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Colour Stability of Acrylic Resin Denture Teeth After Immersion in Different Beverages

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Abstract - *The colour stability of acrylic resin denture teeth in beverages was investigated. A spectrophotometer measured the colour (CIE-L*a*b* system) of all specimens after storage in distilled water for 24 h at 37°C (T_0). Specimens were then immersed in various beverages. After 15 days (T_1) and 30 days (T_2), for each material, the mean ΔE values were calculated and compared by two-way ANOVA and Tukey intervals (α=0.05). In the ΔT_0T_1 period, specimens stored in red wine were significantly discoloured, compared to distilled water (P=0.003). There was no difference between immersion solutions in ΔET_0T_2 (P=0.772) and in ΔET_1T_2 (P=0.058), and no difference between materials in all immersion periods.*

KEYWORDS: acrylic resin denture teeth, acrylic resin materials, beverages, colour, colour measurement

INTRODUCTION

Polymethyl methacrylate (PMMA) has satisfactory chemical properties for use as denture teeth[1]. It is nontoxic and insoluble in oral fluids. A cross-linking agent is usually added to improve its strength and to prevent crazing[2,3]. Other features of PMMA teeth are the low elastic modulus, hardness[4], low abrasion resistance, and high-impact strength. Colour and blend are desired properties for denture teeth. Sets of anterior and posterior teeth —representing each shade from the same manufacturer— should exhibit no perceptible colour differences between each other or the manufacturer's shade guide[5]. Acrylic resin denture teeth moreover should not become discoloured by the dietary habits of denture wearers since colour stability of dentures is an important factor in treatment acceptance by the patient.

The perception of colour is a physiological response of the human eye to light reflected from an object. Light from an object that is incident on the eye is focused in the retina and is converted into nerve impulses that are transmitted to the brain[6]. Because a neural response is involved in colour vision, constant stimulation by a single colour may result in colour fatigue and may decrease the eye's neural response[6]. Many methods are used to assess colour in restorative or prosthetic dentistry. These range from visual subjective comparisons (using paper, coloured porcelain, or acrylic resin shade guides) to objective instrumental measurements using spectrophotometers[7-14] and colourimeters[15-19]. Instrumental colour analysis offers a potential advantage over visual colour determination because instrumental readings are objective, can be quantified, and are more rapidly obtained[20]. Spectrophotometers measure one wavelength at a time from the reflectance or transmittance of an object and have been used to measure the visible spectra of extracted and vital teeth[8].

Colour measurement has been classified by several systems[21-24]. Two most widely used systems for describing colour are the Munsell System and the (CIE, Commission International de I´Eclairge [International Commission on Illumination]) colour/order system. The Munsell system describes colours in a three-dimensional coordinate scheme of hue, value, and chroma. Within the Munsell system, the colour tree is a representation of the tridimensional organisation of the colours[24]. Hue is a feature of a colour that enables distinguishing between different families of colour (e.g. red, blue, and green). Value indicates the lightness of a colour and ranges from pure black to pure white. Chroma is the degree of colour saturation and expresses the strength, intensity, or vividness of a colour[8]. In the CIE concept, all colours can be matched by mixing relative amounts of the 3 primary colours: red (*X*), green (*Y*) and blue (*Z*). The *X*, *Y*, and *Z* values can be mathematically converted to CIE L*a*b*[25]. The CIE L*a*b* system relates colour parameters to human colour perception in three dimensions or directions of colour. In this system, colours are defined by three coordinates of the three axes: L* (i.e. 'lightness') ranges from zero (black) to 100 (white); a* represents colour and saturation on the red-green axis; and b* delineates colour and saturation on the blue-yellow axis[21-24].

Poor colour stability of materials for prosthodontics may lead to patient dissatisfaction and additional replacement expense. Extrinsic factors for discolouration of dental materials include staining by adsorption or absorption of colourants from exogenous sources[26,27]. The extent of discolouration in the oral cavity may be associated with dietary habits[3]. Some authors have reported colour changes and staining of acrylic denture teeth materials that are under conditions of accelerated aging and exposure to oral fluids; however, few references exist in the literature

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concerning colour stability of acrylic resin denture teeth after immersion in different beverages[17,27]. Millstein et al.[28] showed that denture base materials create a measurable change in the chroma of acrylic resin denture teeth, and they suggest that the optimal shade selection of teeth should include a determination of the background effects of denture base materials. Satoh et al.[17] investigated the susceptibility of high-strength plastic teeth to pigments by immersing them in colouring liquids. The authors found that conventional acrylic resin denture teeth are inferior to porcelain teeth in maintaining an adequate aesthetic appearance with wear and discolouration, and thus have a shorter period of durability. Mutlu-Sagesen et al.[27] reported that 6 groups of acrylic denture teeth exhibited staining after immersion them in coffee, tea, or cola.

This study was undertaken to determine the colour stability of 3 acrylic resin denture teeth by subjecting them to several beverages. The null hypothesis was that acrylic resin denture teeth would not discolour after immersion in the beverages.

MATERIALS AND METHODS

Three brands of artificial denture teeth were used, Trilux, Biotone, and Artiplus. Each specimen was the upper right central incisor tooth (A 2.0 shade). Twenty specimens of each brand were immersed in distilled water for 24 h at 37°C before testing[21]. The sample size was determined by power analysis.

Initial colour was measured at 24 h (i.e. T_0) after immersion in distilled water. The specimens were then randomly divided into 4 groups (n = 5) for tests. They were immersed in solutions of coffee (Nescafé Tradição), cola (Coca-Cola), red wine (Vinho Tinto Seco Campo Largo), or distilled water (which served as a control). These solutions were selected because they cause heavy staining of dental composites[27]. The coffee solution was prepared from 300 mL of distilled water with 3.6 g of coffee, based on the concentration suggested by the manufacturer[22,26]. Each specimen was suspended in the solution by dental floss so that the specimen did not contact the container[2,22]. At 15 days (T_1) and at 30 days (T_2) after the start of immersion, the colouring conditions were observed. The distilled water or beverages were discarded and replaced daily. For all groups, each specimen was washed in distilled water, and dried with absorbent paper before the reading of the colour in a spectrophotometer[29].

Colour changes (ΔE) were calculated by using the Commission International de I´Eclairge L*a*b* (CIE L*a*b*) uniform colour scale systems[23-25]. Colour values (L*, a*, and b*) of each specimen were measured by a spectrophotometer (ColorQA) with data processor and software (ColorQA Pro III) that was connected to the spectrophotometer. The measuring characteristics of the spectrophotometer were standard illumination, D65 bright light-emitting diode (LED)[16]; 400-nm to 700-nm spectral width[7]; and a measurement area of approximately 7 mm. Specimens were positioned in the same manner by using a device fabricated in the acrylic resin that was used to standardise the measurement area and avoid variations in colour[14].

Before colour measurements, the spectrophotometer was calibrated by using the supplied white calibration standard. Ten repeated measurements of each specimen were performed to obtain the mean. The colour difference (i.e., ΔE) for each specimen was calculated from the mean ΔL*, Δa*, and Δb* values with the formula: $\Delta E = \frac{1}{2}[(L_1 - L_0)^2 + (a_1 - a_0)^2 + (b_1 - b_0)^2]$[1,21-23].

Statistical analysis was performed within each immersion period by two-way analysis of variation (ANOVA) (Tables 1–3) and by the Tukey multiple comparisons test ($\alpha = 0.05$). In addition to the statistical analysis, the value of each ΔE was multiplied by 0.92, based on the National Bureau of Standards (NBS) specification, to determine what an observer may report regarding acrylic resin denture teeth colour changes after immersion in beverages[1,21,23]. This NBS rating system is based on how the human eye evaluates a colour change (Table 4).

RESULTS

Tables 1–3 present the results of the ANOVA. In ΔET_0T_1, the most severe discolouration was apparent with red wine ($P = 0.005$), compared to the specimens stored in distilled water; this was independent of the brand of acrylic resin denture teeth (Fig. 1). There was no difference between the immersion solutions in ΔET_0T_2 ($P = 0.772$) (Fig. 2) or in ΔET_1T_2 ($P = 0.058$) (Fig. 3). In ΔET_0T_1, the Artiplus teeth presented significant colour alterations after immersion in cola, compared to the control substance ($P = 0.044$). For all immersion periods, there was no difference between the materials ($P = 0.677$ for ΔET_0T_1; $P = 0.232$ for ΔET_0T_2; and $P = 0.222$ for ΔET_1T_2).

Based on the NBS criteria, it was possible to observe ΔET_0T_1, which ranged from 4.67 to 10.02; ΔET_0T_2, which ranged from 7.53 to 12.53; and ΔET_1T_2, which ranged from 3.53 to 6.44 (Table 4). These colour alterations ranged from 'perceivable to the human eye' to 'change to other colour'.

DISCUSSION

Denture tooth shade selection in clinical practice focuses primarily on shade matching the artificial teeth to a patient's existing teeth or to a patient´s characteristics[28]. The dietary habits of denture wearers should not promote any perceptible colour change in the artificial teeth. Extrinsic factors for artificial teeth discolouration include staining by coloured solutions, aliments, and nicotine[3,11]. A spectrophotometric measuring technique was used to determine the colour changes of three acrylic resin denture teeth after immersion in beverages. In the present study, the null hypothesis was rejected, which indicated that acrylic resin denture teeth became discoloured after immersion in beverages. The greatest colour change in the acrylic resin denture teeth occurred with red wine solution. Cola also resulted in a colour change for the Artiplus specimens. The highest colour difference occurred with the red wine groups in all acrylic resin denture teeth. Similar findings have been noted in previous studies[30]. In one study, red wine, tea, coffee, mouth rinse, and ultraviolet irradiation were used as staining agents to evaluate the stainability of composite materials; of these, red wine caused the most severe discolouration[18].

Several studies report that alcohol facilitates staining by softening the resin matrix. Therefore, it is possible that

Table 1. *Results of 2-way ANOVA of ΔET_0T_1 test for acrylic resin denture teeth.*

Source	SS	***df***	MS	F	*P*
Acrylic resin denture teeth	5.06	2	2.53	0.36	0.696
Beverages	91.73	3	30.58	4.40	0.008
Acrylic resin denture teeth*Beverages	105.50	6	17.58	2.53	0.033
Error	333.46	48	6.95		
			2.64		

SS: Sum of Squares, *df*: Degrees of freedom, *MS*: Mean square, *F*: Fisher.

Table 2. *Results of 2-way ANOVA of ΔET_0T_2 test for acrylic resin denture teeth.*

Source	SS	***df***	MS	F	*P*
Acrylic resin denture teeth	18.01	2	9.01	1.41	0.253
Beverages	9.05	3	3.02	0.47	0.702
Acrylic resin denture teeth*Beverages	103.65	6	17.27	2.71	0.024
Error	305.85	48	6.37		
			2.52		

SS: Sum of Squares, *df*: Degrees of freedom, *MS*: Mean square, *F*: Fisher.

Table 3. *Results of 2-way ANOVA of ΔET_1T_2 test for acrylic resin denture teeth.*

Source	SS	***df***	MS	F	*P*
Acrylic resin denture teeth	10.11	2	5.06	1.48	0.237
Beverages	27.24	3	9.08	2.66	0.058
Acrylic resin denture teeth*Beverages	24.34	6	4.06	1.19	0.328
Error	163.68	48	3.41		
			1.85		

SS: Sum of Squares, *df*: Degrees of freedom, *MS*: Mean square, *F*: Fisher.

Table 4. *NBS rating*

0.0 – 0.5	Extremely slight change
0.5 – 1.5	Slight change
1.5 – 3.0	Perceivable change
3.0 – 6.0	Marked change
6.0 – 12.0	Extremely marked change
12.0 - or more	Change to other colour

the alcohol component in wine roughens the composite surface, thereby resulting in increased staining[30]. Since the pH of red wine is approximately 3.7, it is possible that the acidic pH may have had a further deleterious effect on the structure of the materials[31]. A decrease in the quality of a polymer's properties can be expected when low pH solutions are used for immersion since a low pH increases the erosion of the polymers[32]. These possible surface alterations may have favoured the adsorption of natural and artificial colourants on the polymer's surface.

In the present study, the acidic pH of the cola beverage may have been responsible for the discolouration in the Artiplus sample after immersion[11]. Cola reportedly provokes great colour changes in porcelain teeth[20] and decreases the gloss value of heat-polymerised acrylic resin samples[20]. Because cola is an aqueous solution, water sorption may be an additional explanation for colour changes resulting from immersion in this beverage[2].

The results of this study also showed colour change differences for each brand of artificial teeth. The PMMA teeth evaluated in this study had similar chemical structures but different quantities of cross-linking agents, plasticising, and pigments. Colour change may alter the organic matrix; inhibition, hydrolysis, and breakdown of polymeric chains may divide the main chains and separate cross-links, which may explain these differences[14,33]. The addition of cross-linking agents to the acrylic resin could enhance the copolymerisation of methyl methacrylate, thereby resulting in less residual monomer and consequently decreasing the amount of released residual monomer[29]. As a result, the denture teeth displayed enhanced stability and improved clinical properties.

With respect to the brand Artiplus, Campanha et al.[4] investigated the hardness of 5 acrylic resin denture teeth

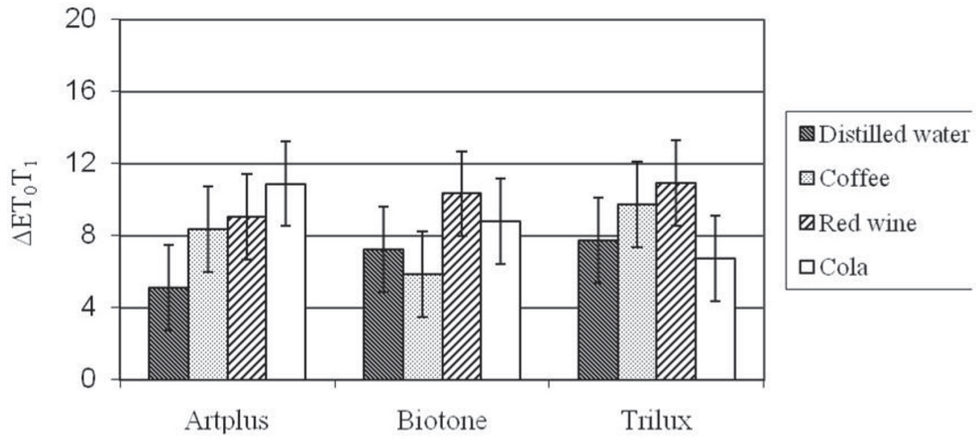

Figure 1. *Changes in colour between the period T_0T_1 (i.e. initial [before immersion] and 15 days of immersion).*

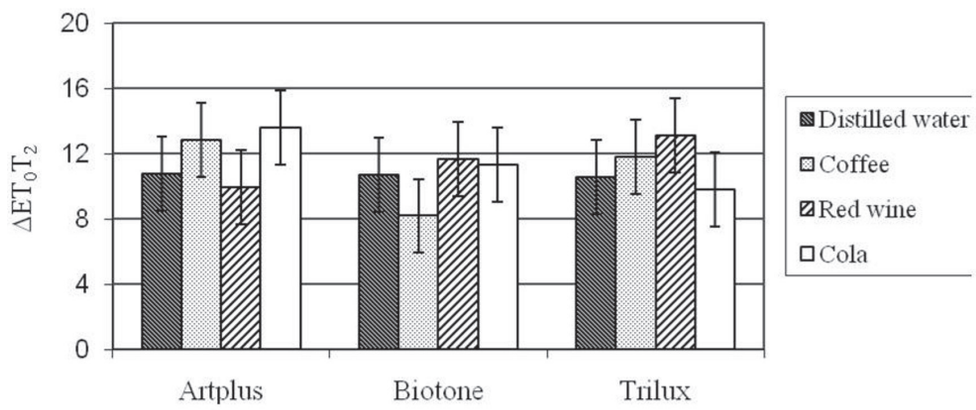

Figure 2. *Changes in colour between the period T_0T_2 (i.e. initial [before immersion] and 30 days of immersion).*

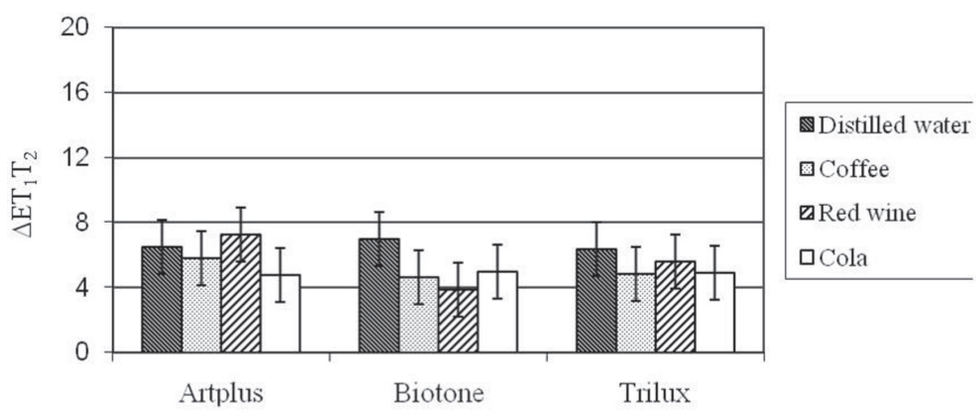

Figure 3. *Changes in colour between the period T_1T_2 (i.e., 15 and 30 days of immersion).*

(including Artiplus) that were stored in distilled water and then subjected to microwave sterilisation. These authors found this brand of tooth significantly softened, compared to the control specimens. This suggests the hydrophilicity of this material. Keyf and Etikan[26] also revealed gloss changes resulting from the testing process in denture base acrylic resins after immersion in water. Significant colour changes exhibited by acrylic resins may result from water sorption[23]. Water sorption may decrease the service life of resin composites by expanding and plasticising the resin component, hydrolysing the silane, and causing microcrack formation[31]. Therefore, discolouration by aqueous beverages may be explained by the adsorption of polar colourants onto the surface of materials. Cola moreover gains its colour through the addition of caramel, which ranges in colour from the palest yellow to the deepest brown and is made by heating sugar or glucose in the presence of an alkali or a mineral acid[11]. Thus, colour alterations caused by cola may be attributable to the absorption of water or to the adsorption of colourants.

The current study concentrates on the staining effects of coffee. In a previous study, Um and Ruyter[3] showed that the soluble components of coffee with blue absorption appeared as yellow colourants since yellow is the complementary colour to blue. Different reverse-phase liquid chromatographic retention times for these components reveal that the yellow colourants have different polarities. Lai et al.[10] showed colour changes in silicone and copolyamide materials that were stored in a coffee solution for 180 days. Mutlu-Sagense et al.[27] show that coffee is the most staining solution and has the highest discolouration value. In the present study, the specimens immersed in coffee significantly exhibited the least colour change for each period. The contrasting results of the present study to the other studies may be attributable to differences in the testing environments used in the studies such as the concentration of coffee, duration of immersion, temperature of the solutions, addition of sugar, and colourimetric instruments[22].

Discolouration can be evaluated visually and by instrumental techniques[8,9]. The visual colour process is affected by many factors such as the experience of the observer, lighting, and individual differences in understanding and perceiving colour[8,20]. Using colour-measurement equipment makes it possible to overcome these basic difficulties of colour evaluation[2]. This is why spectrophotometer technique was used in this study.

The colour system employed in the present analysis was the CIE L*a*b* system[18,19]. The CIE L*a*b* system is a uniform three-dimensional system that determines colour change. It is widely used to determine chromatic differences and is more advantageous than the Munsell colour system[1]. Various studies report different thresholds of colour difference values above which the colour change is perceptible by the human eye. These threshold values were ΔE of 3.3 or higher[12]. However, there is some controversy in the literature with regard to which ΔE values can actually be perceived by the naked eye or are clinically relevant[18]. One study used the ΔE threshold value of 6.7 for clinical acceptance[15]. By viewing various criteria for the clinical acceptance of colour difference and by applying ΔE values between 3.53 and 12.53 to the results of this study, most colour differences caused by the beverages were in the category of 'marked change' or 'change to other colour', based on the NBS system. This demonstrates that the colour alterations are perceptible to the human eye.

The extent of clinical relevance of these results is unclear since it cannot be assumed that acrylic resin denture teeth will be in such long-term contact in the oral cavity with a substance containing a colouring agent. In daily clinical practice, there are a great many complaints about the discolouration of acrylic resin denture teeth. Therefore, within the limitations of this study, red wine caused the greatest chromatic changes, followed by cola. This *in vitro* study may indicate how acrylic resin denture teeth may perform in the oral environment, based on a patient's dietary habits (especially the consumption of beverages). When one of these materials is used for denture teeth, the patient should be informed about possible colour changes caused by red wine.

CONCLUSIONS

Within the limitations of this *in vitro* study, it can be concluded that some complaints about discolouration of acrylic resin denture teeth in daily clinical practice can be attributable to the excessive consumption of red wine or cola, and to a lesser extent, coffee.

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MANUFACTURERS' DETAILS

- Artiplus (Artiplus; Dentsply Industria e Comercio Ltda., Petrópolis, RJ, Brazil)
- Biotone (Biolux; Dentsply Industria e Comercio Ltda., Petrópolis, RJ, Brazil)
- Coca-Cola Company (Curitiba, PR, Brazil)
- ColorQA (PocketSpec, Denver, CO)
- ColorQA Pro III (PocketSpec, Denver, CO)
- Nescafé Tradição (Nestlé Brazil Ltda., Araras, SP, Brazil)
- Trilux (Dental Vipi, Pirassununga, SP, Brazil)
- Vinho Tinto Seco Campo Largo (Vinícula Campo Largo, Campo Largo, PR, Brazil)

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