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The Effect of Experimental Denture Cleanser Solution *Ricinus communis* on Acrylic Resin Properties

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This study evaluated heat-polymerized (HPR) and microwave-polymerized acrylic resins (MPR), after immersion in water, 1% hypochlorite and *Ricinus communis* solution (RC). Knoop hardness, color alteration, roughness and flexural strength tests were performed after obtaining the specimens and after time intervals of 15 (T^{15}) and 183 (T^{183}) days. Variations in data (Δ) were submitted to ANOVA and Tukey tests (P = 0.05). For ΔT^{15} HPR there was greater variation in hardness when immersed in water (P = 0.00) and for MPR, after immersion in RC (P = 0.00). RC caused the greatest variation in roughness (P = 0.015). Color alteration was not significant (P = 24.46). Hypochlorite caused a decrease in flexural strength (P = 0.37). After ΔT^{183}, hypochlorite and RC caused a decrease in HPR hardness value (P = 0.00). MPR showed the greatest variation in roughness (P = 0.01). HPR presented the most color alteration after immersion in RC (P = 0.214). Hypochlorite and RC caused the lowest flexural strength values for MPR (P = 0.89). RC caused alterations in resin properties, and was not shown to be superior to hypochlorite.

Keywords: *acrylic resin, Ricinus communis, properties*

1. Introduction

Denture care is indispensable for maintaining general health, particularly in elderly patients who cannot brush their dentures adequately because of disease, dementia and poor dexterity. In addition to esthetic concerns, the lack of satisfactory hygiene can cause biofilm accumulation and oral infections such as denture stomatitis[1,2]. Dentures can be cleaned with mechanical and chemical cleansers. An ideal denture cleanser should have bactericidal and fungicidal properties, be simple to use, effectively remove organic and inorganic matter from denture surfaces, and be compatible with all denture materials[3]. However, no currently available product fulfills all these requirements, thus the search for new products is welcome and necessary.

It is of clinical importance to determine whether denture cleansers alter the properties of acrylic resins. Some authors have concluded that the daily use of denture cleanser can affect the properties of denture acrylic resin[4]. Denture base polymers are susceptible of color change[5] if the cleaning solutions are not correctly used. The surface roughness is of great clinical relevance since it can affect biofilm formation and make it difficult to remove[6]. Hardness is another relevant acrylic resin property, since it shows whether a material has softened over time. Acrylic denture base fracture is a common problem and occurs during function because of base deformation and consequent resin fatigue[7]. Immersion in denture cleansers and disinfectant solutions may decrease the flexural strength of acrylic resins[8,9].

With regard to the available denture cleansers, sodium hypochlorite is one of the oldest and most widely used disinfectants[10]. It has both bactericidal and fungicidal properties, because it acts directly on the organic matrix of the plaque. However this solution has several disadvantages, such as bad odor, bad taste and it whitens the denture base[10].

The *Ricinus communis* solution has been used in Endodontics and Periodontology[11,12], due to its biocompatibility, as well as antimicrobial and anti-inflammatory activities[11-13]. This solution has good characteristics for use in denture hygiene, since it has a powerful detergent action, antimicrobial activity because of the capacity to break the sugar molecules from the cell walls of pathogenic yeasts and it does not have an unpleasant color and odor. Therefore, an experimental solution of 2% *Ricinus communis* was prepared as denture cleanser and the purpose of this study was to evaluate the effect of this new solution on hardness, roughness, color alteration and flexural strength of a microwave-polymerized acrylic resin and a conventional heat polymerized acrylic resin after long periods of immersion. The null hypothesis was that the properties of acrylic resin would not change after immersion in *Ricinus communis* solution.

2. Materials and Methods

2.1. Specimen preparation

Two commercially available acrylic resins were used: a heat polymerized acrylic resin (with polymerization in hot water) and a microwave polymerized acrylic resin. Their names and batch numbers are presented in Table 1.

2.2. Specimens for hardness and color alteration evaluations

Thirty specimens of each acrylic resin were prepared by investing disc shaped metal dies (14 × 4 mm) in a denture flask. Dies were invested in hard but flexible silicone rubber (Zetalabor; Zhermack, Rovigo, Italy) to allow the formation of the molds for inserting the materials. After the dies were removed, the acrylic resins were manipulated, packed into the molds, pressed and polymerized following the manufacturer's instructions. After polymerization, the specimens were trimmed, finished and polished using a sequence of

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Table 1. Materials used in the study.

Commercial name	Resin polymerization	Manufacturer	Batch number
Vipi	Hot water polymerization	Dental Vipi Ltda. Ind. Com. Imp. Exp. Of products Odont., Ind. Braz. Pirassununga, SP, Brazil	Powder: 4484 Liquid: 4384
Onda Cryl	Microwave polymerization	Clássico Dentistry Articles Ltda. São Paulo, SP, Brazil	Power: 71505 Liquid: 061005

180, 220, 360 and 400-grit abrasive papers (Norton, Saint-Gobain, Acessórios Ltda., Guarulhos, São Paulo, Brazil). After this the specimens were immersed in distilled water for 24 hours to eliminate residual monomers.

2.3. Specimens for the flexural strength and roughness evaluations

The same procedures described were used to obtain the 60 specimens of microwave-polymerized acrylic resin and 60 specimens of hot water polymerized acrylic resin for flexural strength analysis. According to the International Organization for Standardization (ISO/FDIS 1567) the metal dies for obtaining the acrylic resin specimens measured 65 × 10 × 3.3 mm.

2.4. Groups

The 30 disc-shaped and 30 rectangular specimens of each material were randomly divided into three groups: Control (G1: immersion in distilled water at 37 °C); positive control (G2: immersion in sodium hypochlorite 1%, Asfer Chemistry Ind Ltda, São Paulo, Brazil) and experimental group: (G3: immersion in *Ricinus Communis* solution, Chemistry Institute, São Paulo University, São Carlos, SP, Brazil). The solutions were changed daily.

2.5. Hardness and roughness test

The Knoop hardness of the circular specimens was measured in a Microhardness Tester Shimadzu Model HMV-2 (Shimadzu Corporation, Kyoto, Japan) under a 25 g load for 5 seconds. The final arithmetic mean was calculated as a result of 8 hardness values obtained.

The roughness test was performed using a Surface Roughness Tester SJ-201P (Mitutoyo Corp, Kawasaki, Japan). The mean of 3 measurements was used as the roughness value for each specimen. The hardness and roughness measurements were made before the immersion (baseline values) and after immersion time intervals. The hardness and roughness variations were calculated and used in the statistical analysis.

2.6. Color test

For color measurements of the disc-shaped acrylic resin specimen, a mark was made to position the measuring port of the instrument in the same location on the specimen for repeated measures. The colorimeter (BYK-Gardner GmbH – 07/2002, Geretsried, Germany) was calibrated according the manufacturer's instructions before each measurement period using the white calibration cap supplied by the manufacturer. The color alteration was determined using the Standard Commission Internationale de L'Eclairage (CIE LAB) color system, recommended by the American Dental Association. An important aspect of the CIE-LAB is that the color difference between times can be reached using the parameter, ΔE. The color alteration between each specimen, in terms of L*, a* and b*, was calculated by the Equation 1:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2} \quad (1)$$

2.7. 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 load cell at crosshead speed of 1mm/min. The flexural strength (S) of each rectangular specimen was calculated using the Equation 2:

$$S = \frac{3PL}{2bd^2} \quad (2)$$

where P is the maximum load, L is the distance between the supports, b is the specimen width, and d is the specimen thickness. Mean flexural strengths were calculated in MPa.

2.8. Experimental period

The tests were performed after the finishing procedures and storage periods. Initially the specimens were immersed in each of the three solutions for 15 days (T15) continuously, which simulated three years of use, following the regime of daily immersion for 20 minutes. After this period, new color alteration, hardness, roughness and flexural strength tests were performed. After this, the specimens were immersed continuously for 183 days (T183), which simulated one and a half years of following the regime of daily immersion for 8 hours (overnight). After this period, new tests were performed. The calculation of these immersion periods is presented below:

- Simulation of 3 years with daily immersion for 20 minutes: (Protocol 1)
  1 hour = 3 immersions of 20 minutes
  24 hours = x immersions of 20 minutes
  x = 72 immersions of 20 minutes;
  Therefore,
  24 hours (1 day) = 72 immersions of 20 minutes
  3 years = 1095 days
  If, 1 day = 72 days of immersions of 20 minutes
  y days = 1095 days of immersion of 20 minutes
  y = 15 days
- Simulation of one and a half years with daily immersion for 8 hours (overnight): (Protocol 2)
  24 hours = 3 immersions of 8 hours
  Therefore,
  1 day = 3 days of immersion of 8 hours
  1 and a half year = 547.5 days
  If 1 day = 3 days of immersions of 8 hours
  y days = 547.5 days of immersion of 8 hours
  y = 183 days

2.9. Data analysis

The Statistical analyses of the hardness, roughness and color alterations were performed using Statistical software (SPSS 1.0 Inc., Chicago, USA). The variation in data (before and after the immersion period) was used for analysis. The negative values represented a reduction and the positive an increase in the values of the variables. A two way Anova test was performed using materials and immersion solutions as independent variables. After this the multiple comparisons test (Tukey, $P < 0.05$) was used to compare the mean differences.

3. Results

The results of mean and standard deviation comparison values are presented in tables, in which capital letters indicate comparison between columns and lower case letters indicate comparison between lines. The symbol HPR means hot water polymerized resin; MPR means microwave polymerized resin, and RC means *Ricinus communis* solution.

3.1. Knoop hardness test

Table 2 showed that there was a reduction in the hardness of acrylic resins after immersion in all solutions after T15, except for hot water polymerized acrylic resin after immersion in *Ricinus communis* solution.

The results presented in Table 3 after one and a half years of overnight immersion (T183) showed a decrease in hardness for both resins in all solutions. Immersion in water caused the greatest reduction in hardness in hot water polymerized acrylic resin.

3.2. Roughness test

The data presented in Table 4 showed an increase in roughness for both resins after immersion in all solutions after T15. The *Ricinus communis* solution was the main factor responsible for the increase in roughness.

No difference between resins after T183 was showed (Table 5). An increase in roughness was demonstrated for both resins after immersion in sodium hypochlorite and a decrease in roughness after immersion in water and *Ricinus communis* solution.

Table 2. Mean comparison (SD) of variation in hardness (ΔT^{15}) for the interaction between materials and solutions after simulation of a 3-year period.

	HPR	MPR	Tukey
Water	–6.97 (2.25) ^{Aa}	–0.11 (3.13) ^{Ba}	
Hypochlorite	–0.24 (8.42) ^{Ab}	–1.89 (7.19) ^{Aa}	5.78
RC	+5.64 (5.73) ^{Ac}	–9.71 (3.48) ^{Bb}	

Different superscript uppercase letters indicate statistically different means within each column; Different superscript lowercase letters indicate statistically different means within each row.

Table 3. Mean comparison (SD) of variation in hardness (ΔT^{183}) for the interaction between materials and solutions after simulation of a one-and-a-half-year period.

	HPR	MPR	Tukey
Water	–14.84 (2.12) ^{Aa}	–6.32 (3.22) ^{Ba}	
Hypochlorite	–6.51 (7.88) ^{Ab}	–7.85 (8.97) ^{Aa}	4.18
RC	–3.73 (3.50) ^{Ab}	–9.71 (3.48) ^{Ba}	

Different superscript uppercase letters indicate statistically different means within each column; Different superscript lowercase letters indicate statistically different means within each row.

Table 4. Mean comparison (SD) of variation in roughness (μm) (ΔT^{15}) between solutions after simulation of a 3-year period.

	Means (SD)	Tukey
Water	+ 0.06 (0.04) ^{a}	
Hypochlorite	+ 0.05 (0.045) ^{a}	0.03
RC	+ 0.11 (0.04) ^{b}	

Different superscript uppercase letters indicate statistically different means within each column; Different superscript lowercase letters indicate statistically different means within each row.

3.3. Color alteration test

The statistical analysis after 3 years (T15) showed no statistically significant differences between materials and solutions and no interactions.

However after T183, the greatest color alteration occurred for hot water polymerized acrylic resin after immersion in water and *Ricinus communis* solution. For microwave polymerized acrylic resin, the greatest color alteration was shown after immersion in sodium hypochlorite (Table 6).

3.4. Flexural strength test

After T15, there were no differences between the resins. The biggest value of flexural strength was found after immersion in *Ricinus communis* solution. And the smallest value of flexural strength was found after immersion in sodium hypochlorite (Table 7).

After T183, with regard to acrylic resins, there were differences between HPR and MPR only after immersion in hypochlorite, which caused the lowest flexural strength value for MPR. With regard to the solution, there were differences between water and the other solutions for MPR, and the sodium hypochlorite and *Ricinus communis* solutions caused the lowest flexural strength values (Table 8).

Table 5. Mean comparison (SD) of variation in roughness (μm) (ΔT^{183}) between solutions after simulation of a one-and-a-half-year period.

	Means (SD)	Tukey
Water	–0.025 (0.05) ^{a}	
Hypochlorite	+0.015 (0.04) ^{b}	0.035
RC	–0.017 (0.045) ^{ab}	

Different superscript uppercase letters indicate statistically different means within each column; Different superscript lowercase letters indicate statistically different means within each row.

Table 6. Mean comparison and standard deviation (SD) of color alteration (ΔT^{183}) after simulation of a one-and-a-half-year period.

Solution	HPR	MPR	Tukey
Water	2.00 (0.85) ^{Aab}	0.70 (0.39) ^{Ba}	
Hypochlorite	1.23 (0.47) ^{Ab}	1.32 (0.52) ^{Aa}	0.81
RC	2.06 (0.54) ^{Aa}	1.02 (0.77) ^{Ba}	

Different superscript uppercase letters indicate statistically different means within each column; Different superscript lowercase letters indicate statistically different means within each row.

Table 7. Mean comparison (SD) of flexural strength (MPa) between solutions after simulation of a 3-year period.

Solution	Means (SD)	Tukey
RC	106.27 (21.0) ^{a}	
Water	99.86 (21.09) ^{ab}	13.01
Hypochlorite	87.4 (13.63) ^{b}	

Different superscript uppercase letters indicate statistically different means within each column; Different superscript lowercase letters indicate statistically different means within each row.

Table 8. Mean comparison (SD) of flexural strength (ΔT^{183}) for the interaction between materials and solutions after simulation of a one-and-a-half-year period.

Solution	HPR	MPR	Tukey
Water	83.15 ^{Aa}	85.38 ^{Aa}	
Hypochlorite	86.56 ^{Aa}	67.55 ^{Bb}	16.63
RC	71.30 ^{Aa}	64.00 ^{Ab}	

Different superscript uppercase letters indicate statistically different means within each column; Different superscript lowercase letters indicate statistically different means within each row.

4. Discussion

The effect of denture cleansers on acrylic resin properties after long periods of immersion has not been widely studied. However, the hygiene procedures are used for a long time because, according to Zarb, Bolender and Carlsson, 2000[1] the durability of a denture is about 5 to 7 years.

The denture hygiene regime used was immersion for 20 minutes daily and 8 hours daily. According to Furukawa (1998)[15] these periods can lead to penetration of the cleanser into the acrylic resin pores, which is responsible for microorganism destruction.

After simulation of a three-year period (T15), all solutions caused a decrease in hardness values, except the *Ricinus communis* solution, which caused an increase in this property of conventional heat-polymerized acrylic resin. This increase in hardness could be explained by the presence of residual monomer that could be released after immersion[16]. The formation of a *Ricinus communis* pellicle on the specimen surface due to its low superficial tension was noted, which could lead to deposition of some components from this solution, responsible for the increase in hardness. The results of this study are in agreement with those of Neppelenbroek et al. (2005)[17] who found a decrease in the hardness of two acrylic resins after immersion in disinfectant solutions (1% sodium hypochlorite, 4% chlorhexidine gluconate and 3.78% sodium perborate) after 120 days of 10-minute daily immersions.

After one and a half year (T183), all solutions caused a decrease in hardness for both resins. Acrylic resin is hydrophilic and is subject to water sorption[18,19], which acts as a plasticizer, responsible for the decrease in hardness due to the formation of cracking zones resulting from the absorption and adsorption cycles, in addition to the hydrolytic degradation and gradual deterioration of its infrastructure over time[20].

As regards roughness, many studies have evaluated the specimen surface by SEM, which was not done in this study, and may be considered a limitation. However, the values of roughness found in this study are below those recommended in the literature. Thus, the SEM analysis would complement the roughness values, but those obtained in this study itself indicate that a roughness based on the literature would not promote the adhesion of microorganisms[21].

After three years of immersion (T15), all solutions tested caused an increase in roughness, and the *Ricinus communis* solution was responsible for the highest increase. A thick and sticky pellicle was observed on the specimen surface after immersion in *Ricinus communis* solution, which may have caused the increase in roughness values. Moreover, the *Ricinus communis* solution shows the ability to increase the permeability of dental structures[12], a fact which, when applied to the acrylic resin, could explain the increase in roughness. Microscopy tests are needed to confirm this effect.

After the simulation of one and a half year (T183), water and *Ricinus communis* solution caused a decrease in roughness, whereas sodium hypochlorite caused an increase. After immersion in sodium hypochlorite the specimens lost their polishing shine, so that this solution may have interfered with the acrylic resin superficial coat and diffused into its internal mass, exposing irregularities. In spite of the change in roughness after immersion, the values found in this study are close to those recommended in the literature[21].

The color stability is a relevant physical property of dental materials[22], as it can indicate the age and conditions of these materials[23,24].

After the simulation of three years of immersion (T15) there were no statistical differences in color alteration between resins, or between solutions. After one and a half year simulation (T183), the hot water polymerized acrylic resin presented the highest color alteration when immersed in *Ricinus communis* solution. This acrylic resin may have less cross linked agents, which could be responsible for the color alteration, since these agents are resistant and immune to a large number of solvents. Hot water polymerization can lead to acrylic resin absorption, giving rise to a differential expansion of the acrylic surface. Water absorption and thermal effects may combine to cause the acrylic to form zones with different optical properties, producing color alteration[25,26].

Acrylic resin must be correctly polymerized, because the erroneous use of low temperature or time can result in high levels of residual monomer[27,28]. However, Arab, Newton and Lloyd (1989)[29] concluded that the residual monomer is not the main cause of acrylic resin bleaching.

The color alteration may occur due to the inclusion of oils or moisture, possibly from the operator's hands when manipulating the dough. This may cause local deterioration within the resin mass. The high water temperature used by patients in cleaning procedures is a critical factor in acrylic resin bleaching[27,29].

Denture cleansers must be used at the temperature and concentration in accordance with the manufacturer's instructions, in order to avoid color alteration[27].

It has been shown that immersion in denture cleanser solutions can affect the flexural strength and structure of acrylic resins[29]. If this actually occurs, there is an increase in the incidence of fractures both inside and outside of the mouth. Flexural strength is dependent on factors such as the molecular weight of the polymer, presence of residual monomers and plasticizers, temperature, load and water content[8].

After simulation of a three-year period of immersion (T15), there was no statistical difference in flexural strength between the acrylic resins. This result is in agreement with the studies of Levin, Sanders and Reitz (1989)[30], Alkihatib, Goodacre and Swartz (1990)[31] and Reitz, Sanders and Levin (1985)[32] who found no differences in the flexural strength of conventional hot water polymerized acrylic resin and microwave-polymerized acrylic resin. Sodium hypochlorite solution caused the lowest flexural strength. This solution may have altered the polymer resin chain, reducing its strength. The absorption of liquids that act as plasticizers may cause a weakening of intermolecular linkages contributing to a reduction in flexural strength[28].

After one and a half year (T183), the microwave-polymerized acrylic resin presented the lowest flexural strength values, both after immersion in hypochlorite and in *Ricinus communis* solution. According to Smith, Powers and Ladd (1992)[33], the microwave-polymerized acrylic resin absorbs less microwave energy before fracturing, because it has a lower molecular weight than the conventional resin, due to rapid polymerization. This feature is responsible for its low flexural strength values. These results are in disagreement with the results of Barbosa et al. (2007)[34] who found higher flexural strength values for the microwave-polymerized acrylic resin when compared with conventional hot water polymerized acrylic resins.

According to De Clerck (1987)[35] polymerization by means of microwave energy caused greater absorption of energy at the beginning of the reaction and then a rapid increase in resin temperature, which could lead to the formation of porosity and decrease the flexural strength values.

In this study, the denture cleansers had an influence on the flexural strength of microwave-polymerized acrylic resin, but the values are still consistent with the one acceptable by ISO 1567[36], which is 64 MPa.

Future researches concerning *Ricinus communis* solution have to be conducted and clinical and microbiological trials have to be developed.

5. Conclusion

With regard to the effect of the solutions on the acrylic resin properties, both the sodium hypochlorite and the *Ricinus communis* solutions caused alterations in the analyzed properties. In general, sodium hypochlorite showed best results when compared with *Ricinus communis* solution.

When considering the different immersion periods, both caused alterations in the analyzed properties.

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