Effect of denture cleansers on physical properties of heat-polymerized acrylic resin

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Abstract

Purpose: This study aimed to measure the color change, surface roughness and flexural strength of heat-polymerized acrylic resin after its immersion in denture cleansers, simulating a 180-day use.

Methods: Thirty disk-shaped (15 mm × 4 mm) and 30 rectangular samples (65 mm × 10 mm × 3.3 mm) were prepared from heat-polymerized acrylic resin and immersed in Corega Tabs, Bony Plus, and distilled water. Color measurements (\(\Delta E\)) were determined by a portable colorimeter. A surface analyzer was used to measure the roughness before and after immersion (\(\Delta R_a\)). The flexural strength (S) was measured using a 3-point bending test. The \(\Delta E\) values were submitted to statistical analysis by the Kruskal–Wallis test, followed by Dunn’s Multiple Comparisons test. The \(\Delta R_a\) and S values were submitted to statistical analysis by ANOVA, followed by a Student–Newman–Keuls test (\(p = .05\)).

Results: The color changes were significantly higher for the Corega Tabs than for the control group. The mean \(\Delta E\) values quantified by the National Bureau of Standards (NBS) were classified as Trace (0.0–0.5). The Bony Plus group had significantly higher surface roughness than the other groups. Corega Tabs and Bony Plus groups presented lower flexural strength than the control group.

Conclusions: Although the color changes after the immersion in denture cleansers were clinically insignificant, the Corega Tabs group showed higher color differences. The Bony Plus group showed significantly increased surface roughness. Both effervescent tablets Corega Tabs and Bony Plus significantly diminished the flexural strength of the acrylic resin.

Keywords: Heat-polymerized acrylic resin; Immersion effervescent denture cleanser; Color stability; Surface roughness; Flexural strength

1. Introduction

Home care instructions provided to patients during the denture placement appointment help in the maintenance of a healthy oral mucosa [1–3]. Denture care is indispensable for general health, especially in elderly patients who cannot adequately brush their dentures because of disease, dementia and poor dexterity. Beyond the concern for esthetics, the lack of adequate denture hygiene can cause biofilm accumulation and oral infections such as denture stomatitis [3–5]. It is a common infection characterized by inflammation of oral tissues and colonization of the intaglio surface of prostheses by microorganisms [6].

Mechanical methods are the most common and effective procedures for biofilm removal on prosthesis surfaces. The use of chemical cleansers is usually associated to mechanical methods, and their efficacy in removing stains and reducing biofilm formation on the surface irregularities of dentures have been reported [7,8]. Nevertheless, the factors contributing to the infrequent use of denture cleansers include insufficient information provided to the patient, high cost and restricted market access. The effervescent tablets are classified as chemical soak-type products, and when dissolved in water the sodium perborate readily decomposes to form an alkaline peroxide solution. This peroxide solution subsequently releases oxygen, thereby enabling a mechanical cleaning by the oxygen bubbles in addition to the chemical cleaning [1].
It is of clinical importance to determine whether denture cleansers alter the properties of acrylic resins. Denture base polymers are susceptible to color-shifting [9] if the cleaning solutions are not used correctly. The whitening effect relates to the high temperature of the water used in the solution [10–12].

Irregularities and porosities present on denture surfaces offer a favorable niche to retain stain and microbial plaque [13]. The surface roughness is of particular clinical relevance since it can affect the biofilm formation or make its removal difficult [14,15].

Fracture of an acrylic denture base is a common problem and occurs during masticatory function because of base deformation and consequent resin fatigue [16,17]. Immersion in denture cleansers and disinfecting solutions may decrease the flexural strength of acrylic resins [18–20]. Several studies have shown alterations in flexural strength when using hot water to prepare the cleansing solution [12,21].

Because hygiene procedures have been shown to alter the physical and mechanical properties of acrylic resins, the aim of this study was to measure the color change, surface roughness and flexural strength of heat-polymerized acrylic resin after immersion in denture cleansers, simulating a 180-day use. The hypothesis tested was that immersion in effervescent tablets would influence the color stability, surface roughness and flexural strength of denture bases.

2. Materials and methods

2.1. Specimen fabrication

Disk-shaped wax patterns (Wilson; Polidental Ind Com Ltda, São Paulo, SP, Brazil) 15 mm in diameter and 4 mm thick [22] and a Teflon rectangular matrix (65 mm × 10 mm × 3.3 mm) (ISO/FDSI 1567) [23] were invested with type IV dental stone (Durone; Dentsply Ind Com Ltda., Petrópolis, RJ, Brazil) in metallic flasks (MAC Artigos Odontológicos e Protese Ltda., São Paulo, SP, Brazil). One flask contained 10 disks and 10 rectangular) and immersed in one of the two alkaline peroxide effervescent denture cleansers, or the distilled water:

1- Corega Tabs (Block Drug Company, Inc., USA);
2- Bony Plus (Bonyf ag, Principality of Liechtenstein, Switzerland).
3- Control Group (distilled water).

The 10 specimens of each group were immersed at the same time in the same container, with the surface to be measured facing upward, ensuring that the solution covered all specimens [25]. The effervescent cleansers were prepared according to the manufacturer’s directions, by adding one tablet to 200 mL of warm tap water (40 °C) [26]; the immersion time was 5 min for Corega Tabs and 3 min for Bony Plus. After immersion, the resin specimens were removed from the chemical solutions, thoroughly washed in running water, dried with absorbent paper, and then the procedure of immersion was repeated. Thirty immersions were performed over a period of 6 days simulating 180 days of cleansing by the patient. Between the soaking procedures the specimens were kept in distilled water, at room temperature (23 ± 2 °C), as the control group.

2.3. Color analysis

The color measurements were determined by a portable colorimeter (Color-guide 45/0; BYK-Gardner), on the same side as the identifying codes on each disk-shaped specimen. The colorimeter was calibrated according to the manufacturer’s instructions using the supplied white calibration standard. Color changes (ΔE) were calculated by measuring tristimulus values at several wavelengths in the visual spectrum with the use of CIELab color space. The CIELab is a color system representing three-dimensional color space with components of lightness (L), red-green (a), and yellow-blue (b).

The color differences (ΔE) between the measurements (before and after immersion in cleanser solutions), in terms of L, a, and b, were calculated from the following equation:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

in which ΔL, Δa, and Δb are the differences of L, a, and b values before and after immersion.

To relate the color differences (ΔE) to a clinical environment, the color data were quantified by the National Bureau of
Standards (NBS) units \([27,28]\) through the formula NBS units = \(\Delta E \times 0.92\).

2.4. Surface roughness test

A surface analyzer (Surftest SJ-201P, Mitutoyo Corporation, Japan) was used to measure the surface roughness of each rectangular specimen before (baseline) and after immersion procedures. The stylus moved across the specimen surface and three lines were recorded with a distance of 1 mm between each scanning line. The mean arithmetic roughness (Ra) was calculated from three lines as the mean roughness of the specimen. The tracing length was 2.5 mm and the cut-off value was 0.8 mm, at 0.5 mm/s. The resolution of the record data was 0.01 \(\mu m\). The Ra was used to assess surface changes. The roughness values before immersion were subtracted from the values after immersion to obtain the \(\Delta Ra\) (roughness differences).

2.5. Flexural strength test

The flexural strength was measured using a three-point-bending test in a universal testing machine (Model DL 2000–EMIC, São José dos Pinhais, PR, Brazil) with a 50 kgf (kilogram-force) load cell at a crosshead speed of 1 mm/min. The flexural strength (S) of each rectangular specimen was calculated from the following equation:

\[
S = \frac{3PL}{2bd^2}
\]

in which \(P\) is the maximum load, \(L\) is the distance between the supports (50 mm), \(b\) is the specimen width (10 mm), and \(d\) is the specimen thickness (3.3 mm). Mean flexural strengths were calculated in MPa (megapascals).

2.6. Statistical analysis

The \(\Delta E\) values were submitted to statistical analysis by means of the Kruskal–Wallis test, followed by Dunn’s Multiple Comparisons test. The \(\Delta Ra\) and \(S\) values were submitted to statistical analysis by one-way analysis of variance (ANOVA) followed by the Student–Newman–Keuls test, with the aid of the statistical program SPSS 12.0 (SPSS Inc., Chicago, IL, USA). All tests were performed using a confidence level of 95\% \((\alpha = .05)\).

3. Results

3.1. Color stability

Fig. 1 presents the mean \(\Delta E\) values and standard deviations of each denture cleanser.

The Kruskal–Wallis test showed a statistically significant difference for the treatments \((P = .002)\). Further analysis with the Dunn’s Multiple Comparisons test indicated significantly higher \(\Delta E\) for Corega Tabs, following the 180-day simulation, when compared to the control group (distilled water).

![Fig. 1. Mean \(\Delta E\) and standard deviations for each denture cleanser. Different upper case letters represent significant differences \((\alpha = .05)\).](image)

Table 1
One-way ANOVA for surface roughness.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>(F)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface roughness</td>
<td>0.116</td>
<td>2</td>
<td>0.058</td>
<td>6.277</td>
<td>.006</td>
</tr>
<tr>
<td>Error</td>
<td>0.249</td>
<td>27</td>
<td>0.009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.365</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant difference \((\alpha = .05)\).

The data of Fig. 1 were quantified by the National Bureau of Standards (NBS) units through the formula NBS units = \(\Delta E \times 0.92\). The mean \(\Delta E\) values for the distilled water and the two denture cleansers quantified by NBS were classified as Trace (0.0–0.5).

3.2. Surface roughness

The one-way ANOVA (Table 1) data showed statistically significant differences in surface roughness for the treatments. Further analysis with the Student–Newman–Keuls test indicated significantly higher surface roughness for the Bony Plus group than for the group treated with Corega Tabs and the control group (distilled water).

Fig. 2 presents the mean \(\Delta Ra\) and standard deviations of each denture cleanser.

3.3. Flexural strength

The one-way ANOVA (Table 2) data showed statistically significant differences in flexural strength for the treatments. Further analysis with the Student–Newman–Keuls test indicated significantly higher flexural strength for the control group (distilled water) than for the groups treated with Corega Tabs and Bony Plus.

Fig. 3 presents the mean flexural strength and standard deviations of each denture cleanser.

4. Discussion

Based on the results of this study, the research hypothesis was accepted due to the fact that immersion in effervescent...
tablets influences the color stability, surface roughness and flexural strength of denture bases.

Denture cleaning by immersion in chemical solution should not involve any physical, mechanical or chemical change in the acrylic resin. The decontamination process may result in alterations of the surface morphology and changes in the flexural strength [18]. The effervescent tablets are efficient in removing biofilm and stains [29,30], but the alkaline peroxide solution can alter the resin properties if not correctly used. Several studies have investigated the effects of denture cleansers on physical and mechanical properties of denture resins [9,10,20,21,25,28,31].

The water temperature used to prepare the solutions is a critical factor, resulting in whitening of the acrylic resin when patients use hot water [10–12,21,26]. Devlin and Kaushik (2005) [26] showed water absorption on acrylic surfaces caused by hot alkaline peroxide solution, which resulted in irreversible surface whitening when the specimens were left to dry. In the present study, the solutions of Corega Tabs and Bony Plus were prepared with warm water (40 °C), as recommended by the manufacturer.

In the present study, a portable colorimeter was used to measure the color changes. Instrumental color analysis offers a potential advantage over visual color determination, because instrumental readings are objective, can be quantified, and are more rapidly obtained [32]. Results showed a significant change in color of the acrylic resin tested with Corega Tabs; however, when quantified by the National Bureau of Standards (NBS) units, the classification was Trace, or lower than 0.5. This may be due to the correct use of water temperature, concentration and time of immersion. Lai et al. (2003) [27] reported that ΔE values greater than 2 were considered visually perceptible, whereas an NBS unit of greater than 3 was considered unacceptable.

The results of this study are in accordance with Ünlü, Altay and Sahmali (1996) [31], who also detected a significant whitening effect with Corega Tabs relative to the other tested cleansing agents. It may be related to the deleterious combination of oxidation and strong alkaline solution [31], and also because of different compositions of the cleansers [33]. However, Sato et al. (2005) [20] did not detect color changes in the acrylic resins with the use of chemical agents. The result found in this research may be due to the short simulation period (30 days) and visual comparisons made by photographs.

Bollen et al. (1997) [34] reported a dependence of the surface roughness of acrylic resin on the polishing grit. Verran and Maryan (1997) [15] compared the retention of Candida albicans on smooth and rough acrylic resin, and observed higher numbers of cells on roughened surfaces. To produce a flat and smooth surface on the specimens of the present study, a sequence of sandpapers for finishing and a wet rag wheel with slurry of pumice was used, followed by calcium carbonate for polishing the specimens. Thus, the findings of this study could be related to the alterations caused by the denture cleaners. The surface roughness had increased when the specimens were soaked in Bony Plus solutions. Another study [22] reported lower surface roughness measurements when the acrylic resin samples were immersed in a commercial cleanser. The clinical implications of irregularities and porosities on the acrylic resin is that it can make the biofilm removal difficult [14,15].

Another factor involved in the mechanical properties is the residual methyl methacrylate monomer in the polymerized acrylic resin [35,36], which has a plasticizing effect. The specimens of this study were immersed in distilled water for residual monomer elimination [24].

The water sorption by acrylic resins causes dimensional instability and fatigue, which can lead to crack formation and, subsequently, to fracture of the denture [16]. The flexure of denture bases is an important mechanical property. The longevity of dentures depends in part on the flexural strength of the acrylic resin after immersion in denture cleansers.

The denture cleaners Corega Tabs and Bony Plus decreased the flexural strength of the heat-polymerized acrylic resin in

| Table 2 |
| Source of variance | Sum of squares | df | Mean square | F | Sig. |
| Flexural strength | 1786.721 | 2 | 893.360 | 11.194 | <.001 |
| Error | 2154.706 | 27 | 79.804 | | |
| Total | 3941.427 | 29 | | | |

* Significant difference (α = .05).
comparison with water immersion. Similar findings were reported in previous studies. Neppenelenbroek et al. (2005) [37] demonstrated a significant reduction of the mean hardness values for the denture base resins tested with sodium perborate solution. However, the flexural strength results comply with the minimum value (65 MPa) set forth by the ADA specification no. 12 [24], and it may have no clinical relevance.

These results should be clinically interpreted with caution, because different results may be obtained when fatigue stress during function (in vivo) is combined with the chemical action of denture cleansers. If denture cleansers lead to a reduction in strength, a higher incidence of denture fractures could occur [12].

Considering the methodological limitations of this study, the polished surface of the denture was simulated by polishing the specimens with a wet rag wheel, although this method does not result in a flat surface. A felt wheel pad may be more appropriate for polishing the specimens, although the abrasion was minimal and the results were related to the difference after the immersion procedure for all specimens.

This study analyzed only the action of effervescent denture cleansers on heat-polymerized acrylic resin. Further research with biofilm could influence the hygiene solutions [7,38]. In future in vitro studies, other conditions of the oral environment should be simulated, such as continuous cyclic loading. The testing period should be longer for the simulation of long-term use, and the association with mechanical cleaning methods could show potential interactions, i.e. high roughness changes when brushing is associated with one of the tested cleansers. Also, in vivo studies could determine if daily use of a cleanser may cause mucosal irritation and allergy [30].

5. Conclusions

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

- Although the color changes after the immersion in denture cleansers were clinically insignificant, the Corega Tabs group showed statistically higher color differences.
- The effervescent tablet Bony Plus significantly increased the surface roughness of the heat-polymerized acrylic resin.
- Both effervescent tablets Corega Tabs and Bony Plus significantly diminished the flexural strength of the acrylic resin.

The alkaline peroxide effervescent denture cleansers should be used with caution, once a day after brushing the dentures. The patient must follow the manufacturers instructions, especially the water temperature used. The cleaning method applied should not only remove the biofilm but also not change the properties of the acrylic resin, or produce deleterious effects.

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