ORIGINAL ARTICLE

Physical properties of acrylic resin teeth submitted to toothbrushing and immersion in beverages

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ABSTRACT

Background: Brushing and consumption of dye beverages may alter the physical properties of artificial teeth. **Objective:** The objective of this study was to evaluate the effect of toothbrushing and immersion in beverages in roughness and color of two types of artificial teeth: Biotone (B) and Biotone interpenetrating polymer network (IPN). **Materials and Methods:** For each tooth, seven groups were formed (n = 10): Toothbrushing (T), toothbrushing + water (TW), toothbrushing + coke (TCk), toothbrushing + coffee (TCf), immersion in water (W), coke (Ck), coffee (Cf). Roughness and color stability evaluations were performed before treatment and after treatment. According to the group, 11,000 brushing cycles were performed and specimens were immersed in beverages for 12 days, both simulating a period of 1 year. Color variations were captured by a spectrophotometer and roughness was analyzed by a profilometer. Color data were analyzed using analysis of variance (ANOVA) and Least significant difference test whereas roughness data were analyzed using ANOVA and Bonferroni test, both with α =0.05. **Results:** For Biotone, clinical significant color changes according to National Bureau of Standards (NBS) units were observed for the Groups T, TW, W, and Ck, and the results of ΔE were statistically similar among them ($P > 0.05$). For Biotone IPN, clinical significant color changes were found for TCf (4.86 NBS units) and Cf (4.82), and the results of ΔE were also similar among them. Surface roughness Ra (μm), regardless of the teeth, was reduced for the groups submitted to toothbrushing whereas no significant differences were found among the Groups W, Ck, and Cf. **Conclusions:** Toothbrushing had no influence on the color stability but significantly reduced the roughness, irrespective of the type of tooth.

Key words
Artificial tooth, color, complete denture, roughness, toothbrushing

INTRODUCTION

Artificial acrylic resin teeth are commonly used in the partial and complete dentures fabrication, with advantages such as ease of occlusal adjustment, excellent shock absorption, and chemical bond with the denture base.[1] However, they fall short with regard to the maintenance of a proper esthetic appearance due to low wear resistance[2] and low color stability.[3] Thus, to improve some of its properties, the acrylic resin teeth were upgraded over the past years. Acrylic resin teeth interpenetrating polymer network type (IPN), artificial teeth with double cross-linked polymers, and conventional acrylic resin teeth with the addition of inorganic agents were introduced in the dental market with this purpose.[4]

Ideally, the color and the surface of the artificial teeth should remain unchanged over time. However, due to its

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adverse properties, these teeth may have these altered characteristics mainly for carrying out some routine procedures among denture wearers, such as hygiene by brushing and consumption of dye beverages. Considering that toothbrushing is the most used method for denture cleaning,[5] this technique can promote superficial abrasion of the denture base resin and artificial teeth.[6] Abrasion caused by toothbrushing can result in increased surface roughness, which facilitates the accumulation of biofilm, and may still be associated with increased deposition of dyes derivatives of beverages, resulting in staining of teeth and esthetic damage.

Therefore, the aim of this study was to evaluate the effect of toothbrushing and immersion in beverages in surface roughness and color stability of two types of acrylic resin teeth. The null hypothesis tested was that, for each type of tooth, the treatments do not influence on these physical properties.

MATERIALS AND METHODS

The specimens corresponded to maxillary right central incisors (shade A2), two types of artificial acrylic resin teeth (Biotone, B, a conventional acrylic resin denture tooth, and Biotone IPN, I, a cross-linked resin denture tooth-IPN, Dentsply Ind. e Com, Rio de Janeiro, RJ, Brazil). The palatal face of all artificial teeth was flattened using 180-, 220-, 360-, and 400-grit silicon carbide paper (Norton, Saint-Gobain Abrasivos Ltd., Vinhedo, SP, Brazil) in a polishing machine (Aropol 2V, Arotec Ind. e Com. Ltd., Cotia, SP, Brazil) at 300 rpm, to obtain a flat surface to allow the roughness readings. Then, for each type of tooth (B or I), seven groups were formed (n = 10), according to the type of treatment: Toothbrushing only (T), toothbrushing + immersion in beverages (TW toothbrushing + water, TCk toothbrushing + coke, TCf toothbrushing + coffee), or immersion only (W, Ck, or Cf). Roughness and color stability readings were performed at different times: T0 (before treatment) and T1 (after treatment).

The toothbrushing test was performed in a testing machine (MAVTEC - Trade and Services and Development Laboratory, Ribeirão Preto, SP, Brazil), where 11,000 brushing cycles were performed for each face of the artificial tooth (buccal and palatal), simulating 1 year of brushing.[7,8]

A solution of distilled water with toothpaste (Colgate, Colgate-Palmolive, São Bernardo do Campo, SP, Brazil) at a ratio of 1:1 by bulk, and brushes Classic Colgate (Colgate, Colgate-Palmolive, São Bernardo do Campo, SP, Brazil), with soft bristles, were chosen for testing. The brushes and the solution were replaced every 2750 cycles, simulating 3 months in use.

To evaluate the color stability, two drinks were selected, coffee (Nescafé tradição instantâneo, Nestlé Brasil Ltda, Araras, SP, Brazil) and coke (Coca-Cola, Curitiba, PR, Brazil). Furthermore, distilled water was used as control group. The artificial teeth were immersed in 20 mL of each beverage and remained immersed for 12 days at 37°C, simulating 1-year daily consumption of beverages.[9] The color evaluation was performed using a portable spectrophotometer (BYK Gardner, São Paulo, SP, Brazil) and the color measuring was obtained using the CIELAB (Commission Internationale de L'Eclarirage) system, which positions the color in a coordinate system.[10] For each artificial tooth, three measurements of color were made on each occasion (T0 and T1) on the buccal surface, obtaining an average. The color comparison between the readings was made by color difference or ΔE. ΔE values were converted to National Bureau of Standards (NBS) units, using the formula: NBS units = ΔE × 0.92, to denote the color differences in a clinical perspective.[11,12] Table 1 displays the ratings of color differences, according to NBS units.

The surface roughness was analyzed using a digital portable profilometer (Mitutoyo SJ-400, Mitutoyo Corporation, Tokyo, Japan) with a resolution of 0.01 μm, at a stylus speed of 0.5 mm/s, a cut off length of 2.4 mm, and a diamond stylus tip radius of 5 μm. Measurements were performed on the palatal surface of the previously flattened artificial teeth. Three measurements of roughness were made on each occasion (T0 and T1) and a value of average roughness Ra was obtained in μm. Roughness was expressed as the percentage of roughness obtained based on the roughness difference between T1 and T0.

In this study, color stability and surface roughness of two different artificial teeth were evaluated in function of one factor, the type of treatment. Thus, color data (ΔE) were statistically analyzed using analysis of variance (ANOVA) and least significant difference test whereas ANOVA and Bonferroni test were used to analyze roughness data (Ra). All analyses were performed with $\alpha = 0.05$.

Table 1: National Bureau of Standards units for expressing color differences

Color differences	NBS units
Extremely slight change	0.0-0.5
Slight change	0.5-1.5
Perceivable change	1.5-3.0
Appreciable change	3.0-6.0
Much appreciable	6.0-12.0
Change to another color	12.0-+

NBS – National Bureau of Standards

RESULTS

For color stability, ANOVA detected a significant effect of the treatment for the teeth B ($P = 0.033$) and I ($P = 0.053$). Statistical differences for roughness data were also observed among the Groups for B and I ($P < 0.001$). *Post hoc* tests were performed to detect the groups with statistical differences.

Table 2 illustrates the effect of the treatments on color stability for the two types of artificial teeth. Table 3 shows that toothbrushing produced a decrease in the surface roughness of both teeth evaluated. Groups W, Ck, and Co produced similar results of surface roughness Ra (μm) among them and different from the groups submitted to toothbrushing, regardless of the type of tooth.

Table 2: Mean values of color change (ΔE) and classification according to the standards of the National Bureau of Standards

Tooth	Treatment	ΔE	NBS
Biotone	Brushing	5.06 ±2.93) A	4.66*
	Brushing + water	5.77 (±4.78) A	5.31*
	Brushing + coke	1.96 (±1.21) B	1.81
	Brushing + coffee	1.98 (±1.45) B	1.82
	Water	4.87 (±4.02) A	4.48*
	Coke	3.75 (±2.89) AB	3.45*
	Coffee	2.56 (±1.88) AB	2.36
Biotone IPN	Brushing	1.74 (±1.79) A	1.60
	Brushing + water	3.50 (±2.50) AB	3.22*
	Brushing + coke	2.45 (±1.97) AB	2.25
	Brushing + coffee	5.28 (±6.14) B	4.86*
	Water	3.15 (±1.86) AB	2.90
	Coke	1.34 (±1.21) A	1.23
	Coffee	5.24 (±3.72) B	4.82*

Different capital letters indicate a statistically significant difference among the groups (ANOVA and LSD test, α=0.05). *Groups with appreciable color change. NBS – National Bureau of Standards, LSD – Least significant difference, IPN – Interpenetrating polymer network

Table 3: Percentage of surface roughness based on the difference of surface roughness between T1 (after treatment) and To (before treatment)

Tooth	Treatment	Ra (μm)
Biotone	Brushing	–71.53 (±14.34) A
	Brushing + water	–71.39 (±12.64) A
	Brushing + coke	–56.58 (±19.91) A
	Brushing + coffee	–60.19 (±15.91) A
	Water	–32.65 (±17.40) B
	Coke	0.07 (±28.38) B
	Coffee	–6.55 (±16.69) B
Biotone IPN	Brushing	–51.95 (±12.23) A
	Brushing + water	–82.87 (±2.55) A
	Brushing + coke	–71.78 (±4.11) A
	Brushing + coffee	–47.10 (±5.46) A
	Water	1.55 (±14.43) B
	Coke	9.24 (±15.81) B
	Coffee	37.15 (±7.17) B

Negative values represent the roughness decrease. Different capital letters indicate a statistically significant difference among the groups (ANOVA and Bonferroni test, α=0.05). IPN – Interpenetrating polymer network, Ra – Roughness, average

DISCUSSION

In this study, the null hypothesis was rejected since color stability and roughness surface were influenced by the treatments proposed, for both acrylic resin teeth.

The color of the artificial teeth is quite determinant in acceptance of prosthetic treatment for the patients.[13] According to previous studies,[3,14,15] color differences in NBS units up to 3.3 are clinically acceptable in dentistry.

For Biotone, the immersion in coke produced significant color changes according to NBS units. The artificial teeth Biotone are conventional acrylic resin teeth, essentially composed by polymethyl methacrylate macromolecules of low molecular weight, in a linear arrangement, chemically linked to each other through simple covalent crosslinks. Due to these characteristics, these teeth present low color stability and wear resistance.[16] Mutlu-Sagesen *et al.*[16] also observed that the immersion in coke produced the highest color changes in two brands of conventional acrylic denture teeth.

In addition, the influence of toothbrushing on the surface roughness of the artificial teeth was evaluated in this study, since it was tested its possible relation to the increase of susceptibility to color change. However, for Biotone, toothbrushing associated to immersion in coke or coffee did not change color significantly, probably because the surface roughness of these teeth has not been negatively affected by toothbrushing. For these groups, negative values of surface roughness were obtained, which indicates that the treatments turned the more polished surfaces, and thus more resistant to staining. These results are in accordance with Leite *et al.*,[17] who found that polished surfaces of dental materials are more resistant to staining than nonpolished specimens.

The results of color change obtained for Biotone IPN showed that the groups submitted to brushing associated to immersion in coffee, and only immersion in coffee presented color alteration higher and statistically significant when compared to the groups brushing and immersion in cola and similar in relation to other groups of teeth Biotone IPN. According to the NBS classification, the groups brushing associated with immersion in coffee (TCf) and immersion in coffee (Cf) produced the most clinically significant changes. Thus, the IPN teeth proved to be susceptible to staining when subjected to contact with coffee, and there was no statistically significant difference between groups immersion in coffee and brushing associated with immersion in coffee. As observed for Biotone teeth, brushing turned the more

polished surfaces in all groups of teeth Biotone IPN, and thus more resistant to staining.[17]

Biotone IPN artificial teeth are made of acrylic resins with tightly bound interpenetrating polymer chains and present cross-linking agents,[18] which would result in an increase in fracture resistance, abrasion, and staining.[19] In this study, despite these characteristics, it was observed that this type of tooth is capable of staining on contact with coffee. According to previous studies,[1,16,17,20-22] coffee is the most chromogenic solution for different dental materials. In addition, studies of Hipólito *et al.*,[3] Assunção *et al.*,[15] and Gregorius *et al.*[20] also observed the greatest color change values for IPN teeth submitted to immersion in drinks with dye potential (coffee, red wine, and orange juice).

In relation to the roughness, the IPN teeth behaved similarly to Biotone teeth. The results demonstrated that the groups submitted to toothbrushing showed a reduced roughness compared to the groups only immersed in beverages, which indicates that toothbrushing has the most polished teeth. A more polished surface is less susceptible to accumulation of microorganisms, therefore, more favorable in the prevention of oral disease.[6,23-25]

In this study, a period of 1 year of toothbrushing was simulated. The simulation of artificial toothbrushing can be considered a limitation of the study to be more vigorous and, therefore, more abrasive than the manual.[26] The limitations of this study also include the fact that only two types of artificial teeth and two drinks with potential dye were evaluated. Future studies *in vitro* and *in vivo* are suggested for the evaluation of other types of materials and other physical properties.

CONCLUSIONS

Within the limitations of this study, it could be concluded that for the two types of artificial teeth evaluated, toothbrushing combined with immersion in coloring beverages produced color changes similar to those just immersed in beverages. Thus, toothbrushing had no influence on the color stability but significantly reduced the roughness, irrespective of the type of tooth.

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Conflicts of interest

There are no conflicts of interest.

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