COLOR CHANGE IN ACRYLIC RESIN PROCESSED IN THREE WAYS AFTER IMMERSION IN WATER, COLA, COFFEE, MATE AND WINE

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ABSTRACT

*Denture bases may undergo color change over time induced by pigment accumulation within their body; however there is a lack of information regarding the role of yerba mate tea in this process. This work evaluated the effect of five common beverages, including yerba mate tea, on color changes of acrylic denture base resins processed in three different ways. Three different processing techniques were used (P1 - microwave irradiation / microwave activated resin; P2 – heat polymerization / conventional heat activated resin and P3 - microwave irradiation / conventional heat polymerized resin) to make twenty five resin discs each (3.0 mm thick x 20 mm diameter), totaling seventy-five resin discs. The discs made with each technique were randomly divided into five groups (n=5) and placed in the following solutions: G1-water; G2-cola; G3-coffee; G4- yerba mate tea; G5- red wine, for 30 days at 37ºC. The solutions were renewed every 3 days. Color change on the CIE-L*a*b* scale was measured with a Konica-Minolta CR-10 colorimeter and compared with original L* a* and b* values of each specimen prior to immersion. Data were analyzed using 2-way ANOVA, and showed no difference among techniques and significant statistical differences among solutions (p<0.05). Tukey´s post-hoc test showed that the lowest color changes were for water and cola, which were undistinguishable from each other; coffee produced the second lowest color change; yerba mate tea produced second greatest color change, while the greatest color change was produced by red wine. Within the limitations of this study, it was concluded that almost all the solutions used can change color in acrylic resin, especially yerba mate tea, considered distinguishable by professionals, and red wine, considered distinguishable by patients and clinically unacceptable.*

Keywords: *acrylic resins; denture bases; dental prosthesis coloring.*

ALTERAÇÃO DE COR EM RESINAS ACRÍLICAS PROCESSADAS DE TRÊS MEIOS DIFERENTES IMERSAS EM ÁGUA, REFRIGERANTE, CAFÉ, CHIMARRÃO E VINHO

RESUMO

*As bases protéticas em resina acrílica podem sofrer alteração de cor com o tempo em função do acúmulo de pigmentos em seu interior, porém há carência de informação sobre o efeito do consumo de chimarrão neste processo. Este trabalho avaliou o efeito de cinco bebidas diferentes, incluindo chimarrão, na cor de resinas acrílicas processadas por três técnicas diferentes. Vinte e cinco discos de resina acrílica (3 mm de espessura x 20 mm de diâmetro) foram fabricados a partir de cada uma das técnicas de processamento (P1 – polimerização por microondas / resina termopolimerizável por microondas; P2 – termopolimerização convencional / resina termopolimerizável convencional e P3 – polimerização por microondas / resina termopolimerizável convencional). Os discos foram aleatoriamente divididos em cinco (n=5) grupos por técnica: G1 – água; G2 – refrigerante à base de cola; G3 – café; G4 – chimarrão e G5 – vinho tinto, e foram mantidos imersos em cada uma das respectivas soluções por 30 dias a 37 ºC, com trocas das soluções a cada 3 dias. A cor final foi medida na escala CIE-L*a*b* com um colorímetro Konica-Minolta CR-10 e comparada com os valores originais de L*a*b* prévios à imersão de cada corpo-de-prova. Análise de Variância para dois fatores não encontrou diferenças entre as técnicas e apontou diferença estatisticamente significativa (p<0,05) entre as soluções. Teste complementar de Tukey mostrou que as menores variações de cor ocorreram para água e refrigerante à base de cola; o café apresentou a segunda menor variação de cor; o chimarrão apresentou a segunda maior variação enquanto a maior variação de cor foi encontrada para o vinho tinto. Conclusões: Concluiu-se que quase toda solução utilizada provoca mudança de cor nas resinas acrílicas, principalmente com chimarrão e vinho, consideradas distinguíveis por profissionais e clinicamente inaceitáveis respectivamente.*

Palavras-Chave: *Resinas acrílicas, bases protéticas, pigmentação em prótese dentária, cor.*

INTRODUCTION

Removable prosthesis, total or partial, usually have acrylic resin bases to enhance prosthesis support and keep the artificial teeth in position[1]. These bases contribute to aesthetics and functional rehabilitation and may interfere in patient acceptance regarding the service[2]. Acrylic resin is considered a good base material because it is cheap, may be relined, has good aesthetic appearance and low density[3,4]. Despite these advantages, the polymerization technique may induce porosity inside the resin body[2,3,5,6] which may allow sorption of pigmented liquids such as tea, wine, grape juice, cola and coffee, among others[2,7-9]. This process of absorption and adsorption of liquids depends upon environmental conditions and can rapidly change aesthetic, physical and mechanical properties[10]. Among the polymerization techniques, some are relevant because of their widespread use, such as heat polymerization, or because of their ease of processing, such as microwave polymerization.

The continued sorption of pigmented liquids may change the color of prosthesis bases. However, visual determination of this change is usually unreliable and subjective[2]. In 1976, the International Commission on Illumination (*Commission Internationale de l'Eclairage – CIE)* developed a 3-dimensional color space based on axis "L" ("black"(0) to "white"(100) values); "a" ("green"(negative) to "red"(positive) values) and "b" (blue to yellow values)[11] called CIE-L*a*b* scale, which covers all colors visible to the human eye and allows studies in color difference in dental materials[12]. The amount of color change may be described by the ΔE, which shows the distance between two given colors in this space. This scale has been used in several studies of acrylic resin color stability in contact with pigmented liquids[2,8,9,13-15]. However, few studies have evaluated the color stability of conventionally heat polymerized acrylic resin processed by microwave energy or the effect of a beverage that is gaining market share worldwide and is common in southern regions of Brazil and South America - *yerba mate* tea (*Ilex paraguariensis*)[16], on resin color change. The aim of this work was to evaluate three processing techniques (P1 - microwave activation with microwave heat polymerized resin; P2 – conventional thermal activation with conventionally heat polymerized resin and P3 - microwave activation with conventionally heat polymerized resin) and five solutions (G1-water; G2-cola; G3-coffee; G4- *yerba mate* tea; G5-wine) on the color stability of acrylic resin. The null hypotheses, both with reference to ΔE, are: a) there is no difference among techniques and b) there is no difference among solutions.

MATERIALS AND METHODS

Two polymerization activation methods (conventional heat activation - CT - and microwave heat activation - MT) and two kinds of acrylic resins (conventionally heat polymerized – CR -"Clássico" (Artigos Odontológicos Clássico Ltda. - Campo Limpo Paulista – SP - Brazil) and microwave heat polymerized – MR – "Onda-cryl" (Artigos Odontológicos Clássico Ltda. - Campo Limpo Paulista – SP - Brazil)) were used in this study and combined as described below.

Seventy five discs, (3.0mm thick x 20.0 mm diameter), were made from putty silicon Zetalabor (Zhermack - Borda River, New Jersey, USA). These discs were randomly divided into three groups of twenty five and invested in gypsum (Vigodent S/A Ind. e Com. - Rio de Janeiro – RJ Brazil) using flasks as described in Table 1. Then they were removed from the gypsum and in its place was compressed acrylic resin, which was processed after compression. The resins were mixed with the powder/liquid ratio recommended by the manufacturer and processed according techniques described in Table 1.

After polymerization, specimens were left to rest until they acquired room temperature, uninvested, finished with Maxicut burs (Vortex – São Paulo – SP – Brazil) and polished in a mechanical polisher with water/pumice followed by water/calcium carbonate pastes. Then they were stored for 48 hours in distilled water at 37ºC to eliminate residual monomers.

Table 1: Combinations of resins and activation methods.

Group	Material Used	Equipment and activation method	Polymerization Cycle
P1	Microwave Heat Polymerized Resin (MR)	Plastic flask; Microwave oven (MT)	3 min. at 480 W; 4 min. rest and 3 min. at 960 W
P2	Conventional Heat Polymerized Resin (CR)	Metallic flask, Conventional Thermal Bath (CT)	2 hours at 68 ºC ; 1 hour at 100 ºC
P3	Conventional Heat Polymerized Resin (CR)	Plastic flask; Microwave oven (MT)	3 min. at 480 W; 4 min. rest and 3 min. at 960 W

The discs from each processing technique were randomly divided into five groups (n=5) and their color was measured (three readings per disc) on the CIE-Lab scale with a Konica-Minolta CR-10 colorimeter by a blinded investigator. Next they were immersed at 37ºC for 15 days in five different solutions, which were renewed every 3 days: G1-water; G2-cola; G3-coffee (30 g powder / 600 ml water infusion defined by a pilot study) (Utam, Ribeirão Preto, SP, Brazil); G4- *yerba mate* tea (75g fragmented leaves / 500 ml water infusion, defined in a pilot study) (Madrugada, Venâncio Aires, RS, Brazil); G5- red wine (Reserve Cabernet Sauvignon, Concha y Toro, Santiago, Maipo Valley, Chile). After this time, the discs were washed in distilled water and their color was again measured and the ΔE calculated based on original L* a* and b* values of each specimen. The freeware GMC software was used to perform the statistical analysis.

RESULTS

Mean original values are shown in Table 2. Preliminary data analysis showed normal, but not homogeneous, distribution. Data were transformed (log (10.data)) and then presented normal and homogeneous distribution. Means and standard deviation (SD) of transformed data are shown in Table 3.

Table 2: Mean values of original ΔE data.

Group	P1	P2	P3
G1	0.75	0.85	0.53
G2	0.81	0.85	0.95
G3	1.07	1.19	2.24
G4	2.35	1.94	2.47
G5	3.79	3.29	3.97

Two-way ANOVA was used (processing technique and solution) on transformed data and showed no statistical difference in processing technique (P1=P2=P3). The test showed statistical difference among solutions ($p<0.05$). Tukey´s test showed that all solutions, except cola, differed from the control group and among each other. This allowed us to organize the means of transformed data in increasing order, as follows: G1=G2 < G3 < G4 < G5. A graph (Fig. 1) was built to see the interaction between solutions and processing techniques.

DISCUSSION

The mean values of the original data were used as discussed to allow perception of the clinical relevance of statistical results. In order to better relate the ΔE to clinical implications according National Bureau of Standards (NBS), the ΔE were transformed by the formula NBS unit = ΔE x 0,92[2,11,17]. Table 4 shows the NBS units obtained this way, while table 5 shows the NBS classification[2, 11].

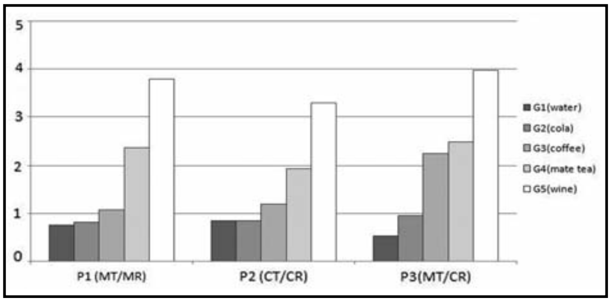

Fig. 1: Mean ΔE values according to solution and processing technique, concerning polymerization (MT- microwave heat activation; CT- conventional heat activation) and materials used (MR- microwave polymerized resin; CR- conventionally polymerized resin). This figure shows that the color change produced by coffee was much higher in P3 than in P1 and P2, which may indicate interaction between coffee and the P3 technique.

Table 3: Mean values and SD of transformed ΔE data.

Group	P1	P2	P3	Mean	Grouping
G1	0.93 (0.16)	0.98 (0.20)	0.80 (0.20)	0.90 (0.20)	a
G2	0.96 (0.23)	0.98(0.12)	1.02 (0.20)	0.98 (0.18)	a
G3	1.07 (0.16)	1.11 (0.09)	1.37 (0.23)	1.14 (0.18)	b
G4	1.39 (0.10)	1.31 (0.12)	1.41 (0.12)	1.40 (0.12)	c
G5	1.59 (0.18)	1.53 (0.14)	1.61 (0.06)	1.60 (0.13)	d
Mean	1.19 (0.3)	1.18 (0.3)	1.24 (0.3)		
Grouping	e	e	e		

In this study we used the CIE-Lab scale, where (L) represents luminescence and varies from 0 (black) to 100 (white); (a) values represent the green-red axis and (b) values represent the blue-yellow axis. Distances between two points (ΔE) on this scale may be calculated with the equation $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{0,5}$, which represents the hypotenuse of a right-angled triangle in a three-dimensional space.

Acrylic resins may absorb water or aqueous solutions, and pigments dissolved in these solutions (a common phenomenon occurring in most of the beverages) may be carried into the resin body[2,8,18], so patients' drinking habits may cause the color of their prosthesis bases to change. This absorption occurs mostly due to hydrophilic nature of polymethylmethacrylate (PMMA) and the porosity created when the resin body is heated above 100.8 ºC, volatilizing some of its monomers or low molecular weight compounds[3,5,6]. Other factors may be related to color change in acrylic resins, such as surface roughness, oxidation, dehydration, water absorption, product degradation and chemical degradation[2,19].

Some papers used sample sizes that were the same as or lower than ours[8,9,14,20] while others used slightly larger sample sizes[1,11,21]. We used three-millimeter thick resin discs as did others studies[2,9,22]. This thickness does not match ADA specification No. 17[8], but was used because it is closer to the thickness found in areas of denture bases that are most susceptible to porosity caused by an increase in heat[5]. To avoid porosity, microwave activated acrylic resins usually include in their composition monomers such as triethylene or tetraethylene glycol dimethacrylates[23]. These dymethacrilates have low vapor pressure when compared with polymethilmethacrylates[5,23]. Nevertheless, in our study, all the processing techniques showed the same behavior regarding ΔE, even when conventional heat polymerized resin was activated with microwave energy. However, specimens thicker than three millimeters, as may occur in some denture base areas, may lead to greater porosity[3,5] and pigmentation of resins this thick are a potential study object in the future. Others studies using a single variation factor may be needed in order to better understand this influence.

When comparing solutions, similar behavior was observed in cola and distilled water, both classified as slight change rate according to National Bureau of Standards (NBS)[2,11]. This agreed with the findings reported by Guler et al,[24] for composite provisional restorative materials. Although coffee showed greater ΔE than cola and water, its mean value (1.41) was within the acceptable limit between one and two points[8, 25, 26] and its NBS unit (1.39) can also be classified by NBS as slight change[2, 11]. However it may be noted in Figure1 that coffee, when processed by T3, had a mean value of 2.24, which is higher than the 2.0 value specified by Xu et al.[26] as distinguishable by professionals and within the range of perceivable change according to NBS[2,11].

Table 4: Means values of NBS units.

Group	P1	P2	P3	Mean
G1	0.69	0.79	0.49	0.66
G2	0.75	0.79	0.88	0.81
G3	0.99	1.09	2.07	1.39
G4	2.17	1.79	2.27	2.08
G5	3.49	3.03	3.66	3.39

Table 5: NBS rating system for expressing color difference.

NBS Units	Critical remarks on color difference
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 color

Yerba mate tea reached the NBS classification of a perceivable change[11,26], without reaching the critical ΔE value of 3.3 points, which is considered easily observable and clinically unacceptable[8,11,25-27].

Yerba mate tea has no other leaf processing than drying and fragmentation, which may lead to a greater concentration of pigments in its solution. In this sense, our results are similar to the findings that tea has greater pigmentation potential than coffee[18,20,28] but different from those of Imirzalioglu et al., 2010[8], which found that pigmentation by tea was insignificant. The kind of tea and leaf processing used may be the object of a future study in order to clarify these differences.

Red wine had the greatest ΔE of all the solutions tested, higher than the 3.3 critical value, as found in others studies[2,13,24,28] and higher than the NBS "marked change" rating. Alcohol and pH maybe explain this finding, because they may degrade resin structure and potentiate pigmentation[2,21].

Our study was based on the abovementioned hypothesis that porosity, among others factors, may affect the color of resins by absorption of beverages[3,5,6]. However, we did not measure porosity caused by the different techniques used, which may be understood as a limitation of the study. Furthermore, despite the agreement of our results with others found in the literature, it is important to note that the clinical relevance of the beverages drunk by patients also depends on how often they are drunk and how much is drunk at a time. Thus, any given beverage does not necessarily affect the aesthetic aspect of a prosthesis in the same way as in this study. Since the high frequency/amount of a given beverage may be more relevant than the beverage itself, other studies may be conducted in order to clarify this aspect.

Within the limitations of this study, it can be concluded that:

a) The tested polymerization techniques make no difference to color change of acrylic resins, showing that any of them can be used without concerns regarding color change;
b) Cola and coffee produced an acceptable color change of acrylic resins. Cola was below the human perception limit (0.87) while coffee was below the trained eye perceptible limit (1.41);
c) *Yerba mate* tea produced a color change (2.25) distinguishable to trained eyes, but which cannot be considered clinically unacceptable or perceivable by patients;
d) Red wine produced the greatest (3.68) color change, which is considered clinically unacceptable and distinguishable by patients. However it may be noted that consumption habits may ultimately change these findings.

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