Color stability and surface roughness of artificial teeth brushed with an experimental *Ricinus communis* toothpaste

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Abstract

**Aim:** To evaluate, in vitro, the effect of brushing with a *Ricinus communis*-based experimental toothpaste on color stability and surface roughness of artificial teeth. **Methods:** Ninety artificial teeth (maxillary central incisors) in different shades, light and dark (NatusDent Triple Pressing, Dentbras) were used. Initial color (Spectrophotometer Easyshade, VITA) and surface roughness (Rugosimeter Surfocorder SE 1700, Kosakalab) readouts were performed. After baseline measurements, samples were assigned to 10 groups (n=9) according to the artificial tooth shade and type of toothpaste used during the mechanical brushing test (Pepsodent, MAVTEC): Sorriso Dentes Brancos – SDB, Colgate Luminous White - CLW (Colgate-Palmolive), Close up White Now - CWN (Unilever), Trihydral - THL (Perlrand Pharmacos) and *Ricinus communis* - RCE (Experimental). After 29,200 cycles of brushing, corresponding to 2 years of brushing by a healthy individual, new color and roughness readouts of the specimens were performed. Data (before and after the tests) were statistically analyzed (2-way repeated measures ANOVA, Tukey, p<0.05). **Results:** RCE toothpaste produced the greatest color stability for dark tooth shade and the second best color stability for light tooth shade. For surface roughness alteration, there was no difference (p>0.05) for any tested toothpaste regardless of tooth shade. **Conclusions:** The experimental *Ricinus communis* toothpaste did not cause color and surface roughness alteration in the artificial teeth, and it may be considered a suitable option for denture cleaning.

Keywords: oral hygiene; toothpastes; castor oil; color.

Introduction

With the increasing life expectancy and consequent ageing of the worldwide population, wear and stain of artificial teeth have become more and more common, jeopardizing the aesthetic appearance of removable prosthesis, since artificial teeth are a significant factor for the aesthetic outcome. One of the most important cautions that the edentulous patients must have is the maintenance of adequate complete denture hygiene¹, which is important to increase denture longevity².

Methacrylate-based resins (acrylic resin) are the most commonly used material for artificial denture teeth in prosthetic dentistry, due to many advantages, such as the chemical bond to denture base, lower susceptibility to fracture, easy handling and limited biofilm accumulation³⁴. However, one disadvantage is the increased wear and discoloration after certain time of use¹. To overcome this shortcoming, highly resistant resin teeth with an interpenetrating polymer network was developed.
increasing the amount of cross-linked agents or blending special polymers and co-polymers. Improved mechanical and physical properties have been achieved\textsuperscript{16-18}, but susceptibility to staining and wear\textsuperscript{19} still remains.

Different from patients with remaining natural teeth, edentulous patients have no periodontal ligament receptors that regulate occlusal forces\textsuperscript{18}. This is an aggravating factor for artificial teeth wear, because despite the reduced maximum occlusal force when compared with natural teeth, edentulous patients have a higher masticatory frequency\textsuperscript{19}.

Cleaning methods for dentures include daily brushing and immersion in denture cleaners\textsuperscript{10}. There is a large number of chemical dental cleansers for immersion, containing substances like alkaline peroxides, alkaline hypochlorites, acids, enzymes and disinfectants, which are widely used for denture cleaning due to their bactericidal and fungicidal properties\textsuperscript{11}. However, some of these solutions may cause alterations in the physical and mechanical properties of denture base resin\textsuperscript{12} and artificial teeth\textsuperscript{13} due to the penetration of these agents into the material.

Brushing is the most commonly used method for denture hygiene, since it is a simple, inexpensive and effective hygiene method\textsuperscript{14}. Furthermore, brushing has the same efficiency as a chemical method for biofilm removal\textsuperscript{12}. The brushing method is combined with the use of toothpastes, which have a complex composition including water, detergents, flavoring, abrasive and therapeutic agents.

Due to its characteristics, many studies have shown that brushing is the cleaning method of choice for complete denture wearers\textsuperscript{15}. However, if improperly used, the acrylic resin may become rough\textsuperscript{16}, leading to microorganism and organic matter retention\textsuperscript{17}, reducing cleaning and increasing stain.

The addition of antimicrobial agents facilitates the cleaning and sanitizing procedures for denture users\textsuperscript{16}. Many plants are known to possess antimicrobial properties, and several innovative attempts have been made to incorporate them into daily oral hygiene products. \textit{Ricinus communis}, also known as castor plant, is found in tropical climates, as in Brazil\textsuperscript{19}. Its oil has been used to produce detergent agents and could be an alternative for denture cleaning due to their bactericidal and fungicidal properties\textsuperscript{11}. However, some of these solutions may cause alterations in the physical and mechanical properties of denture base resin\textsuperscript{12} and artificial teeth\textsuperscript{13} due to the penetration of these agents into the material.

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Due to the constant pursuit of aesthetics, and the importance of durability, staining resistance and color-stability of denture teeth\textsuperscript{12}, the objective of this study was to evaluate in vitro the effect of brushing with an experimental \textit{Ricinus communis}-based toothpaste on color stability and surface roughness of artificial teeth. The tested null hypothesis was that the experimental dentifrice will not produce color change and surface roughness in the artificial teeth.

**Material and methods**

The present study used 90 artificial teeth (maxillary central incisors) in different shades, light (60) and dark (69) (NatusDent Tripla Prensagem - Dentbras Ind, Pirassununga, SP, Brazil). Teeth were embedded in PVC cylinders (1 cm high x 2 cm diameter) with self-cured acrylic resin (VipiFlash, Ltda. Pirassununga, SP, Brazil) using a parallellometer to stabilize their buccal surface facing upwards.

Initial color (Spectrophotometer Easyshade, VITA Zahnfabrik, BadSäckingen, Germany) and surface roughness (Rugosimeter Surfcoreder SE 1700, Kosakalab, Tokyo, Japan) readouts of the specimens were taken. For color readouts, the observation pattern followed the CIE L*a*b* system (Comission Internationale de l’E’ clairage) which simulates a measurement of 45°/0 geometry, D65 standard illuminant, and observer pattern of 2°. The specular component was excluded in order to prevent interference by surface brightness. The L*a*b* system consists of two axes, a* and b*, at right angle and represent the dimension of tonality or color. The third axis is luminosity L*, perpendicular to the a* b* plane.

For color readings, the digital tip of the device (6 mm diameter) was positioned perpendicular to the buccal surface of artificial teeth and three measurements were taken; the mean of them was considered the baseline color value.

For surface roughness measurements, a needle with a very fine diamond at its tip was driven at constant speed over a distance of 4.8 mm with a 0.8 mm cut-off and a 0.25 mm/s speed. Three readouts were taken at different sites on the sample surface to obtain the mean roughness (Rₐ).

After color and roughness baseline readings, samples were assigned to 10 groups (n=9) according to the shade of the artificial tooth and type of toothpaste used during the mechanical brushing test (Table 1).

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Mechanical brushing (Pepsodent, MAVTEC – Com Parts, Acc., and Serv. Ltda. ME, Ribeirão Preto, SP, Brazil) was performed with soft toothbrushes (Tek, Johnson & Johnson Ind. Com Ltda., São José dos Campos, SP, Brazil) – one per specimen. The toothbrush heads were separated from stem and then fitted into the clamp of the equipment. Each brush/ clamp set resulted in a final weight of 200 g.

Each specimen was fitted into a central circular hole (of equal dimensions) of a plexiglass slide (Acrilpress Artefacts Ltda., Pirassununga, SP, Brazil) using a parallelometer to stabilize their buccal surface facing upwards.

Specimens were subjected to 29,200 cycles of mechanical brushing, corresponding to 2 years of exposure to brushing by a healthy individual\textsuperscript{22}. After brushing, new color and roughness readouts were performed. Color alteration (ΔE) was calculated according to the formula:

\[ ΔE = \sqrt{(ΔL^*)^2 + (Δa^*)^2 + (Δb^*)^2} \]

where ΔE=color alteration;  
ΔL=lightness difference (L*), so that the greater L* values, the higher the brightness of the sample;  
Δa=axis a* difference; so that positive values for Δa means redder samples and negative values, greener;  
Δb=axis b* difference; so that positive values for Δb mean yellower samples and negative values bluer, being:
Table 1. Groups formed according to tooth shade and dentifrice used in the study.

<table>
<thead>
<tr>
<th>GROUPS</th>
<th>SHADES</th>
<th>TOOTHPASTE</th>
<th>COMPOSITION</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Light</td>
<td>Sorriso Dentes Brancos (Palmolive Ltda, São Bernardo do Campo, SP, Brazil)</td>
<td>Calcium carbonate, Water, Glycerin, Sodium lauryl sulfate, sodium monofluorophosphate (1450 ppm fluoride), cellulose gum, tetrasodium pyrophosphate, sodium bicarbonate, benzyl alcohol, sodium saccharin, sodium hydroxide and limonene.</td>
</tr>
<tr>
<td>2</td>
<td>Dark</td>
<td>Bernardo do Campo, SP, Brazil</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Light</td>
<td>Colgate Luminous White (Palmolive Ltda, São Bernardo do Campo, SP, Brazil)</td>
<td>Water, hydrated silica, glycerin, pentasodium tripolyphosphate, PEG-12, Tetrapotassium Pyrophosphate, sodium lauryl sulfate, cellulose gum, polyethylene, cocamidopropyl betaine, xanthan gum, sodium saccharin, sodium hydroxide, titanium dioxide, D &amp; C blue 1 aluminum lake (CI 42090) and sodium fluoride (1100 ppm fluoride).</td>
</tr>
<tr>
<td>4</td>
<td>Dark</td>
<td>Bernardo do Campo, SP, Brazil</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Light</td>
<td>Close up White Now (Unilever Ltda, Ipojuca, PE, Brazil)</td>
<td>Sorbitol, water, silica, PEG-32, sodium lauryl sulfate, cellulose gum, sodium fluoride (1450 ppm), Saccharin sodium, PVM / MA copolymer, trisodium phosphate, Mica, CI 74160 and limonene.</td>
</tr>
<tr>
<td>6</td>
<td>Dark</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Light</td>
<td>Trihydral (Perland Pharmacos Ltda, Cornélio Procopio, PR, Brazil)</td>
<td>Sodium fluoride (1500 ppm), sodium monofluorophosphate, 0.2% Chloramine-T, calcium carbonate, propylene glycol, sorbitol, hydroxyethylcellulose, tetrasodium pyrophosphate, sodium laurylsulfate, Decyl polyglucose, Metilpabenzeno and Water.</td>
</tr>
<tr>
<td>8</td>
<td>Dark</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Light</td>
<td>Ricinus communis (Experimental)</td>
<td>Hydroxyethylcellulose, glycerine, EDTA, sodium saccharin, ricinoleic acid ester, Silica (sident 9) Silica (sident 22S), titanium dioxide, methylparaben, sodium lauryl sulfate and water.</td>
</tr>
<tr>
<td>10</td>
<td>Dark</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \Delta L = L_f - L_i \]
\[ \Delta a = a_f - a_i \]
\[ \Delta b = b_f - b_i \]

where \( L_i, a_i \) \( b_i \), are referred to as the initial color measurement and \( L_f, a_f \) \( b_f \) as the final color measurement. Color alteration values greater than 3.3 were considered clinically unacceptable.

Surface roughness alteration (\( \Delta R_a \)) was calculated according to the formula:

\[ \Delta R_a = R_{af} - R_{ai} \]

Where \( R_{ai} \) is the initial roughness measurement and \( R_{af} \) the final roughness measurement.

After verifying the normality of the results, the values were analyzed by 2-way repeated measures ANOVA and by the multiple-comparisons Bonferroni test with 95% significance level.

Results

The means of color alteration (\( \Delta E \)) and surface roughness (\( \Delta R_a \)) were compared (2-way repeated measures ANOVA, Bonferroni test, \( p<0.05 \)), considering Treatments and Tooth shade as variation factors. (Table 2 and 3 respectively).

For light teeth shade, SDB and CLW toothpastes presented greater (\( p<0.05 \)) color change compared with the other toothpastes, which showed no difference (\( p>0.05 \)) between them. Regarding dark teeth shade, the greatest color change (\( p<0.05 \)) occurred after brushing with CLW, a result similar (\( p>0.05 \)) to SDB, which showed no difference (\( p>0.05 \)) compared with other toothpastes. RCE toothpaste produced the greatest color stability for dark teeth shade and the second best color stability for light teeth shade.

When the effect of toothpastes was compared for light and dark teeth shade, only SDB produced significant color change (\( p<0.05 \)), greater for light teeth shade. There was no statistical significance (\( p>0.05 \)) for the other comparisons.

The comparison of surface roughness alterations showed...
no significant difference (p>0.05) for any tested toothpaste regardless of tooth shade.

Discussion

This study evaluated the effect of mechanical brushing (29,200 cycles = 2 years) on the color stability (ΔE) and surface roughness (Δ AR) of two shades (60 and 69) of artificial teeth brushed with different toothpastes. The null hypothesis stated that there would be no difference in the studied properties regardless the tested toothpastes. Considering the results, it was possible to accept partially the tested hypothesis, since there was a greater color alteration for teeth brushed with two types of toothpaste (SDB and CLW), this alteration was greater when SDB was used on light tooth shade. However, there was no surface roughness alteration regardless of the tested toothpaste or tooth shades.

When ΔE was analyzed, light shade samples brushed with RCE (Experimental), CWN and THL toothpastes, showed less color alteration than those brushed with SDB and CLW. The same occurred for dark shade samples, except for those brushed with SDB, which showed a ΔE similar to the samples brushed with the other toothpastes used in the study.

The color alteration of a material is expressed in units of ΔE, which represent the color change after different treatments. In dental literature, several authors23 have used ΔE values to evaluate the “perceptibility” of color differences. Color difference thresholds constitute the lowest perceptual limit to estimate the maximum number of discernible colors by the human visual system. There are two major thresholds for assessing color differences: perceptible and acceptable24, passing from “just noticeable differences” to “color tolerances”25. However, it is noteworthy to underline that the criteria of perceptibility adopted by each author are different.

In this study, the threshold used as perceptible was ΔE = 2.723, above this value, color changes would be considered aesthetically unacceptable. Thus, analyzing the results, it was found that all samples showed acceptable levels of color change, regardless the used type of dentifrice.

The denture teeth used in this study are composed by triple-pressed acrylic layers of PMMA (polymethyl metacrylate) and EDM (dimethacrylate of polymerized ethylene glycol), which is a cross-linking agent. However, even the more resistant teeth are subject to water sorption, demonstrated by microhardness decrease26. The water or aqueous cleansers can act as resin plasticizers, since the small molecules of water diffuse into the polymer mass, causing the relaxation of polymer chains27. Thus, when penetrating the artificial tooth, solvents may also be responsible for the color change of teeth. Furthermore, artificial teeth have small amounts of dibenzoyl peroxide, a heat-sensitive initiator added to the polymer, which remains after polymerization and may also alter the material’s optical properties28.

Even though the color stability may have been compromised by the above-mentioned factors, in this study the teeth showed color changes within the acceptable limits and the experimental Ricinus communis-based dentifrice showed the smallest color change values. This may be justified by the effect of polishing and wear produced by the dentifrice abrasiveness, as evidenced by the negative values found for roughness changes.

Increased values of surface roughness caused by the formation of a Ricinus communis pellicle on the specimen surface have been reported in a previous study12 that used Ricinus communis in an experimental immersion cleaning solution. This pellicle was not observed in the present study, since brushing and subsequent polishing of the tooth surface kept teeth free of this pellicle, with non-significant surface roughness alteration, maintaining the color stability.

Besides the polishing effect, the composition of toothpastes may have also contributed to these findings. SDB has calcium carbonate in its composition, unlike the other tested dentifrices, which have silica as abrasive agent. Calcium carbonate has a lower abrasive potential than silica, but this component is not the sole responsible for dentifrice abrasiveness. CLW is more abrasive than SDB as it presents highly abrasive components in its composition, such as tetra potassium pyrophosphate. One could expect higher levels of color alteration because of the dentifrice abrasiveness; however, color changes occurred within the acceptable limits, which might be justified by the presence of a bleaching agent, sodium hydroxide, in the dentifrice composition.

It is important to highlight the research and efforts undertaken worldwide to develop new plant-derived materials. The experimental Resinus communis-based dentifrice produced similar color alteration when compared with most commercial toothpastes, including the specific dentifrice for denture cleaning (Trihydral), and did not increase the surface roughness of teeth. These are important findings for the validation of the new experimental material.

It may be concluded that artificial acrylic resin teeth brushed with the experimental Ricinus communis-based dentifrice did not undergo color or surface roughness alteration, thus the experimental dentifrice may be considered a suitable option for denture cleaning.

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References


