

Evaluation of methods for stain removal in acrylic resin denture teeth: *in vitro* study

Avaliação de métodos de remoção de manchas em dentes de resina acrílica para prótese total: estudo in vitro

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Resumo

Introdução: O manchamento dos dentes artificiais pode estar relacionado à abrasão da resina acrílica provocada pela escovação, resultando na maior deposição de corantes provenientes de bebidas, e consequentemente maior prejuízo estético. **Objetivo:** O objetivo do presente estudo foi avaliar métodos de remoção de manchas extrínsecas por meio de análise com espectrofotômetro. **Material e método:** Dentes artificiais foram divididos em 12 grupos (n=10), de acordo com o tipo de tratamento (repolimento – Re ou imersão em perborato de sódio, Corega Tabs – Sp), tipo de solução de manchamento, café (Cf) ou Coca-Cola® (Cc) ou água (W) e com/sem escovação (B). Os métodos de remoção de manchas propostos (Re e Sp) foram realizados de acordo com protocolos pré-estabelecidos. Os espécimes Sp foram submetidos a 7 ciclos de imersão (5 minutos cada). O repolimento foi realizado com pastas de pedra pomes e branco de espanha, utilizando escovas de cerdas macias e rodas de feltro. As leituras de estabilidade de cor (ΔE) foram realizadas por meio de um espectrofotômetro: T0 (baseline), T1 (após escovação/imersão em bebidas), e T2 (após Re ou Sp). **Resultado:** Alterações de cor entre T1 e T2 (teste T pareado; $\alpha=0,05$) foram observadas para o grupo CfSp ($p=.032$); e para os grupos BWRe ($p=.000$), BCfRe ($p=.049$) e CcRe ($p=.042$). Os dentes artificiais submetidos à escovação mostraram maior alteração de cor (ANOVA 2 fatores; $p<0,001$). **Conclusão:** Conclui-se que a imersão em perborato de sódio (Corega Tabs) pode ser utilizada para remoção de manchas de café e o repolimento para remoção de manchas de Coca-Cola®. Ainda, a escovação produziu as maiores alterações de cor nos dentes artificiais, independentemente da solução de imersão.

Descritores: Dente artificial; prótese total; escovação; estabilidade de cor.

Abstract

Introduction: The staining of artificial teeth can be related to the acrylic resin abrasion caused by brushing, resulting in higher deposition of dyes from the beverage, and consequently higher aesthetic damage. **Objective:** The aim of this *in vitro* study was to evaluate methods for removal of stains from acrylic denture teeth using spectrophotometric analysis. **Material and method:** Artificial teeth were divided into twelve groups (n=10) according to the type of treatment (re-polishing - Re or immersion in Corega Tabs - Sp), staining solutions, coffee (Cf) and Coca-Cola® (Cc) or water (W) and with/without toothbrushing (B). The Sp specimens were submitted to seven immersion cycles (5 min each). The Re specimens were polished with pumice stone followed by Spain white paste. Color differences (ΔE) were captured by a spectrophotometer: T0 (baseline), T1 (after brushing/immersion in solutions) and T2 (after Re or Sp). **Result:** Statistically significant color change between T1 and T2 (paired T-test; $\alpha=.05$) was observed for the group CfSp ($p=.032$); and for the groups BWRe ($p=.000$), BCfRe ($p=.049$) and CcRe ($p=.042$). Higher color changes were observed for the specimens submitted to toothbrushing (ANOVA two way; $p<.001$). **Conclusion:** It could be concluded that the immersion in sodium perborate (Corega Tabs) can be used for removal of coffee stains from denture teeth, and re-polishing for removal of Coca-Cola® stains. Still, toothbrushing produced greater color changes on denture teeth, regardless of the immersion solution.

Descriptors: Tooth artificial; denture complete; toothbrushing; color stability.

INTRODUCTION

Acrylic resin artificial teeth are frequently used for dentures fabrication due to several advantages, such as the chemical bond to the denture base, improved aesthetics and the ease of adjustment^{1,2}. However, resin teeth have the disadvantage of high susceptibility to stains²⁻⁴.

Clinical discoloration and extrinsic staining in acrylic resin teeth can be affected by many factors, including the type of denture tooth, dietary habits and oral hygiene of patients². Different beverages, accelerated aging, light activation, bleaching, cleaning agents, and smoking affect the color of such materials⁵. The extrinsic stain is time dependent and associated with eating habits, such as consumption of tea, red wine, cola and coffee that act as an extrinsic factor for color alteration due to the absorption and adsorption of these stains^{1,6}. Furthermore, improper brushing techniques could potentially cause wear of denture teeth and acrylic resins and adversely affect the esthetic of the denture, providing an increased roughness and increasing the accumulation of dyes derived from the diet⁶. Therefore, it is possible to suppose that the surface topography affects the amount of staining of a material, and an increased surface area is more prone to be stained than a flattened one⁶. Acidic solutions promoted greater material surface degradations; therefore the pH of the staining solution may be another factor affecting the material color change¹. Bagheri et al.⁷ demonstrated the pH of different staining solutions, among them coffee (pH=5.01), red wine (pH=3.70) and cola (pH=2.70).

The staining of acrylic resin denture teeth may be removed by mechanical or chemical denture cleansing regimens⁸. The abrasive action of polishing has been used to remove extrinsic stains on the surface of acrylic resin⁹, and it is considered a basic procedure for obtaining good aesthetics as well as smooth and polished surfaces¹⁰, facilitating the hygiene and comfort of users of removable dentures¹¹. Alkaline peroxides could also contribute to stain removal by means of the mechanical action of the bubbles of oxygen resulting from the effervescent reaction of this product¹².

Many studies have investigated the effects of staining pigments in denture teeth^{2,5,6}. However, few studies evaluated methods for removing stains from beverages in acrylic resin denture teeth⁸. The aim of this study was to evaluate, by means of spectrophotometric analysis, methods for removal of stains from acrylic denture teeth. The null hypothesis was that color stability of the denture teeth would not be influenced by the procedures for removing stains during the proposed period. In addition, it was hypothesized that toothbrushing would not affect the color change of the denture teeth, regardless of the coloring beverage.

MATERIAL AND METHOD

Experimental Design

The specimens consisted of artificial acrylic resin tooth, maxillary right central incisors; shade A2 (Biotone, Dentsply Ind. e Com, Rio de Janeiro, RJ, Brazil). Artificial teeth were

divided into twelve groups (n=10). Table 1 describes the groups of the study.

Toothbrushing

The toothbrushing test was performed in a testing machine (MAVTEC, comércio e serviços de desenvolvimento para laboratório, Ribeirão Preto, SP, Brazil), where 11,000 brushing cycles were performed on the buccal face of the artificial tooth, simulating one year of brushing^{13,14}.

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 Classic Colgate brushes (Colgate, Colgate-Palmolive, São Bernardo do Campo, SP, Brazil) with soft bristles, were chosen for testing. The brushes and the solution were replaced every 2,750 cycles, simulating three months of use.

Preparation of Staining Solutions

Coffee (Nescafé tradição instantâneo, Nestlé Brasil Ltda, Araras, SP, Brazil) and cola (Coca-Cola, Curitiba, PR, Brazil) were the beverages selected in this study, and distilled water was used as a control group. Coffee solution was prepared by adding 3.6 mg of coffee to 300 mL of boiling distilled water and this solution was used only after its complete cooling.

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 beverages¹⁵. The beverages were replaced every 3 days, and stirred once a day to avoid particles precipitation¹.

Table 1. Description of the study groups (n=10)

Group	Description
BWSp	Toothbrushing + immersion in water + sodium perborate treatment
BCcSp	Toothbrushing + immersion in cola + sodium perborate treatment
BCfSp	Toothbrushing + immersion in coffee + sodium perborate treatment
WSp	Immersion in water + sodium perborate treatment
CcSp	Immersion in cola + sodium perborate treatment
CfSp	Immersion in coffee + sodium perborate treatment
BWRe	Toothbrushing + immersion in water + re-polishing treatment
BCcRe	Toothbrushing + immersion in cola + re-polishing treatment
BCfRe	Toothbrushing + immersion in coffee + re-polishing treatment
WRe	Immersion in water + re-polishing treatment
CcRe	Immersion in cola + re-polishing treatment
CfRe	Immersion in coffee + re-polishing treatment

Protocols Proposed for the Removal of Stains

Chemical method: immersion in sodium perborate

For Groups 1 to 6, the effervescent solution of sodium perborate (Corega Tabs, Stafford Miller Ind., Rio de Janeiro, RJ, Brazil) was prepared according to the manufacturer’s instructions, by adding one tablet to 200 mL of warm tap water (40 °C). The specimens were submitted to seven immersion cycles (5 min each), simulating a 7- day use^{16,17}. After each cycle, the soaking solution was discarded and the specimens were thoroughly washed in running water. After having been subjected to the seven cycles of immersion in sodium perborate, the specimens were washed for 1 minute in an ultrasonic device containing deionized water and 1% detergent, and were then dried with paper towels prior to the color readings¹⁵.

Mechanical method: re-polishing

The specimens from Groups 7 to 12 were subjected to a re-polishing procedure according to the routine laboratory procedures used for polishing dentures. For this, a micromotor coupled to a handpiece was fixed on a device to standardize this procedure. This device was also used to adequately position the specimen (Figure 1).

Each specimen was polished in a two-step procedure: 1) use of a soft bristle brush (Bordente, São Paulo, SP, Brazil) and pumice stone (SSWhite Artigos Dentários Ltda., Rio de Janeiro, RJ, Brazil)

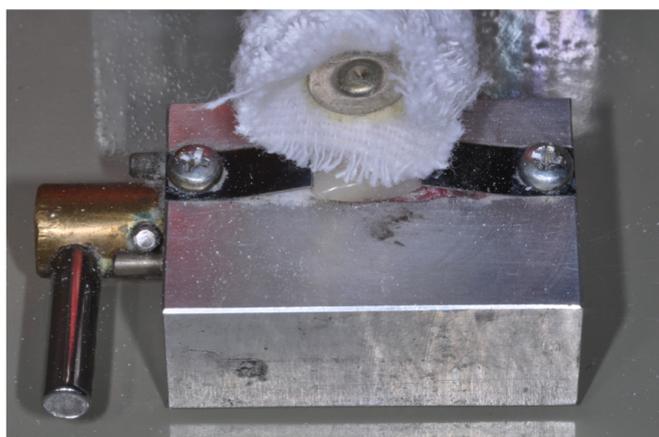


Figure 1. Device used for the re-polishing procedures.

and; 2) use of a felt wheel (Bordente, São Paulo, SP, Brazil) and Spain white paste (Asfer, São Caetano do Sul, SP, Brazil). For each step, each specimen was polished for 10 seconds, six times per specimen, at 3,000 rotations per minute¹⁸. The pumice stone and Spain white pastes were prepared in the proportion of 5.0 g to 1 ml of water. After the re-polishing procedures, the specimens were washed for 1 minute in an ultrasonic bath containing deionized water and 1% detergent and were dried with paper towels prior to color readings¹⁵.

Spectrophotometric Analysis of Color Stability

Color stability readings were performed at different times: T0, T1 and T2, according to the experimental diagram (Figure 2), using a portable spectrophotometer (BYK Gardner, São Paulo, SP, Brazil).

Color measurements were obtained using the CIELAB (Commission Internationale de L’Eclairage) system, which positions the color in a coordinate system¹⁹. For each artificial tooth, three color measurements were made on each occasion (T0, T1 and T2) on the buccal surface of the tooth, obtaining an average. The color comparison between the readings was determined by the color difference or ΔE.

Total color changes were expressed by the formula^{6,20}: $\Delta E^* = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$, where ΔL, Δa, and Δb are the different values of L*, a* and b* at T0, T1 and T2.

Statistical Analysis

In the present study, two separate analyses were performed to compare the values corresponding to ΔE. For comparing the T0T1ΔE and T1T2ΔE, data were submitted to a paired T-test, which showed significant effects of variation factor periods. For the comparison between the proposed stain removal treatments (Sodium perborate and re-polishing), the T1T2 ΔE data were compared by an independent T-test. In addition, ANOVA two way for independent samples was performed to compare data of T0T1ΔE with and without toothbrushing. All analyses were performed with α=.05.

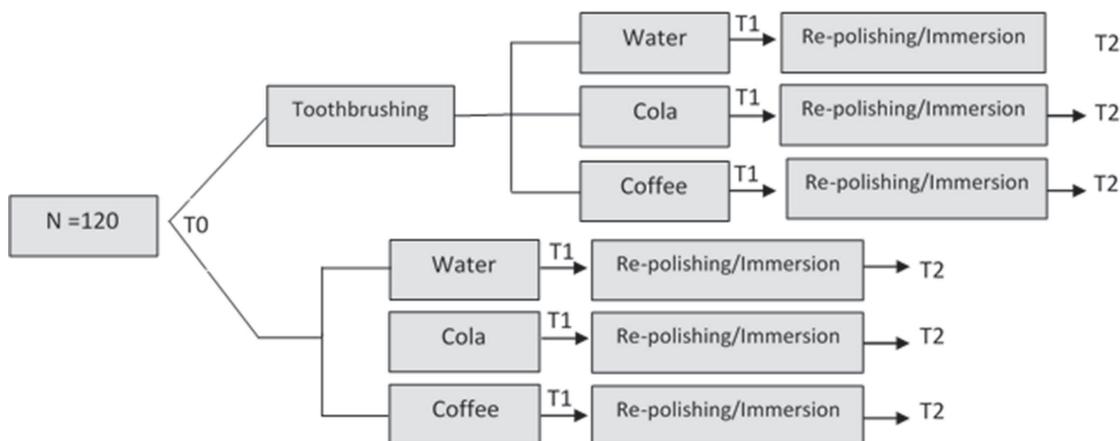


Figure 2. Experimental diagram of the study.

RESULT

In Table 2, for the groups treated with sodium perborate (Groups Sp), the results showed a statistically significant color change between T0T1ΔE and T1T2ΔE, only for group CfSp. For the groups submitted to re-polishing (Groups Re), significant differences between T0T1ΔE and T1T2ΔE were found for groups BWRe, BCfRe and CcRe.

The comparison between the proposed methods for stain removal demonstrated that the type of treatment was significant for all groups except for the group of teeth immersed in water (p =.052). Treatment with Corega Tabs was more effective for the brushing + immersion in cola, brushing + immersion in coffee and immersion in coffee groups. Nevertheless, re-polishing was more effective in teeth submitted to brushing + immersion in water and immersion in cola (Table 3).

Figure 3 shows the comparison of ΔE, for the groups with and without toothbrushing, after immersion protocols in the different solutions (water, cola or coffee). It was observed that toothbrushing produced higher color changes on the denture teeth (ANOVA two way, p<.001), regardless of the solution.

DISCUSSION

The null hypothesis was rejected, since significant differences were found among the color changes of the denture teeth according to the procedures for removing stains and periods evaluated

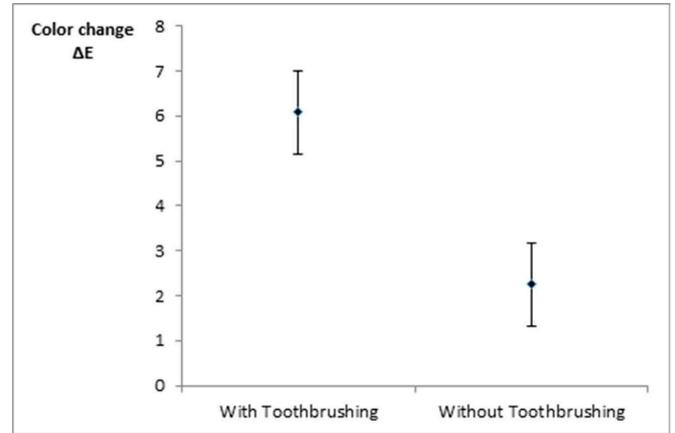


Figure 3. Color changes (ΔE) mean values at 95% of confidence interval of denture teeth with or without toothbrushing, regardless of the solution.

Table 2. Color data in CIE L*a*b* color space, means and standard deviations of T0T1 ΔE (after brushing and / or immersion in beverages) and T1T2 ΔE (after stain removal methods), according to the group

Group	L*	a*	b*	T0T1 ΔE	T1T2 ΔE	P
BWSp	80.73	6.85	19.41	5.24(±5.36)	4.27(±2.61)	0.555
BCcSp	81.07	7.43	20.23	2.45(±2.14)	1.91(±1.52)	0.565
BCfSp	80.67	7.51	20.30	2.29(±1.89)	1.74(±1.64)	0.506
WSp	83.03	6.15	19.75	5.55(±4.85)	2.49(±1.70)	0.091
CcSp	80.55	7.36	19.98	4.37(±3.75)	3.90(±3.32)	0.667
CfSp	80.77	7.10	19.76	2.56(±1.98)	1.13(±0.81)	0.032*
BWRe	79.63	6.49	17.14	5.55(±0.93)	2.16(±1.17)	0.000*
BCcRe	81.21	7.16	19.14	5.08(±4.42)	3.23(±0.90)	0.214
BCfRe	81.20	7.80	18.79	7.61(±3.32)	4.67(±2.00)	0.049*
WRe	81.35	7.91	18.62	1.68(±1.28)	1.29(±0.65)	0.304
CcRe	80.80	7.58	19.08	2.93(±2.20)	1.13(±0.63)	0.042*
CfRe	79.80	7.87	19.01	2.11(±0.52)	2.39(±0.42)	0.206

* P<0.05: significant difference between groups (paired T-test, α=0.05).

Table 3. Means and standard deviations of T1T2 ΔE (after stain removal treatments), according to group

Group	Perborate sodium	Re-polishing	P
Brushing + immersion in water	4.27(±2.61)	2.16(±1.17)	0.032*
Brushing + immersion in cola	1.91(±1.52)	3.23(±0.90)	0.029*
Brushing + immersion in coffee	1.74(±1.64)	4.67(±2.00)	0.002*
Immersion in water	2.49(±1.70)	1.29(±0.65)	0.052
Immersion in cola	3.90(±3.32)	1.13(±0.63)	0.027*
Immersion in coffee	1.13(±0.81)	2.39(±0.42)	0.000*

* P<0.05: significant difference between methods (independent T-test, α=0.05).

(T0, T1 and T2). The results indicated that there were differences in stain removal efficiency depending on the type of treatment of removal of stains. In addition, the hypothesis that toothbrushing would not affect the color change of the denture teeth was also rejected, since higher color changes were observed for the groups submitted to toothbrushing, regardless of the coloring beverage.

Our results are in agreement with Hipólito et al.⁶ and Leite et al.²¹. These authors inferred that the surface profile/topography affects the amount of staining of a material. Thus, the results of this study suggest that toothbrushing produced more rough surfaces favoring the accumulation of stains on the denture teeth.

Extrinsic factors such as adsorption or absorption of extrinsic stains are still a major problem for esthetic restorations⁷. The staining agents selected for this study are in common daily use and have a strong potential to stain acrylic denture teeth, as evaluated in many studies^{1,2,4,6}.

The color change observed among the periods evaluated (T0, T1 and T2) suggests that the treatment of removing stains by immersion in Corega Tabs solution presented positive results only in the group of teeth submitted to immersion in coffee (Group Cfsb). It could be demonstrated that the comparison between the T0T1 ΔE and T1T2 ΔE values for this group was statistically significant ($p=0.032$), and in T2, the ΔE value (1.13) was statistically lower compared to T1 (2.56). According to Jagger & Harrison¹², this chemical method for denture cleaning performs a mechanical cleaning action induced by oxygen released during the effervescent reaction product, which could contribute to the stain removal.

In this study, the re-polishing produced a significant effect for removing stains for the brushing + immersion in water, brushing + immersion in coffee and immersion in cola groups. In these groups, the T1T2 ΔE values were statistically lower compared to the T0T1 ΔE values. The results of this study also suggest that the treatment with Corega Tabs was more effective than re-polishing for stain removal for the brushing + immersion in cola, brushing + immersion in coffee, and immersion in coffee groups. The re-polishing was only effective for stain removal for the group of teeth submitted to immersion in cola.

It could be supposed that re-polishing was more effective method for removal of stains from cola considering that immersion in this beverage produced greater surface degradations due to the acid pH of this beverage ($pH=2.70$)^{6,7,21}. Therefore, re-polishing was more effective than Corega Tabs for removal of stains of cola because re-polishing is capable to alter the surface topography of the material, producing smoother surfaces²², whereas Corega Tabs used as denture cleanser did not alter the surface roughness of acrylic resin^{17,23}.

On the other hand, in this study, the treatment with Corega Tabs was more effective for removal of stains of coffee. Coffee is

considered the most chromogenic agent, which presents yellow dyes with chemical affinity with the acrylic resin^{1,5,6,24}. It could be hypothesized that the mechanical action of the oxygen bubbles produced during the reaction of the sodium perborate solution was effective for removing coffee stains, as observed by Kurtulmus-Yilmaz, Deniz⁸. These authors showed that Corega tabs, among other denture cleansers, were efficient methods for removal of coffee, tea and red wine stains of artificial teeth.

In previous studies, it has been suggested that ΔE greater than 3.3 is considered clinically unacceptable^{2,6}. In the present study, the artificial teeth submitted to immersion in cola and treated with Corega Tabs numerically showed a reduction in color change values, however, this average value reached 3.90 after this treatment. The group submitted to brushing associated with immersion in coffee treated with re-polishing also obtained a reduction in the ΔE value from 7.61 to 4.67. Although the statistical test (paired t test, $p=0.049$) has pointed out significant differences, the final ΔE value was greater than 3.3, indicating a clinically unacceptable color change^{2,6}.

Thus, it could be suggested that the treatment with Corega Tabs could be more indicated for removing stains from coffee and re-polishing would be more appropriate for the removal of cola stains, since in these groups, the color change was significantly reduced and within clinically acceptable values.

Artificial brushing can be considered one of the limitations of this study because it may be vigorous and may be more abrasive than manual brushing²⁵. Another limitation was the protocol used for simulation of methods of removing stains, and maybe other time periods or frequencies of re-polishing methods could provide more effective results. Further studies are needed to evaluate the efficacy of different types of treatments for the stain removal of artificial teeth.

CONCLUSION

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

- Corega Tabs could be more indicated for removing stains from coffee and re-polishing would be more appropriate for the removal of cola stains.
- Toothbrushing produced higher color changes on the denture teeth, regardless of the coloring beverage.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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