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Evaluation of color alteration of heat-polymerized acrylic resin

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Abstract

The present study investigated the color alteration of heat-polymerized acrylic resin specimens exposed to 7 staining solutions (black tea, green tea, coffee, Pepsi, tomato paste, cigarette and diet Pepsi) for two weeks and compared with that exposed to distilled water. Five specimens were used for each group. The specimens were of rectangular shape measuring 5mm width, 40mmlength and 2mm thickness. After the two weeks the light transmission percent values for each specimen were determined by a spectrophotometric device. The result of this study revealed that the distilled water specimen group had the highest mean value of light transmission followed by diet Pepsi and Pepsi groups, coffee group had the lowest one. Further, coffee had a staining effect on resin specimens more than tea, cigarette and tomato paste group. In addition this study showed that resin specimens discolored by black tea more than green tea.

Key words: color alteration, heat-polymerized acrylic resin, denture discoloration.

Introduction

Acrylic plastic have been the most widely used & accepted among all denture base materials and it was estimated that they represent 95% of the plastics in prosthodontics [1,2].

Acrylic resin is a low cost material that requires relatively easy manipulation and construction methods. Discoloration of acrylic resins results in esthetic problems & a denture base polymer should have good esthetics with a smooth & glassy surface & be acceptable of matching the natural appearance of the soft tissues.

For the best esthetic effect, the material should be translucent. Color & translucency should be maintained during processing, and these resins should not get stained or change color in clinical use. The color stability & stain resistance criteria may provide important information on the serviceability of these materials [3,4].

Many studies have been reported on discoloration characteristics of resin-based dental restorative materials [5]. Color changes of denture base materials during exposure to oral fluids, and denture cleaners have been reported [6].

Polymethylmethacrylate absorbs water slowly overtime [7] and there is evidence that beverages such as tea, coffee and wine significantly increase the development of stain on enamel & acrylic resin[8] . However, there is no report on discoloration of denture base

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materials in newly daily used healthy beverages such as green tea or diet Pepsi.

Tea is an infusion of the leaves of the camellia sinensis plant; different processing methods produce different types of tea. It is the most widely consumed beverage in the world, aside from water [9].

Today, people intends to drink tea daily for its health benefits, Black tea and its components benefit oral health by interfering with the harmful plaque bacteria in the mouth that cause gum disease and cavities[10]. Tea contains fluoride and its levels in green and black teas are generally comparable to those recommended for the prevention of dental caries [9]. Also , it can be useful in treating headaches and decreases the risk of myocardial infarction, osteoporosis, kidney stones, obesity and some types of cancer but its excessive consumption is not recommended [9,11]. Today, almost two-thirds of the world's population consumes tea in different forms (78% black, 20% green and 2% oolong tea). A Japanese longevity study suggested that regular green tea consumption could contribute to an extended life span [11].

Also coffee has health benefits in addition to CNS stimulation, it may reduce the risk of developing gall stones, kidney stones and colorectal cancer but it may be considered as a risk factor for coronary heart diseases [12].

Pepsi is a carbonated beverage contains large amounts of sugar which is a leading contributor to tooth decay and diabetes [13].

Diet Pepsi is a low-calorie carbonated cola introduced as a variant of Pepsi-cola with no sugar but contains the artificial sweetener aspartame which has been the subject of a vigorous public controversy regarding its safety [14], few studies showed that daily consumption of aspartame can cause sever damage to DNA which can lead to cancer and degenerative brain disorders later in life [13].

In addition, drinks diet Pepsi over a long period of time can erode teeth enamel because is acidic so drinking through a straw is often advised by the dentists to avoid contact with the teeth, also they recommend to avoid teeth brushing after drinking soft drinks as it can result in additional erosion to the teeth[14].

Cigarette is a product consumed through smoking and manufactured out of tobacco leaves, despite widespread coverage of health effects of cigarettes smoking, peoples used it as a lucrative business or trendy habit specially by those psychological distressed adults [15,16].

Colorimeter is a branch of color science & is based on the digital expression of the color perceived from the object[17].

Color stability is a required characteristic of denture base resins, as specified by various national & international standards and may provide important information on the serviceability of these materials [3]. Therefore, the purpose of this in vitro study was to investigate the color stability & translucency of heat-polymerized acrylic resin by measuring the light transmission through specimen strips subjected to different colorants solutions commonly used by most patients using a spectrophotometer at 400nm & 700nm wave lengths.

Materials and Methods

Forty specimen strips of heat-polymerized acrylic resin material (Q.D, England) measuring 5mm width, 40mmlength and 2mm thickness to meet the demands of the measuring

instrument , were formed in a from of wax patterns that were allowed to undergo short-time polymerization in a water bath at 74°C for 1.5 hour, followed by 30 minutes boiling in 100°C water to ensure adequate processing(ADA,1999) .After being processed, these specimens were finished & polished on both sides using acrylic bur, stone bur, sandpaper of medium grit , pumice and roach to a final thickness of 2±0.1mm.

The specimens were divided into 8 groups , each group contain 5 coded specimens with a small round bur on their periphery and those were stored in 8 different conditions (distilled water, black tea, green tea, coffee, cigarette , tomato paste , Pepsi and diet Pepsi) for two weeks and their color changes were measured by using an ultraviolet-visible recording spectrophotometer.

For carefully avoiding specimen to specimen contact within the staining solution, each specimen was stored individually in a cup of 150ml of the tested solution.

The group of distilled water was used as a control group for comparison.

To prepare a standard staining solutions , 12.5g of black tea (Lipton tea , England) , of green tea (Alattar green tea, Syria) , of coffee(Brazilian café Rio, Lebanon) , of cigarette (Gauloises blonds , European union) and of tomato paste (ZER, Turkey)were dissolved each one in a jar of 750ml boiling distilled water, after 10min of stirring , the tea and cigar solutions were decanted from the leaves then each solution was poured into five cups . The solutions were cooled to room temperature before the specimens were immersed completely in them. 750 ml of Pepsi (Baghdad Co. Iraq) and of diet Pepsi (Jordan Co.) were poured into 5 cups and one coded

specimen was immersed completely in one cup.

To prevent fungal growth, the solutions were changed every day.

Before any color measurements were obtained, all specimens were removed from the staining solutions and rinsed with distilled water, dried with tissue paper and allowed to dry.

Specimens were centered on the measuring head of a spectrophotometer (CARY 100 Conc. UV-visible spectrophotometer, ARIAN, Australia), the amount of light transmission at the 400 & 700 nm wave length of the visible spectrum was measured & recorded.

The recordings were analyzed statistically by the use of descriptive analysis including mean values & standard deviations and analysis of variance (one way ANOVA), statistical analysis was conducted. The significance of color changes exhibited by the acrylic resin in 8 solutions at 400 & 700nm wave lengths were compared for equal length of time with the student t-test. Statistical significance was set at the 0.05 probability level.

Results

The means of the values of light transmission in percent for all specimen groups are illustrated in table (1).

One-way ANOVA test revealed a significant difference between all the specimen groups at the two wave lengths 400 and 700nm (table 2).

At 400nm wave length , there was a statistically significant difference between the means of light transmission values of the control group and the discolored specimen groups of black tea, green tea, coffee , tomato paste & cigarette as shown in the student t- test table (3).

Also, it was shown in this table at the same wave length that there was a statistically non significant difference between the means of light transmission values of the control group and the discolored specimen groups of Pepsi & diet Pepsi.

While at 700nm wave length, there was a significant difference between the control group and the discolored specimen groups of black tea, coffee & cigarette but there was no significant difference between the control specimen group and discolored specimen groups of green tea, Pepsi, tomato paste & diet Pepsi as shown in table (3).

Table (4) showed a significant difference between the means values of the light transmission of all the specimen groups at 400nm and that at 700nm wave lengths.

In general, control specimen group has the highest mean value for light transmission among all the specimen groups at the two wave lengths (figure 1).

For the discolored specimen groups, diet Pepsi group has the highest mean value for light transmission at both wave lengths among all the discolored specimen groups and coffee group has the lowest mean value for light transmission at both wave lengths (figure 1).

It is shown clearly in Figure (1) that the most discoloring beverage to heat-cure acrylic resin specimens is coffee then black tea, cigarette, green tea, tomato paste, Pepsi & diet Pepsi consequently at the two wave lengths.

Discussion

In this study, spectrophotometer digital measuring technique was used to determine the discoloration of heat-cured acrylic resin specimens in 8 test media. Discoloration was expressed in term of light transmission percent for all the specimen groups at 400 and 700nm wave lengths.

Heat-polymerized acrylic resin material behaved differently when exposed to various staining solutions in this study.

For the two wave lengths, the investigated acrylic resin specimens that exposed to distilled water for 2 weeks(control group) revealed significantly a greater mean values of light transmission than those obtained by coffee, black tea and cigarette staining solutions (table 3).

This implies that extrinsic stains played a major role in the discoloration of the investigated materials. This finding is similar to the result of Koran et al [18] study which showed that changes in color caused by staining with tea, lipstick and disclosing solution were larger than changes from color instability of maxillofacial materials under conditions of accelerated aging. Buyukyilmaz & Ruyter[19] also demonstrated that denture base polymers are relatively color stable in water but were superficially stained by coffee and tea solutions.

In this study, when color changes of denture base resin specimens with respect to staining solutions were studied, it was shown that coffee solution is the most staining solution for resin specimens and is more than the tea solution at both wave lengths as shown in table (1) and figure (1).

This might be attributed to the resin's chemical structure as it contains small quantities of different cross-linking agents , fillers, pigments and plasticizers which may explain the difference in staining properties (hydrophilicity) of resins with different staining solutions[8,18].

Most resin-based materials used for prosthetic treatment are subject to sorption, a process of absorption & adsorption of liquids dependent on

environmental conditions [4,20] ; thus staining may produce color changes during service in the oral environment.

This finding is in agree with Buyukyilmaz & Ruyter [19] who demonstrated that coffee produce greater color changes than tea on denture base resins and they concluded that discoloration results from the adhesion of colorants to the surface . However, Polyzois et al [21] showed that tea had higher staining effects than coffee on resilient denture liners. Yu-lin lai et al[22] studied color stability and water sorption of different gingival flange materials and demonstrated that silicon material tended to be hydrophobic and exhibited the least water sorption so is stained by coffee more than tea , whereas a tea solution stained copolyamide material more as it was the most hydrophilic with the largest water uptake while polymethyl methacrylate materials had moderate values of water absorption so are stained by coffee less than silicon and by tea less than copolyamide and more than silicon. this finding also agree to a certain extent with the statement that hydrophobic materials are stained by hydrophobic solutions and hydrophilic materials with high water absorption are stained by hydrophilic colorants in aqueous solutions[4].

This result is in conflict with Nur Hersek et al [8] study who stated that the polymethyl methacrylate denture base resins were hydrophilic that attracted more water soluble dyes & staining on the surface like tea.

Um and Ruyter [23] reported that the yellow colorants of coffee were less polar than the yellow colorants of tea. They described that discoloration of resin-based veneering materials by tea was mainly due to surface adsorption of the colorants but discoloration by coffee was due to adsorption & also to absorption of colorants by some investigated materials. Absorption and penetration of colorants into the organic phase of the resin –based materials are probably due to compatibility of the polymer phase with the yellow colorants of coffee. This explains why acrylic resin presented the greatest discoloration when subjected to coffee solution than other staining solution in this study.

There also seemed to be some molecular interactions between colorants and denture polymers that resulted in acrylic resin discoloration.

Tannin or tannic acid which is present in tea and coffee is the responsible colorant for their staining effect [8].

Tannic acid is a yellow to light brown amorphous powder which is highly soluble in water. Tea and coffee is said to have a naturally high tannin content [24,25] and this may form the intrinsic stain that is absorbed by the hydrophilic acrylic resin specimens.

In the same time, Coffee and tea are regarded the most common sources of caffeine [9,11,12,26] . Scientific researches indicated that tannic acid can conform water insoluble complexes with caffeine [24,25,26] so in this study, these complexes may sediment at resin specimen surfaces and form the extrinsic stain that is adsorbed by the specimen surfaces.

Tea usually contains about half as much caffeine per serving as coffee and certain types of tea such as black tea contains somewhat more caffeine than most other teas like green tea [9,11,12,26], this may explain why the acrylic resin specimens in this study stained by coffee more than tea and by black tea more than green tea.

In this study, cigarette stained resin specimens after coffee and tea which might be related to the content of the tobacco leaves like nicotine which is a hygroscopic oily liquid that is miscible with water in its base form, also nicotine can form salts with acids that

are usually water soluble [16] so it can be absorbed by hydrophilic acrylic material, and the presence of acids found in the mouth may increase the probability of its adsorption to acrylic surface by means of the formed salts.

Cigarette also contain wrappers which are outmost tobacco leaves of varying quality, it determines much of the cigarette character and flavor and as such its color is often used to describe the cigar as whole, wrappers' color vary due to maturing process like yellow-brown, reddish-brown, light-brown and dark-brown. In addition to that cigarette also contains tar, is an oily black liquid [15] that might settled down on the surface of the specimens and cause their staining.

In this study, at 400nm wave length there is a significant difference between light transmission mean values of the control group and that of green tea and tomato paste groups but at 700nm wave length the difference between them is non significant , this data variability might be attributed to the variability of the technical factors.

For this study the spectrophotometer was well suited by use of a computer program for measuring the color alteration of the heat-polymerized acrylic resin caused by the stains. very small changes in color could be detected by this instrumentation especially at short wave lengths which may introduce a more accurate data than other wave length [18], this may explain the significant difference founded between the means values of the light transmission of all the specimens groups at 400nm and that at 700nm wave lengths as showed in table (4). However, Crawford et al [27] believed that 690nm wave length is the most sensitive for the material under test.

For tomato paste solution staining , can be related to the small amount of nicotine found in tomato , it is regarded as a close cousin for tobacco[28] , paste tomatoes are characterized by processing high amount of water soluble vitamin c, sugars ,acids and pectin , the paste's color varies with the type of tomatoes from bright red to deep red[28]. In this study, soluble contents of the paste might be absorbed by the specimens cause an intrinsic stain but to a less amount than coffee, tea and cigarette as it contain less natural colorants than the others.

In the current study, at the two wave lengths there was no significant difference between distilled water specimen group and specimen groups of Pepsi and diet Pepsi but Pepsi had slightly more staining effect on acrylic (table 3, figure 1).

Staining effect of both types is related to caramel artificial coloring, it is made from caramelized sugar provides a wide range of end colors in foods and beverages ranging from light yellows to reddish-brown found in Pepsi to darkest brown. It is stable coloring agent tolerant of a wide range of physical and chemical environments of the food and beverages. It is soluble in water but the presence of aspartame in diet Pepsi may decrease its coloring effect on specimen surfaces. the food colorants may stain structures because they have electrostatic charges, as they have charged and ionizable groups in their chemical structures , the polymethyl methacrylate denture base resins were hydrophilic that attracted more water soluble dyes on the surface and staining, which occurs as a result of electrostatic charges[8].

Discoloration of the denture base polymers may be caused by the oxidation of the amine accelerator or by the penetration of the colored solutions [5,19]. and this study prove that artificial colorants found in Pepsi and diet Pepsi has a little staining effect on resin material than natural colorants found in coffee, tea and cigar.

There is also important evidence found in this study that the color stability of the resin specimens was accepted clinically after their immersion in staining solutions for two week continuously and the patient can limited his denture discoloration by home care.

Absorption of staining solution by resin specimens is undoubtedly due primarily to the polar properties of resin molecules. However, it has been proven that the mechanism is diffusion of water molecules that penetrate according to the laws of diffusion. The diffusion coefficient of a heat-cured denture acrylic resin is reduced by one half when the temperature drops from 37°C to 23°C; for these reasons, the diffusion coefficient may be lower than the in vivo environment [29].

When discussing the clinical applications of these results, it must be considered that the oral environment differs in several ways from in vitro conditions. Factors such as variety of food, thermal and mechanical stresses and their interactions may intensify discoloration in vivo [22].

In this study, the effect of staining solutions was examined in a saliva- and diet-free medium; however, the actual oral environment is comparatively different because of the pellicles formed by the proteins and glycoproteins in saliva that lead to the formation of plaque adhering to the denture. These soft materials are affected by the dyes in food and beverages more quickly and undergo color changes [30]. In addition, in vivo cigarette is ignited so that its smoke may be drawn into the smoker's mouth [15].

Conclusions

1- The resin specimen groups that were immersed in distilled water for two weeks revealed less discoloration values than those immersed in different staining solutions.

2- The coffee solution had higher staining effects on acrylic material than tea solution.

3- Resin specimens were stained by black tea more than green tea.

4- Cigarette and tomato paste solution had high staining effect after coffee and tea.

5- Pepsi and diet Pepsi revealed the lowest staining effect on acrylic resin specimen.

6- The polymethyl methacrylate resin specimens had clinically acceptable color stability.

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Table(1): Mean No. and Standard deviation for light transmission values in % of all the specimen groups at 400 & 700 nm wave lengths.

	400 wave length		700 wave length	
	Mean	SD	Mean	SD
Control group	7.316	2.744	18.188	5.574
B.T	3.942	1.432	10.198	2.340
G.T	4.158	1.328	12.08	4.554
Cof.	3.446	1.510	8.898	3.466
Pe.	5.642	1.835	16.56	4.217
Tom.	4.824	1.387	14.504	3.635
Cig.	4.102	1.335	11.266	3.432
d.pe	6.264	2.417	17.678	3.457

Table(2):one-way ANOVA test for the mean No. of light transmission values in % of all the specimen groups at 400 & 700 nm wave lengths.

	F-test	P-value	Sig.
400	2.68	0.027	S
700	4.08	0.003	S

*P<0.05 Significant

Table(3): student t-test between the mean No. of light transmission values of control group and discolored specimen groups.

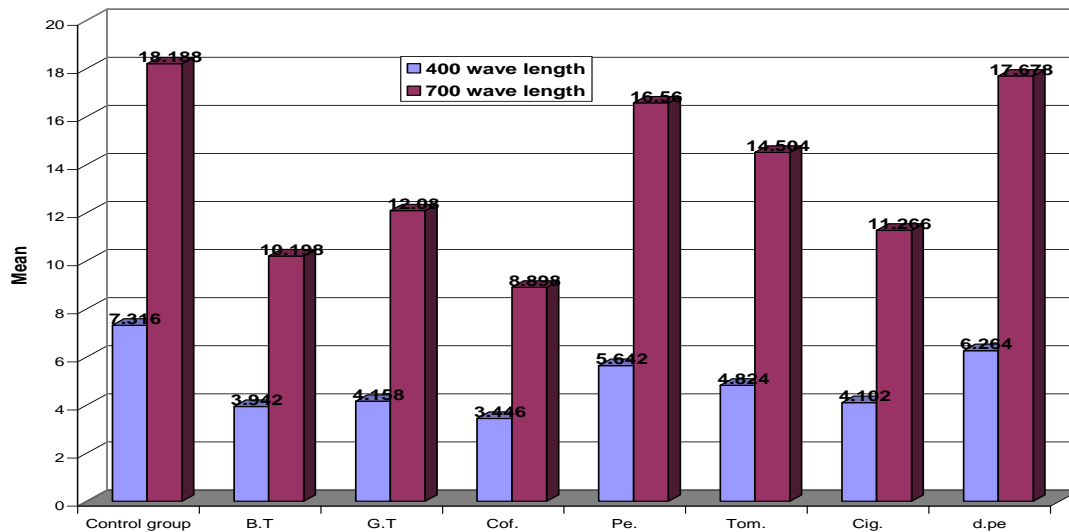|	400 wave length			700 wave length		
	t-test	P-value	Sig.	t-test	P-value	Sig.
B.T	2.44	0.049	S	2.96	0.032	S
G.T	2.32	0.049	S	1.90	0.100	NS
Cof.	2.76	0.033	S	3.16	0.019	S
Pe.	1.13	0.300	NS	0.52	0.620	NS
Tom.	2.81	0.049	S	1.24	0.260	NS
Cig.	2.35	0.048	S	2.36	0.049	S
d.pe	0.42	0.640	NS	0.17	0.870	NS

*P<0.05 Significant   **P>0.05 Non significant

Table(4): student t-test between the mean No. of light transmission values of all specimen groups at 400nm & that at 700nm wave lengths.

	t-test	p-value	Sig
Control group	3.91	0.0110	S
B.T	5.10	0.0022	S
G.T	3.73	0.0200	S
Cof.	3.22	0.0230	S
Pe.	5.31	0.0032	S
Tom.	5.56	0.0026	S
Cig.	4.34	0.0074	S
d.pe	6.05	0.0050	S

*P<0.05 Significant

Figure(1): histogram for the mean No. of light transmission values in % of all the specimen groups at 400 & 700 nm wave lengths.