ORIGINAL ARTICLE

IN VITRO SPECTROPHOTOMETRIC EVALUATION OF ACRYLIC TEETH STAINING RELATED TO DIETARY AND ORAL ANTISEPTIC AGENTS

RALUCA DRĂGHICI[1], CRISTINA TEODORA PREOTEASA[1]*, LĂCRĂMIOARA POPA[2], CĂTĂLINA MURARIU-MĂGUREANU[1], ANA MARIA TANCU[1], DANIELA MEGHEA[1], ANCA DIANA CRISTEA[1], ELENA PREOTEASA[1]

[1]*Faculty of Dental Medicine, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania*
[2]*Faculty of Pharmacy, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania*

**corresponding author: cristina_5013@yahoo.com*

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Abstract

The aim of this study was to analyse the colour stability of acrylic teeth, after exposure to several dietary agents (types of coffee, red wine), and the oral antiseptic chlorhexidine (0.2% mouthwash). Distilled water was used as control. The teeth colour was assessed using a spectrophotometric method. Acrylic teeth from 4 manufacturers were immersed in staining agents over a period of 11 days. Acrylic teeth showed a high susceptibility to staining, dependent on teeth manufacturer (lowest for Vita teeth), and staining agent (highest for coffee, especially espresso, and for red wine). Chlorhexidine mouthwash had a low staining potential, similar to distilled water. In conclusion, tests for staining susceptibility can be carried out by spectrophotometry before selecting teeth from one manufacturer, using specific colouring agents according to patient food preferences. Chlorhexidine, an oral antiseptic frequently prescribed, has low staining potential of acrylic teeth.

Rezumat

Scopul studiului a fost analiza stabilității culorii dinților acrilici prin expunerea la diferiți agenți alimentari (tipuri diferite de cafea, vin roșu) și antiseptice orale (apa de gură cu clorhexidină 0,2%). Controlul a fost reprezentat de apa distilată. Culoarea a fost înregistrată folosind o metoda spectrofotometrică. Dinți acrilici poveniți de la 4 producători au fost imersați în agenți cu potențial colorant pe o perioadă de 11 zile. Aceștia au înregistrat o susceptibilitate mare la colorare, variabilă în funcție de producător (cea mai mică pentru cei fabricați de firma Vita) și de agent (cea mai mare la cafea, mai ales la *espresso* și la vin roșu). Apa de gură cu clorhexidină a avut efect colorant similar apei distilate. În concluzie, înaintea alegerii dinților acrilici, pot fi făcute testări ale acestora prin spectrofotometrie, utilizând agenți în acord cu preferințele alimentare ale pacientului. Clorhexidina, un agent antiseptic oral cu indicații frecvente, are risc de colorare a dinților acrilici scăzut.

Keywords: artificial teeth, spectrophotometer, teeth colour, denture, coffee, red wine, chlorhexidine

Introduction

The colour of teeth is an important parameter of facial aesthetics, regardless of age. Studies that assess the perception of aesthetics at the teeth level suggest that older patients tend to largely focus on the colour of teeth and give a higher aesthetic ranking in direct correlation with the level of teeth whiteness [1]. Restoration materials used in dentistry are exposed to a wide variety of colouring agents, extrinsic colorations being linked to smoking, certain food or drinks consumption, eating habits, wrong or insufficient cleaning of the dental prosthesis, even the use of some oral hygiene products - all of them possibly contributing to the pigmentation of the resin matrix [2-6]. The colouring changes of the prosthetic components, primarily the artificial teeth, negatively impacts the aesthetic, and consequently patient's satisfaction [7].

The aim of this *in vitro* study was to analyse the colour stability of artificial acrylic teeth used for removable prostheses, after exposure to several dietary agents (types of coffee, red wine), and an oral antiseptic (0.2% chlorhexidine mouthwash).

Materials and Methods

Artificial teeth sets. Acrylic artificial teeth are used in removable prosthesis, for replacement of natural teeth. For this *in vitro* study, 4 different prefabricated acrylic teeth sets were selected: Vita MFT® (Vita Zahnfabrik; Germany); Ivostar® (Ivoclar Vivadent; Liechtenstein); Spofadent Plus® (Spofa Dental; Czech Republic); New Ace Anteriors® (Yamahachi Dental; Japan). Given the different morphology for teeth, that could generate errors in the colour spectrophotometric determinations, it was decided for this experiment to use only the right central upper incisor. This tooth has the highest aesthetic relevance and

given its morphology the plainest vestibular surface (lower convexity) and largest surface (compared with the others) thus favouring a more accurate spectrophotometric colour determination.

Staining agents. The artificial teeth were immersed in 7 liquids, 6 of them considered as possible staining agents and 1 solution, distilled water, used as control. The following solutions were used: *espresso coffee*, with a 0.45 mm granulation (mode of preparation: 9 g of coffee for 45 mL of water); *filter coffee*, with a 0.55 mm granulation (mode of preparation: 3.75g of coffee for 45 mL of water); *french (pressed) coffee*, with a 0.35 mm granulation (mode of preparation: 4.5 g of coffee for 45 mL of water); *boiled coffee*, with a 0.35 mm granulation (mode of preparation: 4.5 g of coffee for 45 mL of water); *red wine*, (*Feteasca Neagră*, Tohani Domains, Romania); *mouthwash*, with a 0.2% chlorhexidine content (Curasept ADS 220®, Curaden Healthcare, Italy), an oral antiseptic agent frequently prescribed; *distilled water*, was used as control.

Artificial teeth colour measurement. The colour of the artificial teeth was measured in the middle third of the vestibular surface of the tooth crown of the central right upper incisor, using the Easyshade spectrophotometer (Vita Zahnfabrik, Germany). The Easyshade device is designed to determine the colour for natural teeth and it is widely used because of its high accuracy [8, 9]. It is also used for assessing the colour of artificial teeth [10], using the parameters of CIE (Comission Internationale de l'Éclecleragе) L*a*b* colour space [11].

To ensure that colour is measured in the exact same spot of the artificial tooth surface each time, a custom designed device was manufactured (Figure 1).

Figure 1.
Custom designed device for positioning the teeth and spectrophotometer

The device had two parts - one designed to fix the spectrophotometer in the desired position, and one for holding the artificial tooth. The two parts were joined through two metal arms that were immobilized after positioning the elements in the desired position for colour recording. Tooth positioning jigs were manufactured from light-curing pink base plates used for manufacturing of individual impression trays (Evo Plaque, Poka).

Colour recording was carried out following the manufacturer recommendations. The Easyshade spectrophotometer was calibrated before each measurement, each record being carried out in the "Single Tooth" mode and every measurement being repeated until two very similar subsequent scores were attained. Colour was registered using the parameters: L* - Lightness (on black-white axis); a* (on red-green axis), b* (on yellow-blue axis).

Conducting the experiment – followed steps. The experiment was carried out in a room with a constant ambient temperature of 21°C and lightning. A total of 28 artificial teeth were selected, 7 upper right central incisors from each manufacturer, and positioning jigs were made for them. In the next step, 28 identical recipients were prepared – sets of 4 for each of the 7 liquids, each filled with 45 mL of solution, each one being labelled with the name of the manufacturer and the solution type. The temperature of solutions when poured into the recipient was always controlled to be 21°C thus trying to alleviate the thermic influence as a potential factor in colouring the artificial teeth.

Teeth were rinsed in distilled water for 5 minutes to imitate the natural cleaning process of saliva, and dried on a paper towel before measuring their colour with the Easyshade spectrophotometer, all registrations being made by the same person. Next, each tooth was immersed in the solutions with one tooth per recipient. Subsequent colour determinations were carried after 6 hours, 12 hours, 1 day, 2 days, 3 days, 4 days, 7 days, 9 days, 11 days following the same protocol: teeth were rinsed, dried and then positioned in the device for colour determination. The solution was changed after each measurement, before re-introducing the tooth.

Data analysis. To quantify the colour difference between the various points in time, the following formula was used:

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

For data analysis Spearman and Kruskal - Wallis statistical tests were used. Statistical significance was set at $p < 0.005$. The software used was SPSS Statistics for Windows.

Results and Discussion

Measurements performed through the 11 days period proved that the acrylic teeth registered significant colour changes. Through the entire experiment, a minimum staining ($\Delta E = 2.92$), probably not detectable by the human eye, was observed in a single tooth, while for the rest high values were recorded, with $\Delta E > 8$ (Table I). There was also found a positive correlation between ΔE after 6 hours and ΔE for the entire experiment (Spearman $r = 0.684$; $p < 0.001$), suggesting long term colouring pattern can be observed after only 6 hours of *in vitro* testing.

Table I

Colour changes of artificial teeth in time

ΔE	initial - 6 h	6 h - 12 h	12 h - day 1	day1 - day 2	day 2 - day 3	day 3 - day 4	day 4 - day 7	day 7 - day 9	day 9 - day 11	initial - day 11
Mean	1.87	2.06	1.23	1.87	2.33	1.54	1.99	1.88	2.89	17.70
Median	1.50	2.17	0.89	1.70	2.14	1.48	1.19	1.32	1.95	16.55
Minimum	0.33	0.36	0.14	0.22	0.49	0.14	0.24	0.00	0.14	2.92
Maximum	8.26	6.81	4.86	6.13	6.17	3.41	7.21	5.56	8.98	39.37

Difference in colour change of artificial teeth, in relation to their manufacturer. The artificial teeth manufactured by Vita showed the least amount of discoloration, while teeth manufactured by Spofa and Ivoclar showed the highest degree of colour change. Analysing the progressive colour changes (Figure 2), it can be observed that the overall tendency to colour change can be detected early - the teeth that have changed colour the most in the first 6 hours were those that changed colour the most through the entire period of 11 days. There was a statistically significant difference in the colour change (ΔE) between teeth fabricated by different manufacturers after 6 hours, 12 hours, and 4 days (Table II).

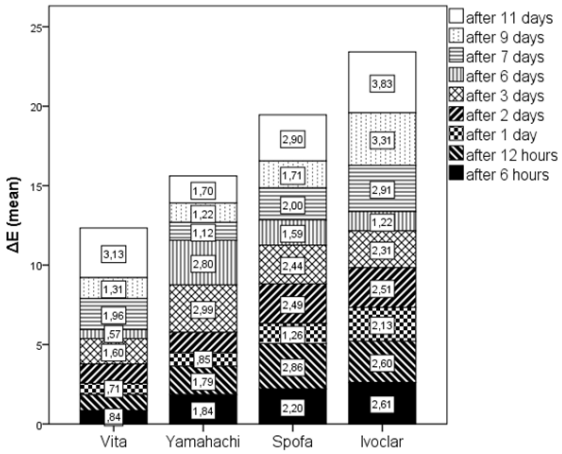

Figure 2.

Colour changes progress for each set of teeth

Table II

Comparative analysis of the teeth sets regarding the staining susceptibility

ΔE	initial - 6 h	6 h – 12 h	12 h - day 1	day1 - day 2	day 2 - day 3	day 3 - day 4	day 4 - day 7	day 7 - day 9	day 9 - day 11	initial - day 11
χ^2	9.06	10.18	4.53	6.50	5.87	14.71	2.73	7.78	5.60	6.54
df	3	3	3	3	3	3	3	3	3	3
p	0.028	0.017	0.210	0.089	0.118	0.002	0.434	0.051	0.133	0.088

Grouping Variable: teeth set by manufacturer; Kruskal - Wallis Test

Analysis of the staining effect of the various dietary and oral antiseptic agents. The artificial teeth that were immersed in distilled water and chlorhexidine experienced the least colour variations, while coffee (especially espresso type) and red wine expressed the highest colour. Similar to previous results, the initial impact of the colouring agent is a good indicator of the overall colouring effect through a longer exposure (Figure 3). The difference in colour change (ΔE) between the seven colouring agents was not statistically significant (Table III).

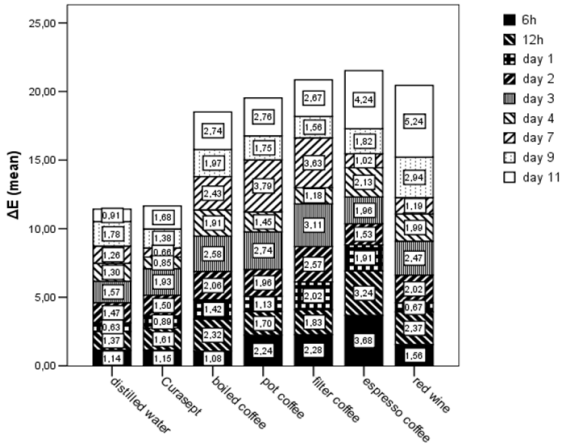

Figure 3.

Colour changes progress for each staining agent

Table III

Comparative analysis of agents tested regarding staining susceptibility

ΔE	initial - 6 h	6 h - 12 h	12 h - day 1	day1- day 2	day 2 - day 3	day 3 - day 4	day 4 - day 7	day 7 - day 9	day 9 - day 11	initial - day 11
χ^2	8.94	5.59	6.50	0.84	3.67	5.13	11.66	3.42	9.87	10.02
df	6	6	6	6	6	6	6	6	6	6
p	0.177	0.470	0.369	0.991	0.721	0.527	0.070	0.754	0.130	0.124

Grouping Variable: colouring agent ; Kruskal - Wallis Test

The acrylic artificial teeth have recorded a high susceptibility to staining in the presence of various colouring solutions (food and oral hygiene products) its pattern being noticed after 6 hours of immersion in the liquid. Artificial teeth from Vita exhibited the lowest coloration susceptibility. Red wine and coffee showed the highest colouring potential, while chlorhexidine mouthwash had similar staining potential to distilled water.

According to this study, staining susceptibility is different for each agent and depends on the duration of exposure. To contextualize the results of this study, the 11 days of the experiment are equivalent to 2 - 2.5 years of coffee consumption (with an average of 1 cup/day), approximate 1.5 years of wine consumption (average intake of 200 mL/day), and approximate 10 years of 0.2% chlorhexidine mouthwashes rinses for one minute twice per day. It can be observed that especially the corresponding duration of exposure for food dyes is lower than the average lifespan of an acrylic denture, which is generally higher than 5 years. Research from other authors also point out that in artificial teeth the food dyes have a high staining effect, discolorations being suspected to reach rather fast a level which is detectable by the human eye [12, 13]. This study suggests that chlorhexidine based mouthwash has a low colouring effect of acrylic teeth compared with food based colouring agents, these results being similar to the ones of Silva *et al.* [14]. Acknowledgment of lower staining potential of artificial teeth compared to natural teeth, under the influence of chlorhexidine mouthwash, acts as a positive recommendation for using it in the cleaning and disinfection process of the acrylic dentures, situation in which the prosthetic device is considered a reservoir of microbial agents, etiologically linked to some conditions as denture stomatitis [15, 16].

All teeth used in this experiment were acrylic teeth, known to present a high susceptibility to discoloration in time. Besides material ageing, another explanation may be linked to the known fact that acrylic polymers absorb water, which reduces the hardness of artificial teeth, favours formation of micro-cracks and lead to a gradual deterioration of their structure over time [17, 18].

Study limitations include the lack of analysis of other numerous suspected colouring agents not included in this experiment, and their possible combined effect. Also, the colouring process for artificial teeth may require a longer period of time due to the intermittent nature of exposure to coloured drinks and the dilution effect that saliva and other fluids may have.

Conclusions

This study confirms that artificial acrylic teeth have a high staining susceptibility to food agents, varying among variants of different manufacturers. Coffee, especially espresso type, has a high colouring potential, while chlorhexidine (an oral antiseptic frequently prescribed) has a lower one, being comparable to the effect of distilled water. The artificial teeth from Vita and Yamahachi showed less colouring effects when compared with those from Ivoclar and Spofa. It is necessary to improve the quality of acrylic artificial teeth, in order to enhance their colour stability, for a good long-term outcome that ensures patient's satisfaction.

Given the relative simplicity of carrying out an initial assessment of staining susceptibility, we suggest the possibility of using it as an individualized approach of selecting the acrylic artificial teeth, based on the anamnesis and the food preferences of each patient. Selecting a set of teeth with higher colour stability and low probability of discoloration to specific food agents generates a better (long term) aesthetic result and improves patient satisfaction.

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