrast, after water immersion at T30, the Ti-6Al-4V alloy was not as rough as the Co-Cr alloy, probably due to the stronger passivity of the former as noted above.[8,10,23]

Table 4. Mean and Standard Deviation (SD) for the Alloys' Surface Roughness (μm) (n = 8)

	Treatments					
	WA		*MA*		*PO*	
Time (Days)	*Co-Cr*	*Ti-6Al-4V*	*Co-Cr*	*Ti-6Al-4V*	*Co-Cr*	*Ti-6Al-4V*
T0	0.1 (0.02)^{a}	0.1 (0.03)^{A,*}	0.1 (0.02)^{a}	0.2 (0.17)^{A}	0.1 (0.05)^{a}	0.1 (0.01)^{A}
T1	0.3 (0.17)^{a}	0.2 (0.08)^{A}	0.1 (0.03)^{b}	0.2 (0.09)^{A}	0.1 (0.08)^{c}	0.1 (0.02)^{A}
T15	3.1 (0.37)^{a}	3.2 (0.60)^{A}	2.8 (0.26)^{a}	3.1 (0.59)^{A}	0.1 (0.02)^{b}	0.1 (0.01)^{B}
T30	4.0 (1.03)^{a}	2.3 (0.77)^{A,*}	2.4 (0.66)^{b}	2.6 (0.78)^{A}	0.1 (0.07)^{c}	0.1 (0.04)^{B}

Note: Means followed by superscript letters are statistically different ($p < 0.05$).
Small letters show differences between treatments for Co-Cr alloy.
Capital letters show differences between treatments for Ti-6Al-4V alloy.
Means followed by an asterisk (*) show differences between alloys in each period of time and treatment.

Therefore, it is important to emphasize that the pellicle formed on the acrylic resin and alloy surfaces has possibly influenced the hardness and roughness measurements obtained in this study. As denture cleansers are commonly used by RPD wearers, additional clinical research is necessary to determine if the pellicle formed during the use of the neutral peroxide material could influence the cleaning performance of this agent.

Conclusions

Within the limitations of this study, it can be concluded that compared to water, the denture cleanser containing sodium perborate was unable to remove the pellicle formed on the acrylic resin and alloys, and this fact could lead to an increased surface hardness and roughness of these materials. In contrast, commercial cleansers containing hydrogen peroxide could remove the pellicle and may be more effective in the cleaning of removable prostheses without affecting surface hardness and roughness of either resin or dental alloys.

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