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ORIGINAL ARTICLE

Comparative Evaluation of Color Change Between Two Types of Acrylic Resin and Flexible Resin After Thermo Cycling. An In Vitro Study

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Abstract Evaluation of the effect of different beverages (tea with sugar, coffee with sugar, and Pepsi), and immersion time cycles (2, 4, and 12 weeks) on color change property, and dimensional change of Vertex Dental BV, Netherlands heat cured acrylic resin, recently modified Vertex Dental BV, Netherlands heat cured acrylic resin with additive (20 % banana oil), and Valplast® flexible resin (FR) denture base materials by using artificial saliva cycle. The total samples of this study for color, and dimensional changes were 360 samples, divided into three groups according to the type of the material, Vertex Dental BV, Netherlands heat cured acrylic resin, modified heat cured acrylic resin (Vertex with additive 20 % banana oil), and Valplast® FR groups, each group contains 120 samples. The thermal cycling used in this study was as follows: The samples were incubated in distilled water at 37 ± 1 °C for 2 days for conditioning. Then, the samples were immersed in beverage solutions for 10 min daily at 50 ± 1 °C temperature for tea, and coffee with sugar, while for Pepsi at 20 ± 1 °C. Then, the samples were immersed in artificial saliva at 37 ± 1 °C for 5 h, and 10 min. This cycle was repeated three times daily, and then the samples were immersed in distilled water at 22 ± 2 °C room temperature for 8 h at night. This cycle was repeated for 2, 4, and 12 weeks. At the end of each time period, the immersed samples were tested to evaluate the color change property. Descriptive statistics, ANOVA, and Duncan's multiple range tests were used to analyze the collected data. The results of this study showed that, in comparison between the materials at different times for colors L*a*b* properties, there were significant differences at $P \leq 0.05$ except in color b* at 12 weeks, which showed no significant difference at $P > 0.05$ between materials. And there was a significant difference in dimensional change at $P > 0.05$ for different beverages, and times of immersion. The largest color, and dimensional changes were observed in the Valplast® FR, whereas tea was found to be the most chromatic agent, and showed unaccepted color change ($\Delta E \leq 3.7$) in vitro study as compared with coffee, Pepsi, and artificial saliva solutions.

Keywords Color · Flexible resin · Beverage

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Introduction

The ideal denture base material should possess several key physical attributes. Some of these properties include biocompatibility, good esthetics, high bond strength, with available denture teeth, radio opacity, ease of repair, and should possess adequate physical and mechanical properties [1].

Acrylic resins have been widely used due to their acceptable esthetics, and desirable characteristics such as easy handling, good thermal conductivity, low permeability to oral fluids, and color stability. A major problem of this material can be seen as the dimensional change during processing, frequently due to the polymerization shrinkage. Therefore flexible resins (FRs) were introduced on the market as an alternative to the use of conventional acrylic resins in the construction of complete, and partial removable dentures that exhibited higher dimensional, and color stability [2, 3].

Color is one of the optical properties of dental restorative material, and it is the quality of the object, or substance with respect to the light reflected, or transmitted through [4].

The degree of color change can be affected by a number of factors including: incomplete polymerization, water sorption, chemical reactivity, diet, oral hygiene, and surface smoothness of material [5, 6].

All colors in nature are obtained through blending of three basic colors i.e., red, green, and blue in certain proportions. The CIE L*a*b* system has been developed on the basis of this practice [7].

Color determination may be precisely performed with spectrophotometers; however this technique is time consuming, and requires special devices [8].

In in vitro study, the color changes value ($\Delta E \leq 3.7$) is considered to be clinically acceptable. While in in vivo study, the color changes value ($\Delta E \leq 6.8$) is considered to be clinically acceptable [9, 10].

MATLAB stands for "MATrix LABoratory", and is a high level technical computing language, and interactive environment for algorithm development, data visualization, data analysis, and numeric computation [11].

MATLAB has built-in functions for solving problems requiring data analysis, image processing, curve fitting, optimization, and several other types of scientific computations. It also contains functions for 2-D and 3-D graphics, and animation [12].

The CIE L*a*b* which is a method developed in 1978 by the Commission Inte′rnationale de l'E′ clairage for characterizing color based on human perception, The basic CIE concept is that all colors can be matched by mixing relative amounts of the three light primaries: Red (X), Green (Y), and Blue (Z). These can then be transformed to L^*, a^*, and b^* values. L^* is a measure of lightness.The a^* value represents positions on a red-green axis. As a* becomes more positive in value, the color is more red; as a^* becomes more negative in value, the color becomes more green. The b^* value represents positions on a yellow–blue axis. As b^* becomes more positive in value, the color becomes more yellow; as b^* becomes more negative in value, the color becomes more blue [9, 10].

In computing, a scanner is a device that optically scans images, printed text, or an object, and converts it to a digital image, and by Photoshop program MATLAB program can analyze a digital image to its primary colors: red, green, and blue, and by CIE $L^*a^*b^*$ color system can be used to measure color change (ΔE). MATLAB program has wide range of applications, including signal, and image processing, communications, control design test, and measurement, financial modeling, and analysis, and computational biology [13, 14].

Dimensional stability of dentures during processing and in service is of major importance, since it affects the fit of a denture [15]. Although acrylic resin is the most commonly used material in dental construction, it is subject to polymerization shrinkage and distortion approximately 8 % [16, 17].

The aims of this study is to evaluate the effect of different beverages (tea with sugar, coffee with sugar, and Pepsi), and immersion time cycles (2, 4, and 12 weeks) on the color change property and dimensional change of Vertex Dental BV, Netherlands heat cured acrylic resin, Vertex heat cured acrylic resin modified with additive (20 % banana oil), and Valplast® FR denture base by using artificial saliva cycle.

Materials and Methods

Materials used in preparing samples (heat cured acrylic resin, modified heat cured acrylic resin, and flexible materials), and for preparing solutions were listed in Table 1.

The total samples of this study were 360. The samples were divided into three main groups; each group contains 120 samples. Each main group was subdivided into four subgroups as follows:

1. First group (Control): The samples were made from Vertex Dental BV, Netherlands heat cured acrylic resin.
2. Second group: The samples were made from Vertex Dental BV, Netherlands heat cured acrylic resin modified by incorporation of 20 % banana oil [18].
3. Third group: The samples were made from Valplast® FR.

Each main group was subdivided into four subgroups according to types of beverage solutions used for immersion of samples:

(i) First subgroup as Control group: (30) samples immersion in artificial saliva for three time periods (2, 4, and 12 weeks).
(ii) Second subgroup: (30) samples immersion in Alghazaleen Tea with ALOSRA sugar solution for three time periods (2, 4, and 12 weeks).
(iii) Third subgroup: (30) samples immersion in Brazilian coffee with ALOSRA sugar solution for three time periods (2, 4, and 12 weeks).
(iv) Fourth subgroup: (30) samples immersion in Pepsi solution for three time periods (2, 4, and 12 weeks).

All the samples were incubated in distilled water at 37 ± 1 °C for 2 days for conditioning before testing [19].

30 g of Coffee powder (Brazilian coffee) and 30 g of tea (Alghazaleen tea) were added each one into one liter of boiling distilled water. Then simmered for 5 min and filtered through filter paper[20], then 40 g of white sugar were added to tea and coffee solutions and stirring for 5 min. Then the samples were immersed in beverage solutions (tea, and coffee with sugar at 50 ± 1 °C, and Pepsi at 20 ± 1 °C) for

Table 1 Denture base materials and solutions

Product	Type	Manufacturer	Batch No.
Vertex regular	Heat curing resin powder and liquid pink	Vertix-Dental bv Johan Van Oldenbamevertlaan, 62,3705 HJ Zeist the Netherlands	ISO1567 Type 1 Class 1
Silky rock	Gypsum (die stone) Type IV	Whip-mix corporation, Louisiville, USA	078598004
Isodent	Separating medium	Spofo Dental Kenn Company	1753815
Valplast®	Thermoplastic nylon	China	
Easy-vac gasket	Hard elastic foil 3, 2.5, and 1.5 mm thickness	3A MEDES company, Korea	1824
Cellophane paper	Separating medium	Vertix-Dental bv Johan Van Oldenbamevertlaan, 62,3705 HS Zeist the Netherlands	ISO1567 Type 1 class 1
Favoring agent (additive)	Banana oil	Iraqi company for flavors	256
Alghazaleen	Tea 3 %	Akbar Brothers (Pvt) Ltd.334, T.B. Jayah Mawatha Colombo 10. Sri Lanka	501417 6000127
Brazilian club	Instant coffee 3 %	Javilen Group Ltd. USA	78960 192018 34
Alosra	White sugar 4 %	United Sugar Company, Saudi Arabia	6281011 411052
Pepsi Saudi	Pepsi	Pepsiar Arbia Saudi company	22621

10 min followed by immersion in artificial saliva at 37 ± 1 °C for 5 h and 10 min, this cycle was repeated three times. Then the samples were immersed in distilled water at 22 ± 2 °C room temperature for 8 h. This cycle was repeated for 2, 4, and 12 weeks. At the end of each period, the samples were tested to determine color change and dimensional change tests as shown in Figs. 1 and 2.

Vertex Dental BV, Netherlands Heat Cured Acrylic Resin (HCAR), and Modified with Additive Banana Oil (MHCAR) Samples Preparation

Vertex Dental BV, Netherlands heat cured acrylic resin specimens were prepared in a mold made by investing a hard elastic foil.

The Gypsum die-stone type IV (Silky-Rock, Whip-mix) was mixed with distilled water in ratio; 100 g: 23 ml, according to the manufacturer instructions, with manual spatulation for 20–30 s. Gentle vibration, by electrical vibrator, was used for 1 min to get rid of air bubbles, then the mixture was poured into lower half of flask. Elastic foil was lubricated by using Vaseline (Original Pure skin jelly, Indian Batch. 89004258) before investing into gypsum die-stone, which was then allowed for setting for 1 h before pouring a second layer of gypsum. After setting, the die-stone gypsum surface was coated with Isodent separating medium; then the upper half of the flask was filled with gypsum, and left for another 1 h [18].

Powder (polymer) and liquid (monomer) of heat cured acrylic resin (HCAR) were mixed together in glass jar 2.3 g: 1 ml by volume (according to the manufacturer instructions).

The experimental groups of heat cured acrylic resin modified with additive (MHCAR) have been prepared by mixing powder (polymer), with liquid consist of (80 % monomer and 20 % banana oil) [18] together in glass jar 2.3 g:1 ml by volume. The oil was added gradually (drop by drop) to the polymer with continuous mixing, then the monomer was added gradually to the mixture. After reaching dough stage, the mixture was inserted into the prepared mold.

Two-step packing procedure has been used; over filling the gypsum-die stone mold by acrylic dough, then the cellophane paper has been placed above the dough for trial packing. The flask has been placed under press (800–2,000 pound), and then opened, and excess acrylic resin was removed by sharp wax knife, then left for 45 min before curing [21, 22]. The samples were cured according to the regular Vertex heat cured acrylic resin manufacturer's instructions curing cycle at 100 °C for 30 min.

The flasks were left for bench cooling at room temperature; the samples were removed, carved, and adjusted with engine stone bur, then incubated in distilled water at 37 ± 1 °C for 48 h for conditioning before testing [18].

Valplast® Flexible Samples Preparation

Valplast® FR specimens were prepared in a mold made by investing a hard elastic foil as a master models.

The machines injection type (ZB-A) oven used for flexible samples preparation (Fig. 3). Gypsum die-stone was mixed with water, and poured into the lower half of the flask for flexible acrylic. Elastic foil specimens with specific dimension were inserted into the investing gypsum-

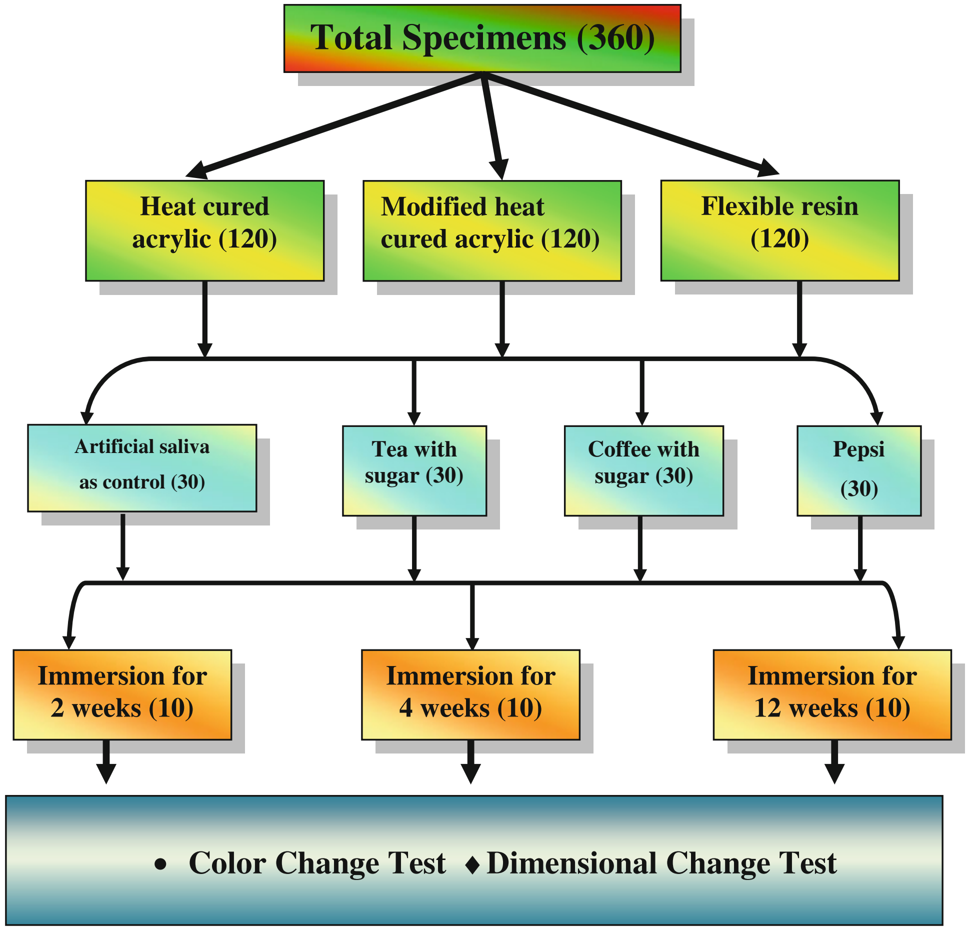

Fig. 1 Experimental design of this study

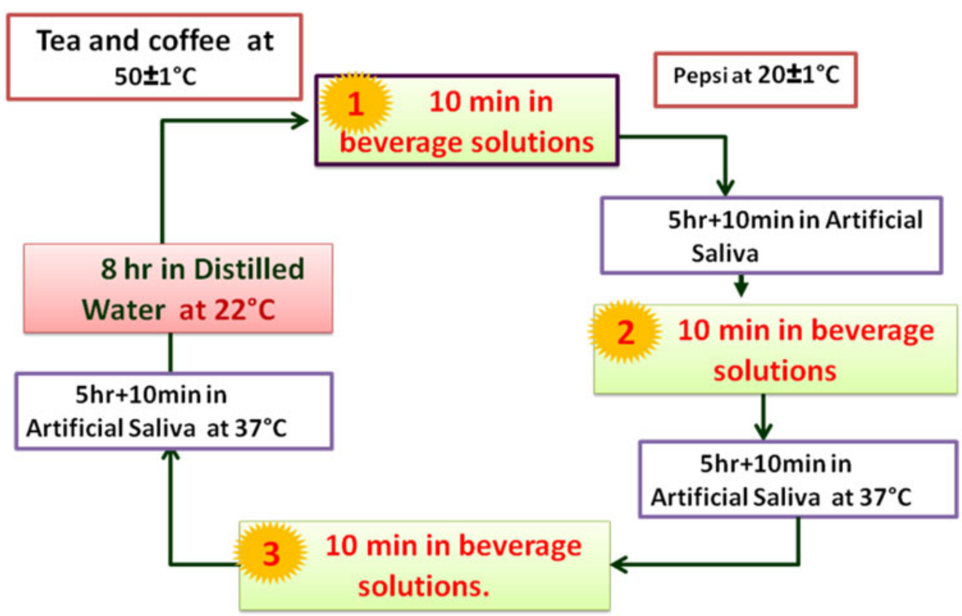

Fig. 2 24 h daily cycle for immersion of samples in beverage solutions

die stone, and after final setting of material; these samples were connected with each other with hole of flask by three sprues wax as shown in Fig. 4. The gypsum surface was coated with separating medium, and then the upper half of the flask was filled with gypsum die-stone mixture. After setting of the gypsum, the master models with sprues have

Fig. 3 Flexible injection system

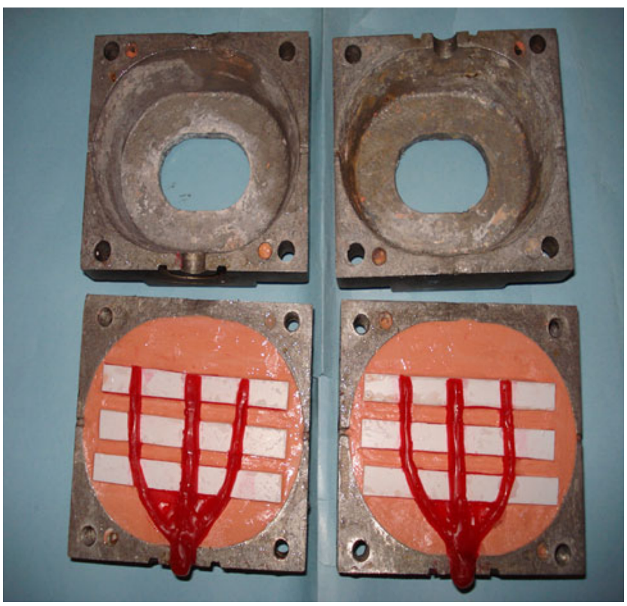

Fig. 4 Flasking of flexible samples

been removed. The flasks are going to be locked by screws tightly after coating the surfaces of gypsum in the two pieces of the flask with separating medium. Valplast® capsule of flexible material were used. After the oven fixed at a temperature of 288 °C, the capsule was grasped by a special holder, and placed in a hole inside the oven for 16 min. The material was injected inside the flask using a manual press through a hole inside the flask. The flask was left inside press for 5 min, then removed, and left for bench cooling for about 1 h, then deflasked and the samples were cleaned (according to manufacturer instructions).

Methods for Measurement of Color Change

The samples (120) were prepared with uniform dimensions of 30 × 20 × 1.5 mm (length, width, and thickness respectively) as shown in Figs. 5 and 6 [18, 23].

The samples were converted to digital images on computer by using digital scanner (CanoScan LiDE 100, Canon solutions). The images were digitized, with an input resolution of 1,200 pixels per inch (Fig. 7) [24].

These digital images were prepared with dimension 760 × 960 pixels for each polished surface of sample (exclude area of labeling on sample) by software program Adobe Photoshop (9.0). These images were saved by MATLAB 2010 program, then, each image was analyzed to the basic primary colors Red, Green, and Blue (RGB).

MATLAB 2010 program would measure primary color RGB for 729600 pixels that were presented in these surface areas of image, and then each primary color RGB for all pixels in images would be given mean values.

The values for each primary color range from 0 to 255. When the values for red, green, and blue equal (255,255,255) mean the color is white, while the values equal (0, 0, 0) mean the color is black.

Primary colors RGB values were converted to (CIE *L*a*b**) system by Photoshop 9.0 program.

CIE *L*a*b** color difference metric was used to perform color change test by using Photoshop 0.9 program to obtain the baseline *L**, *a**, and *b** values, and the total color change (ΔE) of each sample was calculated, at each evaluation using the following formula [10, 25]

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

$$\Delta E = \left[(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2\right]^{1/2}$$

In principle, when no color difference will be detected after its exposure to the testing environment ΔE value of zero [9]. Delta E value of (3.7), or less, was considered to be clinically

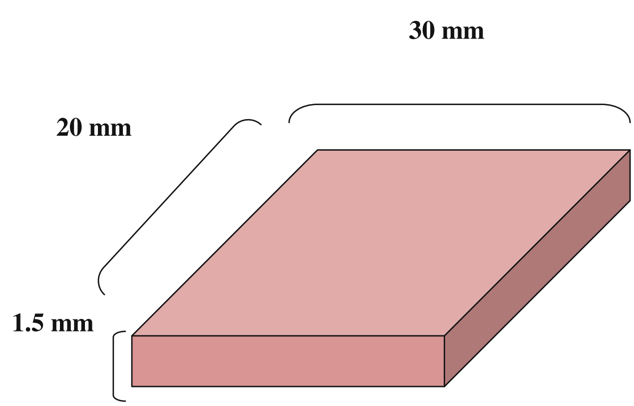

Fig. 5 Color change testing sample dimensions

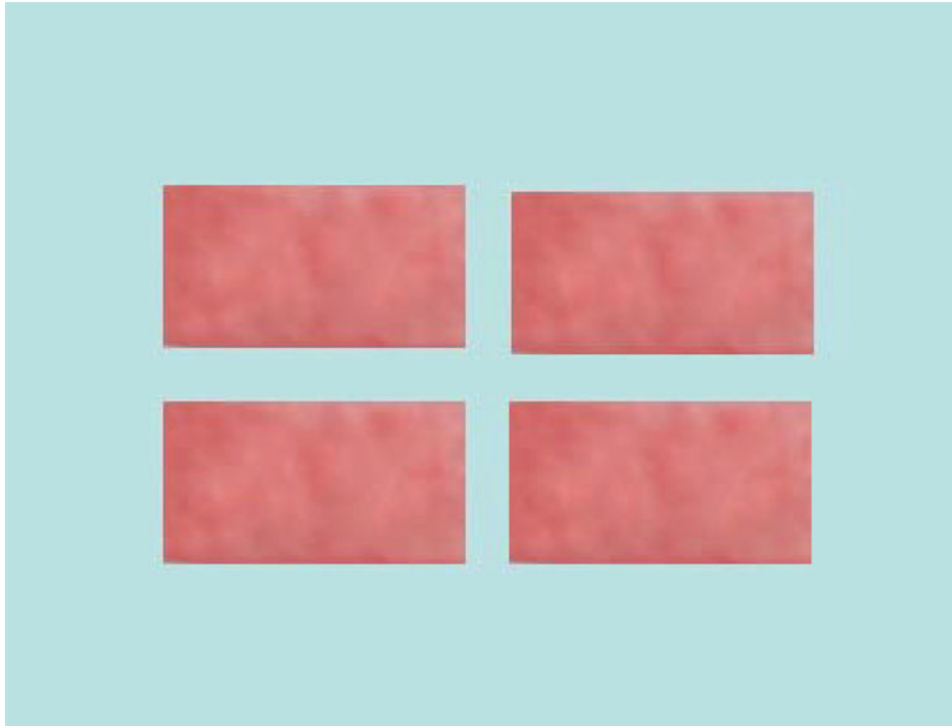

Fig. 6 Color change testing samples design

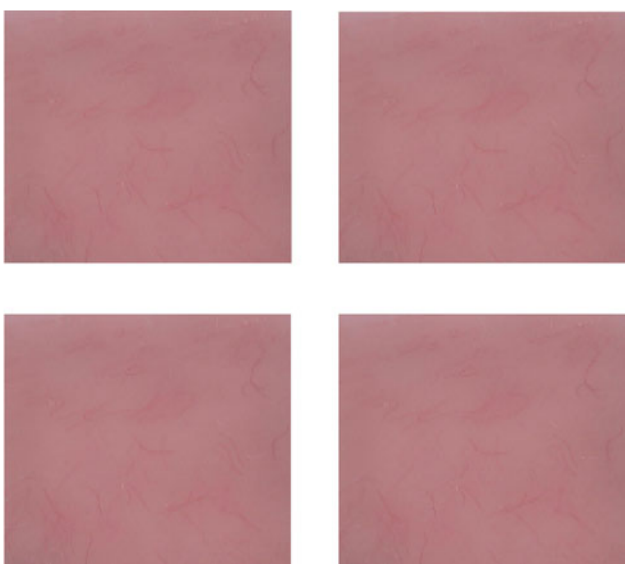

Fig. 7 Scanned Color Samples

acceptable in in vitro study, and of (6.8) was considered to be clinically acceptable in in vivo study [9, 10].

The color change test for each type materials in specific immersion cycle for 2, 4, and 12 weeks was compared with the control group in each material.

Dimensional Change

The samples (120) were prepared in the dimensions of 65 × 10 × 2.5 ± 0.03 mm (length, width, and thickness respectively) according to ADA specification No. 12 [18]. Electronic digital caliper (0.01 mm. accuracy) was used to determine the dimensional changes for each distance. Mean of the measurements were done for control group, and the other samples after immersion cycle for 2, 4, and 12 weeks [18].

Results

Color Change

Descriptive statistics, ANOVA, and Duncan's multiple range tests of color measurement values of each material at 2, 4, and 12 weeks of color *L, a,* and *b*. demonstrate that there was a significant difference at $P \leq 0.05$ (Fig. 8; Table 2), except for color *b* at 12 weeks there was no significant difference between {Vertex Dental BV, Netherlands heat cured acrylic (HCAR), modified Vertex Dental BV, Netherlands heat cured acrylic with banana oil (MHCAR), and FR}.

Color Change (ΔE) according to the (CIE L^* a^* b^*) Color System: At 2, 4, and 12 weeks, the two types of acrylic resin (HCAR), and (MHCAR)} indicated an acceptable color change (ΔE) in vitro, except groups of tea at 2, 4, and 12 weeks, and coffee at 12 weeks within FR which showed unacceptable color change (ΔE ≥ 3.7) as shown in Tables 3, 4, 5.

Tables 3–5, also show that the color change (ΔE) accepted (ΔE ≤ 3.7), and not accepted (ΔE ≥ 3.7) when denture base materials (HCAR, MHCAR, and FR) were

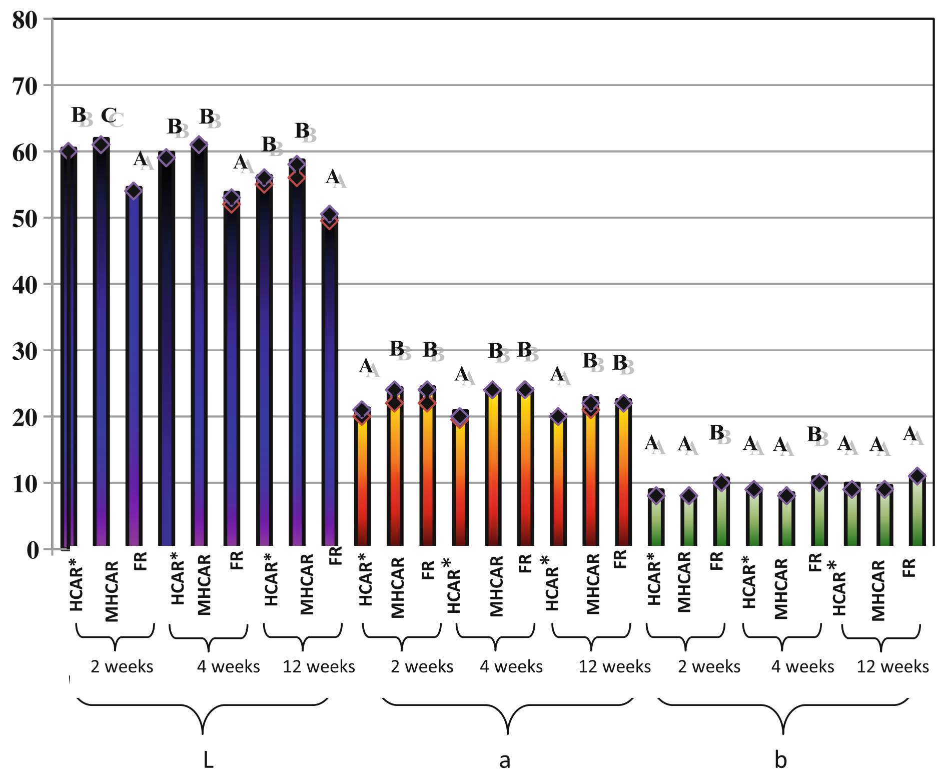

Fig. 8 Descriptive statistics, and Duncan's multiple range test of color L*, a* and b* values for comparison between materials at different times of immersion in beverages. *Different letters mean significant difference at $P \leq 0.05$. ***HCAR* heat cured acrylic resin (control group), *MHCAR* modified heat cured with banana oil, *FR* flexible resin

immersed in beverage solutions at 2, 4, and 12 weeks, color change of denture base materials increased proportionally with immersion period. In comparison among solutions, the results showed that the highest color change occurred in tea, followed by coffee, and Pepsi solutions.

Dimensional Change

ANOVA test (Table 6) demonstrated that for all denture base materials, there was no significant difference at $P > 0.05$ in the dimensional accuracy among artificial saliva, coffee, tea and Pepsi at different times (2, 4 and 12 weeks). While Fig. 9 and Table 7 showed that there had been a significant difference at $P \leq 0.05$ in the dimensional accuracy (length, width, and thickness) between materials (HCAR, MHCAR, and FR).

Discussion

There are no previous study used additives materials flavors (Banana oil) to heat cured acrylic resin to correlate the results of this study with it.

Color Change

According to the findings from the results of this study, color change in beverage solutions (tea, coffee, Pepsi, and artificial saliva), and the color *L*, a*,* and *b** values of two types of acrylic resin and FR changed in relation to immersion period. In the assessment of color *L**values, it was determined that the samples became darker with time. The *a** values was shift toward green and *b** values toward yellow. This result is in agreement with Koksal and Dİkbas [26].

This study showed (in comparison among materials) that the highest color change (ΔE) occurred in FR, followed by HCAR, while lowest color change occurred in MHCAR. These findings could be due to two reasons. The first one was that the nylon hydrophilic materials which have a higher degree of water sorption and a relatively higher discoloration value with staining solutions than hydrophobic materials. This result is in agreement with Lai et al. [27] who concluded that color change in co-polyamide material is higher than acrylic resin because the FR was the most hydrophilic with the largest water uptake, while acrylic resin has moderate values of water sorption. Therefore the nylon material had color change higher than PMMA because nylon material absorbed more water, and leached out plasticizer more than PMMA. It is also in agreement with Goiato et al. [28] who concluded that the Valplast presented the greatest chromatic alteration after accelerated aging. As for the second reason, it was because the surface roughness for FR was larger than HCAR, and MHCAR, this is in agreement with Chung [29], and Setz and Engel [30] who found that the surface roughness of the

Table 2 ANOVA for comparison of color *L*,a*, and b** values between materials at different times

Color	Time (weeks)		Sum of square	df	Mean square	F value	*P* value
L	2	Between groups	760.747	2	380.373	66.628	0.000*
		Within groups	411.040	72	5.709		
		Total	1,171.787	74			
	4	Between groups	778.560	2	389.280	40.705	0.000*
		Within groups	688.560	72	9.563		
		Total	1,467.120	74			
	12	Between groups	967.547	2	483.773	6.424	0.003*
		Within groups	5,422.240	72	75.309		
		Total	6,389.787	74			
a	2	Between groups	164.507	2	82.253	50.983	0.000*
		Within groups	116.160	72	1.613		
		Total	280.667	74			
	4	Between groups	172.987	2	86.493	39.177	0.000*
		Within groups	158.960	72	2.208		
		Total	331.947	74			
	12	Between groups	97.280	2	48.640	5.253	0.007*
		Within groups	666.640	72	9.259		
		Total	763.920	74			
b	2	Between groups	82.240	2	42.120	20.569	0.000*
		Within groups	147.440	72	2.048		
		Total	231.680	74			
	4	Between groups	78.587	2	39.293	16.626	0.000*
		Within groups	170.160	72	2.363		
		Total	248.747	74			
	12	Between groups	35.227	2	17.613	2.873	0.063
		Within groups	441.360	72	6.130		
		Total	476.587	74			

* Significance $P \leq 0.05$

Table 3 Color change in (CIE L*, a*, and b*) color system between the different solutions for each material at 2 weeks

Material	Group	ΔE	In vitro
Heat cured acrylic resin	AS	0.663	Accepted
	Coffee	2.097	Accepted
	Tea	5.926	Not accepted
	Pepsi	2.044	Accepted
Modified heat cured acrylic resin	AS	0.346	Accepted
	Coffee	1.754	Accepted
	Tea	5.688	Not accepted
	Pepsi	1.311	Accepted
Flexible resin	AS	0.665	Accepted
	Coffee	2.236	Accepted
	Tea	6.209	Not accepted
	Pepsi	2.315	Accepted

$\Delta E = 0$ No change in color. $\Delta E \leq 3.7$ Change in color accepted in vitro

AS artificial saliva

Table 4 Color change in (CIE L*, a*, and b*) color system between the different solutions for each material at 4 weeks

Material	Group	ΔE	In vitro
Heat cured acrylic resin	AS	0.936	Accepted
	Coffee	2.630	Accepted
	Tea	8.306	Not accepted
	Pepsi	2.535	Accepted
Modified heat cured acrylic resin	AS	0.692	Accepted
	Coffee	2.374	Accepted
	Tea	8.121	Not accepted
	Pepsi	1.649	Accepted
Flexible resin	AS	0.938	Accepted
	Coffee	2.885	Accepted
	Tea	8.694	Not accepted
	Pepsi	2.785	Accepted

$\Delta E = 0$ No change in color. $\Delta E \leq 3.7$ Change in color accepted in vitro

AS artificial saliva

Table 5 Color change in (CIE L*, a*, and b*) color system between the different solutions for each material at 12 weeks

Material	Group	ΔE	In Vitro
Heat cured acrylic resin	AS	1.311	Accepted
	Coffee	3.458	Accepted
	Tea	24.340	Not accepted
	Pepsi	3.379	Accepted
Modified heat cured acrylic resin	AS	1.039	Accepted
	Coffee	2.863	Accepted
	Tea	22.113	Not accepted
	Pepsi	2.289	Accepted
Flexible resin	AS	1.318	Accepted
	Coffee	4.044	Not accepted
	Tea	26.037	Not accepted
	Pepsi	3.382	Accepted

$\Delta E = 0$ No change in color. $\Delta E \leq 3.7$ Change in color accepted in vitro

AS artificial saliva

Table 6 ANOVA for comparison of dimensional accuracy between solutions of heat cured acrylic resin at different times

Solutions		Sum of square	Df	Mean square	F value	*P* value
Artificial saliva	Between groups	0.015	2	0.007	0.438	0.656
	Within groups	0.200	12	0.017		
	Total	0.215	14			
Coffee	Between groups	0.006	2	0.003	0.261	0.775
	Within groups	0.144	12	0.012		
	Total	0.150	14			
Tea	Between groups	0.006	2	0.003	0.261	0.775
	Within groups	0.144	12	0.012		
	Total	0.150	14			
Pepsi	Between groups	0.025	2	0.013	0.750	0.493
	Within groups	0.200	12	0.017		
	Total	0.225	14			

* Significance $P > 0.05$

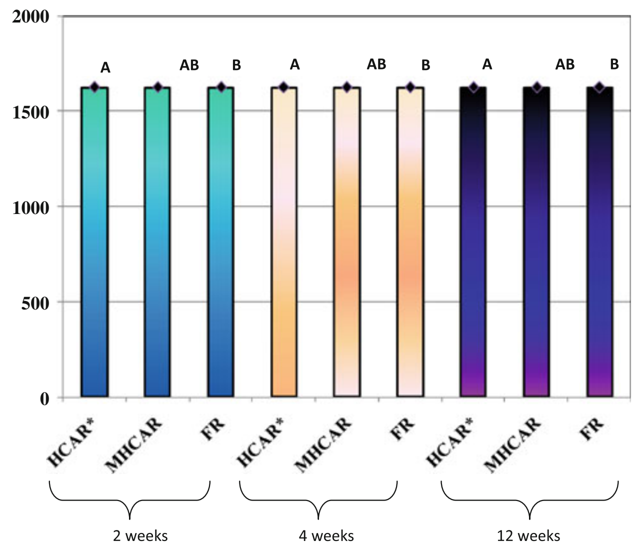

Fig. 9 Descriptive statistics and Duncan's multiple range test of dimensional accuracy for comparison between materials at different times of immersion in beverages. For each time, different letters mean significant difference at $P \leq 0.05$. *HCAR*: heat cured acrylic resin. *MHCAR*: modified heat cured acrylic resin. *FR*: flexible resin. *Control group

Table 7 ANOVA for comparison of dimensional change between materials at different times

Time (weeks)		Sum of square	Df	Mean square	F value	*P* value
2	Between groups	0.102	2	0.051	3.888	0.025*
	Within groups	0.941	72	0.013		
	Total	1.043	74			
4	Between groups	0.140	2	0.070	4.611	0.013*
	Within groups	1.096	72	0.015		
	Total	1.237	74			
12	Between groups	0.165	2	0.083	4.952	0.010*
	Within groups	1.203	72	0.017		
	Total	1.368	74			

* Significant difference at $P \leq 0.05$

denture base materials is an important factor in controlling its rate of staining.

This study showed that the color changes occurred in MHCAR material were less than HCAR because of hydrophobic properties of banana oil that was added to acrylic resin lead to lower water sorption, and less color changes for MHCAR after immersion in beverage solutions. This is in agreement with Bagheri et al. [31] who demonstrated that the hydrophobic materials showed low water sorption, and a relatively lower discoloration.

This study showed also that the color change of denture base materials (HCAR, MHCAR, and FR) immersed in tea solution was more than in coffee, Pepsi, and artificial saliva solutions. This result is in agreement with Polyzois et al.

[32], and Keyf and Etikan [33] due to higher polarity components tea (yellow colorants), and lower polarity components coffee (yellow colorants), therefore tea solution exhibited more staining capacity on acrylic denture base, than the coffee solution. This result is in disagreement with many authors [20, 26, 31, 34–36], who demonstrated that the specimen of heat cured acrylic resin immersed in the coffee solution, produced higher discoloration than those immersed in tea solution due to discoloration of resin-based materials by tea, this was mainly due to surface adsorption of the colorants, while discoloration by coffee was due to adsorption, and absorption of colorants resin materials.

Finally, this study demonstrated that the color change in tea, and coffee was more than in Pepsi. This result is in agreement with many authors [20, 31, 33, 35] who found that the extremely low pH of Pepsi can be a contributing factor to change in the color of the materials, but less change than in coffee, and tea solutions.

Dimensional Change

This study demonstrated that there was no significant difference at $P > 0.05$ in the dimensional accuracy among artificial saliva, coffee, tea and Pepsi at different time, this result is in agreement with Sartori et al. [37] who concluded that the heat cured acrylic denture base resin immersed in warm water had no effect on dimensional accuracy. This study showed that the HCAR have highest dimensional accuracy as compared with MHCAR and FR, this result is in agreement with Yassin et al. [18] who found that these slight changes in dimensions of MHCAR may be related to the water sorption between the gaps of polymer that are created by flavors. This study showed that the dimensional changes for FR were higher than both HCAR, and MHCAR, because the nylon material was the most hydrophilic with largest water uptake [26].

Conclusions

1. Modified Heat Cured Acrylic Resin (additive Banana oil) MHCAR showed lowest color changes after immersed in beverage solutions at different times.
2. Dimensional accuracy and color changes of Valplast® FR showed the highest effect after immersed in beverage solutions at different times.
3. Tea was found to be the most chromatic agent, and showed unaccepted color change ($\Delta E \leq 3.7$) in vitro study as compared with coffee, Pepsi, and artificial saliva solutions.

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