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Colour Stability of Denture Teeth Submitted to Different Cleaning Protocols and Accelerated Artificial Aging

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Abstract - *Acrylic resin is widely used for artificial teeth manufacturing due to several important characteristics; however, this material do not present acceptable colour stability over the course of time. This study evaluated the effect of different cleaning protocols and accelerated artificial aging on colour stability of denture teeth made of acrylic resin. Sixty denture teeth in dark and light shades were used, and separated according to the treatment to which they were submitted. Results demonstrated that colour stability of artificial teeth is influenced by the cleaning solution and artificial aging, being dark teeth more susceptible to colour alteration than lighter ones.*

KEY WORDS: Denture tooth, Acrylic resin, Staining, Accelerated artificial aging.

INTRODUCTION

Artificial teeth are a fundamental part of complete denture and partial removable denture aesthetics. In order to maintain this function over the course of time, these artificial teeth must to present clinically acceptable colour stability[1-5].

With the appearance of acrylic resin Poly(methylmethacrylate), around the 1930s, artificial teeth made of acrylic appeared on the market as a new option for dental treatment. Acrylic resin is the most widely used material for manufacturing artificial teeth because due to its important characteristics, such as: chemical bond to the denture base acrylic resin[6], which is resistant to cracks and organic solvents; it feels more natural when the teeth come into contact[7,8], has a more natural appearance,[7,9], less friability[10-12], reduced occlusal sounds[9,13], easy characterization[8,14] and greater impact resistance and flexural strength[9,15,16].

On the other hand, acrylic artificial teeth have the disadvantages of low wear resistance[11,17], they easily absorb odors[10] and do not have acceptable color stability[10,18,19], as the suffer the action of organic colouring agents, water, sunlight and chemical agents.

The intrinsic colour of aesthetic materials may be altered as a result of composite aging under various physico-chemical conditions, such as visible light and UV irradiation, and changes in temperature and humidity[19-22]. However, microfractures, micro cavities and porosities on the surface appear to be the preferential pathways for penetration of solutions that promote staining of the material[19,24].

Generally, a complete denture has a useful life of approximately 7 years, this period being dictated by the acrylic resin characteristics, artificial teeth used and the patient's bone resorption pattern[24]. In order to attain this period without compromising the patient's aesthetic appearance and oral health, the patient needs to perform correct denture hygiene by mechanical and chemical methods[25].

Brushing is the method most commonly used by complete denture wearers[16] and has the advantage of being a simple, low cost and effective method for removing stains and organic deposits[25]. However, it has the disadvantages of being difficult to perform by patients with problems of motor coordination[16], and its incorrect use causes acrylic resin wear[17] and damage to the surfaces of the materials used in possible relining[13].

Considering that artificial teeth undergo colour alteration with the course of time, and this alteration may be related to the cleaning methods, the aim of this study was to evaluate the colour stability of artificial teeth made of acrylic resin, which were submitted to different cleaning protocols and aging. The null hypothesis tested was that none of the protocols promoted significant colour alteration in the teeth.

MATERIALS AND METHODS

To conduct this study 60 maxillary central incisors made of poly(methylmethacrylate) (SR Vivodent®) were used, 30 being of a dark (2E) and 30 of a light (1C) shade.

Initially, colour readouts (VITA Easyshade®) of the teeth (baseline) were taken according to the CIE L*a*b* system[21,22], which consists of three axes representing the dimension of colour, with a* and b* being perpendicular to one another representing the range of tonality (green-red and blue-yellow, respectively), and a third axis L* representing luminosity. The third axis is perpendicular to plane a*b*. With the use of this system, any colour can be specified with the coordinates L*, a* and b*.

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After this, the teeth were randomly separated into 5 groups (n=6), according to the treatment to which they would be submitted, as shown in Table 1.

The samples of Groups 1, 3 and 4 were fixed on acrylic plates using transparent silicone-based sealant (Brascoved Super®). On each plate 12 teeth were fixed, being 6 from Group 1C and 6 from Group 2E, according to the type of immersion performed in each group. All the solutions used for immersion were changed daily. In G3 and G4, after the immersion period, the teeth were washed under running water and transferred to another receptacle containing artificial saliva and remained there for the rest of the day.

The samples of Group 2 were submitted to accelerated artificial aging **(**AAA - C-UV®) for 384 hours, which corresponded to approximately 1 year of clinical use[22]. The AAA system allows one to predict the relative durability of materials. For this purpose, eight ultraviolet light sources (UV-B) are used, composed of 40 watt fluorescent tubes with emission concentrated in the UV-B region, with radiation concentrated at 280/320 nm, in addition to allowing temperature control. The teeth were bonded to the fixation plates of the appliance using silicone (Colamais®) and taken to the condensation chamber facing the UV light source at a distance of 50 mm. The fixed working program was 4 hours of exposure to UV-B at 50ºC and 4 hours of condensation of water saturated air at 50ºC.

In Group 5, each tooth, with its buccal face facing upwards, was embedded in the centre of a PVC ring (26 mm in diameter x 7 mm thick), using colourless self-polymerizing acrylic resin (Jet®). After the resin was polymerized, these rings were fixed onto Plexiglass plates and adapted to a brushing machine, model Pepsodent®, under a force of 200 g on each brush. For each tooth a soft brush (Tek®) with 26 tufts of bristles 0.25 mm in diameter and 10 mm high was used. The tooth brush handles were cut off so that the brushes could be fitted into the machine brush handle holes. Dentifrice (Colgate Máxima Proteção Anticáries®) was diluted in distilled water in the proportion of 1:1 (60 g paste to 60 ml water) and 15 ml of the solution was put in for each sample brushed. Brushing (33247 cycles) was performed at a speed of 356 revolutions per minute, with a distance of 3.8 cm run by the brush and total brushing time of 100 minutes.

After each of the tests was performed, the teeth were submitted to new colour readout, after which the colour alteration (ΔE) of the samples was calculated by the formula:

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

where: $\Delta L^* = L^*_{final} - L^*_{initial,}$

$\Delta a^* = a^*_{final} - a^*_{initial}$ and

$\Delta b^* = b^*_{final} - b^*_{initial}$

ΔE values above 3.3 were considered clinically unacceptable[1].

The normal distribution of data was tested by the Kolmogorov-Smirnov test and the values obtained after colour reading were submitted to statistical analysis (2-way ANOVA, Bonferroni test, at the level of significance of 95%) with the aid of Graphpad Prism 4.0 Software (GraphPad Software, La Jolla, CA, USA).

RESULTS

The mean values and standard deviations of ΔE are shown in Table 2.

When ΔE values were compared considering denture teeth colour, 1C presented less colour alteration than 2E, with statistically significant difference for Groups 3, 4 and 5 ($p < 0.05$). For 2E teeth, only the samples of Group 1 and 2 presented ΔE values within the clinically acceptable limit (ΔE<3.3).

When the treatments were compared, no statistically significant difference was verified ($p > 0.05$) for teeth 1C. Teeth 2E submitted to AAA presented statistically significant difference for all groups ($p < 0.05$), with the exception for Group 1 ($p > 0.05$).

The mean values and standard deviations of ΔL are shown in Table 3.

When ΔL values were compared considering denture teeth color, no statistically significant difference was verified ($p > 0.05$). However, when the treatments were compared, 2E teeth submitted to mechanical brushing presented the greatest decrease in ΔL mean value, with statistically significant difference for Groups 1 and 2 ($p < 0.05$).

Table 1. Division of groups evaluated.

Group	*Treatment*	*Time*
G1 (control)	Immersion in artificial saliva at 37ºC for 16h and distilled water for 8h	30 days
G2	Accelerated artificial aging	384h
G3	Alkaline Peroxide (CoregaTabs, GlaxoSmithKline, Brentford, Middlesex, United Kingdom)	5 minutes/ 30 days
G4	0.5% Sodium Hypochlorite	20 minutes/ 30days
G5	Mechanical brushing with soft brush and dentifrice	100 minutes

Table 2. Means and standard deviations of the Delta E values.

Group	*2E*	*1C*
1	3.13 (1.59)^{aBC}	3.18 (2.64)^{aA}
2	1.99 (0.99)^{aC}	3.61 (1.52)^{aA}
3	6.68 (1.36)^{aA}	2.31 (1.15)^{bA}
4	5.36 (1.86)^{aAB}	1.25 (0.50)^{bA}
5	7.59 (2.36)^{aA}	2.19 (0.94)^{bA}

Different letters, lower case letters on the line and capital letters in the column indicate statistically significant difference ($p < 0.05$).

Table 3. Means and standard deviations of the Delta L values.

Group	*2E*	*1C*
1	0.72 (0.58)^{aB}	-0.13 (1.63)^{aA}
2	0.78 (0.43)^{aB}	0.57 (0.52)^{aA}
3	0.12 (0.69)^{aA}	0.43 (0.82)^{aA}
4	0.42 (0.57)^{aAB}	0.06 (0.43)^{aA}
5	-0.88 (0.90)^{aA}	0.07 (0.50)^{aA}

Different letters, lower case letters on the line and capital letters in the column indicate statistically significant difference ($p < 0.05$).

DISCUSSION

This study evaluated the colour stability of artificial teeth made of resin, submitted to different cleaning protocols and AAA. The cleaning procedures performed in the laboratory simulated the procedures used by removable denture wearers during a period of 30 days. When the loss of one or more dental elements occurs, these teeth are frequently replaced with the use of dentures, whereby the individual's aesthetic appearance is restored by means of artificial teeth[4].

The methodology used in the present study is in agreement with that carried out in previous studies[14,22] which used spectrophotometry and the CIE L*a*b* system of coordinates. The CIE L*a*b* system was selected to verify colour alteration (ΔE), because it enables small colour alterations to be identified, and has advantages such as sensitivity, repeatability and objectivity[21].

Comparing the two tooth shades, only teeth 2E presented statistically significant difference ($p<0.05$) among all the protocols to which the teeth were submitted, whereas the teeth of Group 2 (AAA) presented the lowest colour alteration. Due to the large quantity of pigmentation in their composition, it is believed that AAA was not capable of causing darkening as accentuated as occurred in teeth 1C, which were lighter, and therefore, more susceptible to colour alteration by AAA. Changes in the molecular structure of polymers resulting from the AAA process may be attributed to the following factors: breakage of the polymeric chain by UV light, plasticizer lixiviation and water sorption[19].

Water sorption is known as one of the main properties of resins[11,15]. The effect of water in the polymeric network have been described as plasticization, which leads to sub-surface alteration of polymeric materials, such as artificial teeth, due to relaxation of the bonds along the polymeric network[15,26]. According to Ferracane[26], the decrease in several properties, such as colour stability, occurs due to the separation of the polymer chains by a molecule which does not form chemical bonds with the chain, however, act as a space occupier. The main effect of the solvent - water - (present in AAA procedure) is to reduce the interactions along the polymeric network, as entanglements and secondary bonding. So, the effect is greater for surface properties, such as hardness, roughness, wear resistance and colour stability, and lower for bulk properties. Thereby, the ΔE value above the clinically acceptable limit (ΔE<3.3) for teeth 1C (Group 2) can be explained by the absence of surface treatment on the samples, differently to that which occurred in the other groups, in which the treatments to which they were submitted may have led to the removal of the surface layer altered by water sorption resulting from the action of the physico-chemical agents[24], which allowed greater alteration.

The shade 2E teeth (darker) were those that presented the greatest colour alteration (ΔE) in all the cleaning protocols, leading to rejection of the null hypothesis tested. Group 5 of teeth 2E presented the greatest colour alteration in comparison with all groups, possibly due to the removal of surface layers of resin from the tooth[13,16], exposing the deeper layers that contained a larger quantity of pigment[12]. In addition, this group presented the greatest decrease in ΔL values, which can be interpreted as loss of luminosity. Groups 3 and 4 of teeth 2E also presented elevated colour alteration values, possibly due to the presence of plasticizer in the resins[16], which influences their whitening. The action of the solvent in the polymeric network leads to the release of by-products, as methacrylic acid, formaldehyde and specific molecules of methacrylate, such as the plasticizers[26]. The action of the immersion substances causes relaxation among the molecules of which the resin is composed and leads to degradation of the coloring agents or pigments used by the manufacturer[16]. As teeth 2E had a larger quantity of pigments in their composition than teeth 1C, they showed greater variation in ΔE.

The results obtained in this study showed that the colour stability of artificial teeth made of acrylic resin is influenced by the cleaning solution, artificial aging and distilled water, which corroborates the findings of other authors[4,5,16], and that dark teeth are more susceptible to colour alteration than lighter teeth, when submitted to cleaning procedures.

In spite of the limitations of this *in vitro* study, it was observed that denture cleaning agents and AAA have an influence on the colour stability of artificial teeth.

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MANUFACTURERS' DETAILS:

- SR Vivodent®; Ivoclar Vivadent AG, Bendererstrasse 2, 9494 Schaan, Liechtenstein.
- VITA Easyshade®; VITA Zahnfabrik, Postfach 1338, D-79704 Bad Säckingen, Germany.
- Brascoved Super®, Brascola Ltda., Rua Dona Francisca 8300, Zona Industrial Norte 89219-600, Joinville, SC, Brazil.
- AAA - C-UV®; Comexim Matérias Primas Ltda., Avenida Casa Verde 1758, Casa Verde 02520-000, São Paulo, SP, Brazil.
- Colamais®; Tecnofix - Elementos de Fixação Ltda., Rua Soares de Avelar 769, Jabaquara 04306-020, São Paulo, SP, Brazil.
- Jet®; Artigos Odontológicos Clássico, Avenida Diógenes Ribeiro de Lima 2720, Alto de Pinheiros 05458-002, São Paulo, SP, Brazil.
- Pepsodent®; MAVTEC Comércios e Serviços, Rua Almirante Barroso 32, Campos Elíseos 14080-480, Ribeirão Preto, SP, Brazil.
- Tek®; Johnson & Johnson Ind. Com. Ltda., Rodovia Presidente Dutra km 154, Jd. das Indústrias 12240-907, São José dos Campos, SP, Brazil.
- Colgate Máxima Proteção Anticáries®; Colgate-Palmolive Comercial Ltda., Rua Rio Grande 752, Vila Clementino 04018-002, São Paulo, SP, Brazil.

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