Oral biofilms are aggregates of multiple microbial species that can adhere to oral tissues and restorative materials.1 Eliminating and preventing biofilm accumulation is imperative in the fight against oral infections2 and in the maintenance and longevity of rehabilitation materials. Therefore, hygiene control is fundamental.3 Mechanical brushing in association with the use of cleansing solutions is the most widespread method due to the simplicity of the technique, greater accessibility, and clinical efficacy.4

The chemical solutions used in the hygiene of overdentures can cause deleterious effects such as color alteration in the acrylic resin, alteration in the soft materials, and corrosion of the metal,5,6 which lead to premature aging and the need for their periodic replacement. The materials currently used in the manufacture of prosthetic components (such as retention capsules for overdentures) are susceptible to the effect of these solutions.6–8 If, on the one hand, studies show consistency regarding the negative effect of sodium hypochlorite (NaOCl) on the retention of attachments,5–10 others7,9 report that the use of Listerine may improve the retention exhibited by some systems. There are therefore no conclusive data.

**Aims:** To evaluate the effects of different cleansing solutions on the physical-mechanical properties (roughness, surface hardness, and fatigue resistance) of three polymeric materials used to manufacture retentive attachments for overdentures. **Materials and Methods:** The roughness and surface hardness analyses each employed 150 specimens measuring Ø 9 mm × 2 mm in thickness (polyacetal, polytetrafluoroethylene [PTFE], and polyethylene terephthalate [PET]; n = 50 each). For fatigue resistance analysis, 180 retentive attachments measuring 4 mm × 3 mm in height (n = 60 each) were used. The properties were evaluated before and after immersion in different cleansing solutions: distilled water, alkaline peroxide, 0.5% sodium hypochlorite (NaOCl), and Listerine. After the data distribution was verified using Shapiro-Wilk test, parametric or nonparametric analysis was applied (α = .05). **Results:** The use of NaOCl caused a significant alteration in the roughness of the materials (P = .011), with a reduction in roughness in polyacetal and an increase in PTFE. The type of solution also influenced the surface hardness (P = .036); with the exception of distilled water, the other solutions promoted increased hardness. During the 24-month period, immersion in water, peroxide, and NaOCl (0.5%) caused increased fatigue resistance (P < .05) of the PET attachments. The immersion protocol resulted in greater fatigue resistance (P < .05) in polyacetal, while PTFE was not affected (P > .05). **Conclusion:** Regarding the physical-mechanical properties evaluated, the polymers PET, polyacetal, and PTFE were susceptible to cleansing solutions. Int J Prosthodont 2020;33:74–80. doi: 10.11607/ijp.6445
Overdentures are submitted to daily insertion/removal cycles at least four times a day. In addition, immersion in chemical cleansing solutions at night also contributes to the wear and corrosive effects of the prosthesis. O-ring attachments offer advantages such as ease of insertion/removal, hygiene, maintenance, low cost, and elimination of the superstructure of the bar. However, they are more susceptible to wear and require periodic replacements due to the gradual loss of retention.\textsuperscript{11–13}

As an alternative to the metal o-ring attachments,\textsuperscript{6,14} nylon components have been used in overdenture support because they are more easily replaced, provide sufficient retention, and protect the ball accessories from wear because the nylon/metal friction generates less wear on the attachment ball (patrice) compared to the wear promoted by the metal-metal friction.\textsuperscript{15,16}

However, these materials are also subject to wear with the use of cleansing solutions.\textsuperscript{6}

The use of alternative biocompatible materials with better mechanical properties and greater clinical longevity has become a requirement in dentistry. However, understanding the interactions among these different materials is necessary to ensure the effectiveness of new proposals. Thus, the objective of this study was to evaluate the physical-mechanical performances of three polymers (polyacetal, polytetrafluoroethylene [PTFE], and polyethylene terephthalate [PET]) through the parameters roughness, surface hardness, and fatigue resistance after immersion in different cleansing solutions to test their viability as alternative materials in the manufacture of attachments for implant-retained overdentures. The null hypothesis tested was that the physical-mechanical properties of the polymers evaluated would not be altered after immersion in the different cleansing solutions.

**MATERIALS AND METHODS**

**Preparation of Specimens**

To perform the roughness and surface hardness analyses, for each test, 150 specimens measuring $\varnothing$ 9 × 2 mm in height were made in polyacetal, PTFE, and PET ($n$ = 50 for each material) (Fig 1a). The roughness was analyzed on one face of the specimen, and the hardness on the opposite face, before and after exposure to the different cleansing solutions.

For the fatigue resistance test, 180 capsules\textsuperscript{17} ($n$ = 60 for each material) measuring $\varnothing$ 4 × 3 mm in height were made (Fig 1b).

**Protocol for Immersion in Cleansing Solutions**

The immersion protocol was used to simulate a 6-month oral hygiene routine (180 days); immersions of 5 minutes were repeated 180 times to simulate 5 minutes of daily immersion for a 180‐day period.\textsuperscript{6,18,19} For the groups submitted to distilled water, 0.5% sodium hypochlorite (NaOCl), and Listerine Cool Mint, the immersions were carried out at room temperature (23°C ± 2°C) in hermetically sealed bottles under protection of light with 50 mL of each solution. For the groups submitted to alkaline peroxide (Corega Tabs), the effervescent cleansers were prepared according to the manufacturer’s directions. Each tablet was dissolved in 200 mL of water at a temperature of 35°C ± 2°C, and the specimens were submitted to an immersion time of 5 minutes. After each immersion, the specimens were removed from the solution, rinsed in running water, and dried. A new solution was prepared, and the procedure was repeated. Immersion procedures were repeated 180 times to simulate 180 days of use. At the end of the immersion period, the specimens were washed in...
The specimens of all the tests (roughness, surface hardness, and fatigue resistance) were subjected to the same immersion protocol. The different groups were as follows: Control 1 = no immersion; Control 2 = distilled water; Experimental 1 = NaOCl; Experimental 2 = alkaline peroxide; Experimental 3 = Listerine Cool Mint. For the roughness and surface hardness tests, 10 test specimens were subjected to each immersion solution, and for the fatigue resistance test, 6 specimens were subjected to each immersion solution (Table 1).

### Surface Roughness Test

To analyze surface roughness, an SJ-201P rugosimeter (Mitutoyo) (NBR ISO 4287: 2002) was used. The equipment operates with a surface analyzer tip in a granite base that has a low potential of expansion, avoiding disbalance. The analyzer tip of the equipment ran a distance of 4 mm in each specimen, directed to the largest diameter. Three measurements were taken on each sample to obtain an average value (µm).

### Surface Hardness Test

Surface hardness analysis was performed using a Shore A durometer (ASTM D2240). To perform the test, the specimens were placed under the vertical stem of the durometer at a distance of approximately 2 mm from the penetration point and subjected to a constant force of 1 kg (ASTM D2240-64) for 5 seconds. Five random and equidistant measurements were performed on each specimen to obtain an average hardness value.

### Fatigue Resistance Test

To simulate implants placed in the mandible, a polyurethane resin matrix (20 × 10 × 30 mm) (F16 polyol, Axson) with two single-body mini-implants of Grade 5 titanium (Ti-6Al-4V) (2.0 × 10.0 mm) (MDL, Intra-Lock International) with a 1.8-mm–diameter ball attachment was used. The implants were 25 mm apart and parallel to each other.

A total of 180 polymeric capsules measuring Ø 4 × 3 mm in height were developed using PTFE (n = 60), polyacetal (n = 60), and PET (n = 60). To capture the capsules following the ideal path of insertion (ideal position), a dental surveyor (B2, Bio-Art Dental Equipment) was used. The polyurethane matrix was positioned in the horizontal surveyor base, and the capsules were adapted to the mini-implants and captured in pairs with acrylic resin (JET, Clásico) using a test device screwed to the dental surveyor rod (Fig 2).

A fatigue resistance testing device was used to simulate the insertion and removal of the overdentures and to assess the retention force (N) of the capsules. To perform the test, the matrix and resin bases were fixed in the device. A total of 2,900 cycles were performed.

---

**Table 1** Immersion Protocols

<table>
<thead>
<tr>
<th>Control 1 (no immersion)</th>
<th>Polyacetal</th>
<th>PTFE</th>
<th>PET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Solution</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control 2</th>
<th>15 h</th>
<th>Distilled water</th>
<th>15 h</th>
<th>Distilled water</th>
<th>15 h</th>
<th>Distilled water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental 1</td>
<td>15 h</td>
<td>Sodium hypochlorite 0.5%</td>
<td>15 h</td>
<td>Sodium hypochlorite 0.5%</td>
<td>15 h</td>
<td>Sodium hypochlorite 0.5%</td>
</tr>
<tr>
<td>Experimental 2</td>
<td>15 h</td>
<td>Alkaline peroxide</td>
<td>15 h</td>
<td>Alkaline peroxide</td>
<td>15 h</td>
<td>Alkaline peroxide</td>
</tr>
<tr>
<td>Experimental 3</td>
<td>15 h</td>
<td>Listerine Cool Mint</td>
<td>15 h</td>
<td>Listerine Cool Mint</td>
<td>15 h</td>
<td>Listerine Cool Mint</td>
</tr>
</tbody>
</table>

---

© 2019 BY QUINTESSENCE PUBLISHING CO, INC. PRINTING OF THIS DOCUMENT IS RESTRICTED TO PERSONAL USE ONLY. NO PART MAY BE REPRODUCED OR TRANSMITTED IN ANY FORM WITHOUT WRITTEN PERMISSION FROM THE PUBLISHER.
Assuming 4 full cycles per day, the test simulated 24 months of overdenture insertion and removal. The test was performed at a rate of 20 cycles per minute and at a constant speed of 35.79 mm/second. The data were analyzed at intervals corresponding to 0, 6, 12, 18, and 24 months of use, and each interval corresponded to the arithmetic mean of 10 consecutive insertion and removal cycles. The force required for each insertion and removal cycle was recorded with the LabVIEW 8.0 software (National Instruments) linked to a load cell in the testing apparatus. The mini-implant and capsule set remained immersed in distilled water at 37°C throughout the test to simulate the temperature conditions found in the oral environment.

**Statistical Analyses**

The data distribution was verified using Shapiro-Wilk test ($\alpha = .05$).

To evaluate the intrinsic differences in the surface roughness of each material, before being submitted to the immersion process (Control 1), a nonparametric analysis was performed using Kruskal-Wallis test followed by Dunn post hoc test. Kruskal-Wallis test followed by stepwise step-down test were used in order to compare the different materials and immersion products.

In order to evaluate the intrinsic differences in the surface hardness of each material, before being submitted to the immersion process, parametric analysis was used with one-way analysis of variance (ANOVA) followed by Tukey post hoc test. A two-way ANOVA followed by Duncan post hoc test was used in order to compare the interaction between the different materials and the immersion products. To evaluate the interactions among the materials, immersion products, and immersion time for fatigue resistance, the data were submitted to three-way ANOVA followed by Bonferroni test.

**RESULTS**

When evaluating the surface roughness of the different materials before the immersion protocol, it was observed that PTFE presented the highest values, being significant compared to all other materials ($P < .001$) (Fig 3).

To evaluate the effect of immersion, the roughness (Ra) values were converted to $\Delta$Ra (final roughness – initial roughness). The type of solution influenced the roughness of polyacetal: NaOCl promoted greater reduction in this property compared to alkaline peroxide ($P = .037$). There was no influence of type of solution on PET ($P = .101$) or PTFE ($P = .568$) roughness.

There was a significant difference in the $\Delta$Ra of the materials when under the effect of NaOCl ($P = .011$), so that for polyacetal, there was a reduction of 0.31 μm, and for PTFE, an increase of 0.12 μm. PTFE was the only material in which the roughness increased regardless of the solution used (Table 2).

The materials differed in surface hardness before the immersion process ($P < .001$). Polyacetal had the highest values and PTFE the lowest (Fig 4).

To evaluate the immersion effect, the hardness (HK) values were converted to $\Delta$HK (final hardness – initial hardness). Table 3 shows that there was no statistically significant difference among the materials ($P = .727$), but there was an influence of type of solution ($P = .036$). The distilled water caused reduction in hardness in all materials.

The material factor influenced the fatigue resistance of the capsules ($P < .001$). TPET presented the highest values, and PTFE the lowest (Fig 5).
For polyacetal, in general and regardless of time, the samples immersed in Listerine and NaOCl presented lower strength in comparison to samples without immersion \( (P < .05) \). The group without immersion increased in strength over time \( (P < .05) \), and this did not occur in the other groups \( (P > .05) \) (Table 5).

For PTFE, there was no influence of time \( (P = 1.000) \) or immersion solution \( (P = 1.000) \) (Table 6).

### DISCUSSION

Prosthetic components made from alternative materials that are more durable and have better properties provide greater longevity to implant treatments. Polymers, synthetic or biodegradable, are an integral part of...
several sectors of the economy, including health. Synthetic biomaterials, for example, have properties such as biocompatibility and mechanical strength that allow for a variety of applications, from the administration of drugs to the manufacture of orthopedic implants.21

The chemical composition and properties of the different materials can directly affect the adhesion of microorganisms and the maturity of oral biofilm.22–25 Therefore, the use of adjuvant antiseptic solutions in the hygiene of prostheses for bacterial control is recommended; thus, evaluating the influence of these solutions is fundamental to ensure greater durability of the components in the long term.

The results support the rejection of the null hypothesis because the physical-mechanical properties of the polymers evaluated were altered after immersion in the cleansing solutions. The immersion of PET in the alkaline peroxide solution increased the fatigue resistance of this material compared to the protocol without immersion, while NaOCl (0.5%) and Listerine reduced this property in the polyacetal. These results are in agreement with another study6 that observed lower retention of o-ring and polymer components after the use of Listerine. In the case of PET, this may be associated with the intrinsic characteristic of some polymers that, when submitted to repetitive efforts, undergo hardening, improving the retention force.26,27

Among the materials, PET and polyacetal presented the best parameters of hardness, surface roughness, and fatigue resistance. During the 24 months of simulation, PET presented a higher retention of 18.99 N and a significant increase in this condition after immersion in alkaline peroxide, distilled water, and sodium hypochlorite. This material has already demonstrated biocompatibility and good long-term results28,29 for use in the medical field, such as for vascular grafts and orthopedic components. Polyacetal showed the second highest retention of 13.16 N. The influence of the solutions was significant only after the first year; thus, more resistant in the protocol with no immersion.

Although PTFE exhibited the lowest mean retention of 4.30 N, it did not change in strength over time due to immersions, a factor associated with its intrinsic characteristic of resisting most chemical attacks.30 However, this material presented the highest initial roughness, 2.42 μm, and, after immersion in NaOCl, there was an increase of 0.12 μm, which may lead to a higher accumulation of microorganisms and peri-implant contamination.

NaOCl appears to cause greater retention loss when compared to other cleansing solutions.7 Clinically, this would mean discomfort for the patient and the need for frequent replacement of the components. In the present study, immersion in NaOCl also promoted reduced fatigue resistance for polyacetal. Thus, its use should be avoided when there are o-ring type attachments6,9,10 and polymer components such as those evaluated.

An extended time of 2 years of prosthetic use was simulated in the present study. Although others5,6 have also evaluated the fatigue resistance of components for

### Table 5  Mean (Standard Deviation) Fatigue Resistance (N) of Polyacetal According to Immersion Solution and Time

<table>
<thead>
<tr>
<th>Solution</th>
<th>Initial</th>
<th>6 mo</th>
<th>12 mo</th>
<th>18 mo</th>
<th>24 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>No immersion</td>
<td>15.34 (1.76)</td>
<td>17.60 (4.74)</td>
<td>21.02 (4.93)</td>
<td>20.89 (6.94)</td>
<td>22.46 (7.24)</td>
</tr>
<tr>
<td>Water</td>
<td>11.22 (1.73)</td>
<td>12.50 (3.95)</td>
<td>12.55 (3.74)</td>
<td>13.02 (4.25)</td>
<td>13.26 (4.48)</td>
</tr>
<tr>
<td>Alkaline peroxide</td>
<td>13.97 (4.54)</td>
<td>16.26 (4.76)</td>
<td>16.89 (4.55)</td>
<td>16.85 (4.69)</td>
<td>17.15 (4.38)</td>
</tr>
<tr>
<td>Sodium hypochlorite</td>
<td>10.72 (2.21)</td>
<td>9.74 (3.11)</td>
<td>9.81 (3.55)</td>
<td>9.89 (3.15)</td>
<td>10.05 (4.15)</td>
</tr>
<tr>
<td>Listerine</td>
<td>7.31 (3.53)</td>
<td>8.01 (4.89)</td>
<td>7.66 (4.37)</td>
<td>7.00 (3.60)</td>
<td>7.80 (4.50)</td>
</tr>
</tbody>
</table>

Among the materials, PET and polyacetal presented the best parameters of hardness, surface roughness, and fatigue resistance. During the 24 months of simulation, PET presented a higher retention of 18.99 N and a significant increase in this condition after immersion in alkaline peroxide, distilled water, and sodium hypochlorite. This material has already demonstrated biocompatibility and good long-term results28,29 for use in the medical field, such as for vascular grafts and orthopedic components. Polyacetal showed the second highest retention of 13.16 N. The influence of the solutions was significant only after the first year; thus, more resistant in the protocol with no immersion.

Although PTFE exhibited the lowest mean retention of 4.30 N, it did not change in strength over time due to immersions, a factor associated with its intrinsic characteristic of resisting most chemical attacks.30 However, this material presented the highest initial roughness, 2.42 μm, and, after immersion in NaOCl, there was an increase of 0.12 μm, which may lead to a higher accumulation of microorganisms and peri-implant contamination.

NaOCl appears to cause greater retention loss when compared to other cleansing solutions.7 Clinically, this would mean discomfort for the patient and the need for frequent replacement of the components. In the present study, immersion in NaOCl also promoted reduced fatigue resistance for polyacetal. Thus, its use should be avoided when there are o-ring type attachments6,9,10 and polymer components such as those evaluated.

An extended time of 2 years of prosthetic use was simulated in the present study. Although others5,6 have also evaluated the fatigue resistance of components for

### Table 6  Mean (Standard Deviation) Fatigue Resistance (N) of PTFE According to Immersion Solution and Time

<table>
<thead>
<tr>
<th>Solution</th>
<th>Initial</th>
<th>6 mo</th>
<th>12 mo</th>
<th>18 mo</th>
<th>24 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>No immersion</td>
<td>5.30 (1.17)</td>
<td>4.35 (0.45)</td>
<td>4.85 (0.22)</td>
<td>4.84 (0.52)</td>
<td>4.71 (0.45)</td>
</tr>
<tr>
<td>Water</td>
<td>3.89 (0.65)</td>
<td>2.96 (0.32)</td>
<td>2.79 (0.15)</td>
<td>2.88 (0.33)</td>
<td>2.86 (0.31)</td>
</tr>
<tr>
<td>Alkaline peroxide</td>
<td>6.20 (1.20)</td>
<td>4.93 (0.62)</td>
<td>4.94 (0.51)</td>
<td>4.96 (0.50)</td>
<td>4.96 (0.57)</td>
</tr>
<tr>
<td>Sodium hypochlorite</td>
<td>5.59 (0.72)</td>
<td>3.97 (0.32)</td>
<td>3.98 (0.33)</td>
<td>3.98 (0.32)</td>
<td>4.10 (0.31)</td>
</tr>
<tr>
<td>Listerine</td>
<td>4.62 (1.43)</td>
<td>4.11 (0.49)</td>
<td>3.93 (0.50)</td>
<td>3.80 (0.69)</td>
<td>3.83 (0.61)</td>
</tr>
</tbody>
</table>
overdentures immersed in chemical cleansing solutions, most of them simulated only 6 months of prosthesis use. The proposal for more effective, simple, and less expensive materials is an excellent strategy to improve the quality of treatments and consequent quality of life of patients and professionals. In the comparison among the materials exposed to the cleansing solutions, given the method used, PET and polyacetal presented desirable characteristics for their use as components of implant-retained overdentures because they presented high mechanical strength and low roughness even when submitted to immersion protocols. PTFE, although known to be inert to microorganisms and contamination in general, did not present interesting physical-mechanical properties for this purpose.

**CONCLUSIONS**

Through the proposed methodology, the evaluated physical-mechanical properties of PET and polyacetal, although satisfactory, were influenced by the cleansing solutions. In the fatigue-resistance analysis, PTFE was not influenced by the solutions, however, its evaluated properties were inferior. Thus, other studies are necessary to confirm the effectiveness of this polymer in the preparation of prosthetic components.

**ACKNOWLEDGMENTS**

The authors thank the Laboratory of Biomechanical Studies in Prostheses and Implants, School of Dentistry Ribeirão Preto, University of São Paulo, for the facilities offered and the Foundation for Research Support of the State of São Paulo (grant number: 2016/23569-7) for the financial support of this work.

**REFERENCES**