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Modification of heat cured acrylic resin by using additives to make a flexible acrylic resin denture base material: A pilot study

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ABSTRACT

Aims: The study was conducted to modify heat cured acrylic resin denture base material with additives [flavoring agents (caramel, banana)], and plasticizer into a flexible heat cured acrylic resin as a Flexite thermoplastic material. Methods: One hundred ninety-five samples of heat cured acrylic resin (HCAR) that consist of control group and three types of additives with two concentrations 15%, and 20% [flavoring agents (caramel, banana)], and plasticizer di-butyl phthalate (DBP) addition to (HCAR) 20% group, plasticizer (DBP) addition to (HCAR) group, flavoring (caramel) addition to (HCAR) group, flavoring (banana) addition to (HCAR) group and flexite thermoplastic material group were prepared to examine tensile strength, water sorption, solubility, color change and dimensional accuracy. Results: Statistically significant differences were identified between groups with and without additives exhibited higher mean value of tensile strength of flexite thermoplastic group. Duncan's multiple range test, and ANOVA were done to evaluate the effect of additives against each additive, concentration and storage time of samples. The result showed that the dimensional accuracy, water sorption and solubility tests of the groups (caramel + plasticizer + heat cured acrylic resin) had statistically lower changes than other groups with additives but were still higher than control group and Flexite thermoplastic during seven days. They also showed color change between groups. The first group (caramel + plasticizer + heat cured acrylic resin) with the concentration of 20% showed lowest change in their properties when compared with the plasticizer group and the other groups of flavors additions (caramel and banana) after seven days and six months. Conclusions: Within the limitation of this research, it was concluded that all prepared samples with additives (caramel, banana, and plasticizer) have better properties than the control group except the Flexite thermoplastic group which showed to have a higher tensile strength than control group during the periods of two and seven days.

Keywords: Flavoring banana, Flavoring caramel, Plasticizer Di-butyl phthalate, Tensile strength

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INTRODUCTION

The material most commonly used for the fabrication of complete dentures is polymethyl methacrylate despite its popularity in satisfying aesthetic demands. It is still far from fulfilling the mechanical requirements of prosthesis [1].

Polystyrene, polyvinyl acrylic and polyamides were used in fabrication of denture base. A light activated urethane dimethacrylate was also introduced for denture base application [2].

There are several types of removable partial dentures (RPD). The removable partial dentures use standard teeth as replacements for the missing natural teeth. The differences between them, the materials used to support the denture teeth and retain the RPD in the mouth [3].

Polymethyl methacrylate is the material of choice for denture base fabrication. Introduced in 1937 by Dr Walter Wright, PMMA continues to be used because of its favorable working characteristics, processing ease, accurate fit, and stability in the oral environment, superior esthetics, and use with inexpensive equipment. Despite these excellent properties, there is a need for improvement in the fracture resistance of PMMA [4].

Soft acrylic resin materials are used to provide a soft lining for dentures, as obturators and other maxillofacial prostheses. They are usually presented in powder/ liquid format; comprising a higher methacrylate polymer powder usually polyethyl methacrylate with a liquid comprising a higher methacrylate monomer (ethyl n-butyl) and a plasticizer (commonly a phthalate). The main problem with this type of material is that in aqueous environments. The plasticizer will gradually leach out causing the material to harden [5].

Thermoplastic materials for dental prostheses, Valplast (United states) and Flexible (Germany) were related to polyamides group and were used for dental applications (nylon plastics) [6]. Dental applications of thermoplastic materials include partial denture clasp, flexible tooth born partial dentures, temporary crowns and bridges, occlusal appliances implant abutments, orthodontics and sleep apnea appliances [7].

Flexible resins are more expensive but are longer-lasting than traditional soft liner. However, the material showed to be non-porous, so that no bacteria can build up within it. Hamanaka et al. [8] concluded that the injection molded thermoplastic resins had significantly lower flexural strength at the proportional limit, lower elastic modulus, and higher or similar impact strength than the conventional heat cured acrylic resin.

The aim of the current study is conducted to modify heat cured acrylic resin denture base material with additives [Flavoring agents (caramel, banana)], and plasticizer into a flexible heat cured acrylic resin as a Flexite thermoplastic material.

MATERIALS AND METHODS

The first part of this study started with preparing fifty samples of heat cured acrylic resin that consisted of three types of additives [Flavoring agents (caramel, banana)], and plasticizer for two and seven days:

The groups of the first part of the study were as follows:

1. Control (Heat cured denture base without additives).
2. Heat cured acrylic resin denture base with flavoring agents (caramel) 15%.
3. Heat cured acrylic resin denture base with flavoring agents (banana) 15%.
4. Heat cured acrylic resin denture base with Plasticizer (15%).
5. Heat cured acrylic resin denture base with Plasticizer (20%).

In the second part, one hundred forty-five of heat cured acrylic resin with and without additives samples and Flexite thermoplastic (Valplast) sample were prepared to find out some properties.

The groups of the second part of the study were as follows:

1. Control group (Heat cured denture base without additives.
2. Flexite thermoplastic denture base without additives.
3. Heat cured acrylic resin denture base with flavoring agents (caramel) +plasticizer Di-butyl phthalate (DBP) (20%).
4. Heat cured acrylic resin denture base with plasticizer (DBP) (20%).
5. Heat cured acrylic resin denture base with flavoring agents (banana) 20%.
6. Heat cured acrylic resin denture base with flavoring agents (cramel) 20%.

The samples were prepared by cutting the hard elastic foil (master model) for tensile strength (90×10×3)±3 mm. (length, width and thickness respectively) [9, 10], dimensional accuracy (66.5×10×2.5)±0.03 mm. [11], water sorption and solubility (0.5mm thickness and 50 mm in diameter), and for color properties (30×20×1.5)±0.03 mm. [12]. Then it was carved, polished and cleaned (Figure 1).

Heat cured resin and modified heat cured samples

All samples of control group and the other groups of heat cured resin material mixed with additives were prepared in a conventional method (flasking, packing, curing according to short cycle, deflasking, finishing, polishing, and incubation in distilled water at 37±1 °C. (ADA specification no. 12, 1975) before testing [11, 12].

Flexite thermoplastic (Valplast®) samples preparation

The samples of Flexite thermoplastic material were prepared by using machine injection type (ZB-A) oven. Mold preparation was done by wax sprues with three roots and master model. After the oven was fixed at a temperature of 288°C, the capsules were grasped by a special handle and were placed inside a hole within the oven for 11–20 minutes depending on capsules size, then the material was injected inside the flask using a hydraulic press. Later, the flask was left on a cooling bench for about an hour (depending on the manufacturer's instructions). Finally, the samples were cleaned and polished (Figure 2).

Figure 1: Samples of heat cured acrylic resin with additives (flavoring agents) materials.

Figure 2: Flexite Samples prepared by machine injection type (ZB-A) oven. (A) Flexite oven, (B) Hydraulic press and the hole of flask, (C) Flexite (Valplast) samples.

Tensile strength

Sixty samples of heat cured resin material and Flexite thermoplastic material were measured after two and seven days by using Terco Universal testing machine. The measurements were calculated by equation no. 1:

Tensile strength = F (N)/A (mm^2).....no. 1.

After these two periods, the group which showed the minimum tensile strength change would be stored for 6 months, to re-measure.

Water sorption

Twenty five samples of heat cured resin material which included control group and the other four groups with additives were tested according to ADA specification No.12 [11], and Kazanji and Watkinson [13], and were calculated according to equation No. 2: [weight after immersion (mg) - conditioned weight (mg)]/surface area (cm^2)=sorption (mg/ cm^2).....No. 2.

Water Solubility

After the final weighing of samples in water sorption test, the disks were reconditioned to constant weight in the desiccators at 37 ± 2°C. The lost soluble matter during immersion was determined to the nearest 0.01 mg/ $cm^2$and calculated by equation No.3: [conditioned weight (mg) - reconditioned weight (mg)]/surface area (cm^2) = solubility (mg/cm^2)....No.3.

Color change

Thirty samples of heat cured acrylic resin with additives, control group (HCAR) and Flexite thermoplastic material were divided into six groups and measured by using computerized ultraviolet-visible spectrophotometer (Genesys20, USA). The absorbed light was measured with accuracy up to 0.001 nm, and it is also called the optical density [14]. The wavelength of maximum absorption was usually reported as **λmax.** The wavelength **(λmax.)** of heat cured acrylic resin was 345 nm. [15].

Dimensional accuracy

Thirty samples were prepared to measure the dimensional accuracy after two and seven days by using digital caliper (accuracy of 0.001 mm.) [16].

RESULTS

Table 1 gives the mean, standard deviation of tensile strength (2 and 7 days) for the materials added to the PMMA in the first part of the current study.

The mean and standard deviation of groups with additives, viz, (plasticizer and flavoring agents (caramel, banana) showed lower tensile strength than the control

after a period of 2 days, whereas the group with plasticizer of 15% concentration manifested the highest tensile strength (36.556N/mm²) after control group. Moreover, the group with caramel additives showed the lowest tensile strength (22.437 N/mm²)

The mean and standard deviation of groups with additives (plasticizer and flavoring agents (caramel, banana) after a period of seven days showed a change in tensile strength, whereas the group with caramel additive showed the lowest change (26.337 N/mm²). Finally, the group with plasticizer 20% additive showed the highest change in tensile strength (37.240 N/mm²).

The ANOVA test showed that there were statistically significant differences (p=0.05) among groups with Additives (plasticizer and flavoring agents (caramel, banana) after two and seven days (Table 2).

According to the results of the first part, the higher concentration of flavors (caramel, banana) was taken as an attempt to increase the flexibility of the PMMA which was intended to be studied in the second part of this study.

Table 3 illustrates the mean, standard deviation, and Duncan's multiple range test of tensile strength (two and seven days, and six months) for the materials that were added to the PMMA in the second part of the present study.

The ANOVA test showed that there were statistically significant differences (p=0.05) among groups with Additives (plasticizer and flavoring agents (caramel, banana) after two and seven days (Table 4). Based on the results, it can be comprehended that the control group of heat cured acrylic resin showed the lowest change in tensile strength from the period of two to seven days, while the plasticizer group showed the highest tensile strength change from the period of two to seven days (about 30.462 to 36.446±0.226 N/mm²). After six months, the ANOVA and Duncan's multiple range tests showed that there were statistically significant differences (p=0.05) among groups.

Water sorption and solubility

Table 5 provides the mean and standard deviations of the water sorption and solubility of the control group, and the modified heat cured acrylic groups.

The ANOVA test and Duncan's multiple range test showed that there were statistically significant differences (p=0.05) among groups with Additives (Tables 5, and 6).

The mean of control group of water sorption and solubility was within the range of ADA specification No.12.

The group with plasticizer showed the highest water sorption (1.289±0.077 mg/cm²), while the group with flavoring (banana) showed the lowest water sorption among the groups treated.

The Duncan's multiple range test showed that there was no significant difference of the solubility between the control group and the groups with flavors additives, while the group with plasticizer showed a significant difference in comparison to the other groups with flavors addition (at α=0.05).

For Flexite thermoplastic material group, it was difficult to obtain samples with the dimensions of 50mm. in diameter and 0.5 in thickness according to the ADA specification No.12. Therefore, it was excluded from water sorption and solubility tests.

Color change

Table 7 provides the mean and standard deviations of the absorbance in (nm),of the control group, and the modified heat cured acrylic groups.

The ANOVA test and Duncan's multiple range test showed that there were statistically significant differences (p=0.05) among groups with Additives (Tables 7, and 8). The group with plasticizer addition showed the lowest absorbance (0.823 nm), while the group with flavor (caramel) showed the highest Absorbance (1.724 nm).

Table 7 presents the mean and standard deviations of dimensional change in (mm³),of the control group, and the modified heat cured acrylic groups.

The ANOVA test and Duncan's multiple range test showed that there were statistically significant differences (p=0.05) among groups with Additives (Tables 7, and 8).

The Duncan's multiple range test showed that, after six months, the control group of heat cured acrylic resin manifested the lowest dimensional change (1625.0022 mm³) then the Flexite thermoplastic material (1624.9812 mm³), and eventually the group of mixture flavor (caramel) and plasticizer (DBP) (1624.9454 mm³).

DISCUSSION

Considerable work has been performed in order to improve the properties of acrylic denture base material without causing deleterious effect on other properties.

To the best of knowledge, very rare if no ever previous studies changed the heat cured acrylic resin to flexible denture base with additives of flavoring agents with and without plasticizer. Hence, it was crucial to examine these experimental groups in order to retain useful properties of HCAR.

Since the introduction of the acrylic resin for denture construction, there has been continuous research for modifying this material or find a new one, that is more flexible, comfortable and more acceptable by the patients. In addition, the ordinary heat cured acrylic resin does not fit many cases.

Tensile strength

The mean tensile strength of the untreated group (heat cured acrylic resin) obtained was (54.552 N/mm²). This result was identical to Graig's et al. [17], while the result of the Flexite thermoplastic material (Valplast®) group was (63.292 N/mm²). These two groups showed a slight change in tensile strength from two to seven days.

Table 1: Mean and standard deviation for plasticizer and flavoring agents with control group for tensile strength after two and seven days

Groups	No.	Mean (two days) N/ mm2± Std.	No.	Mean (seven Days) N/ mm2± Std.
Control	5	54.335±0.671	5	54.976±0.577
Flavoring agents(caramel) 15%	5	22.437±0.771	5	26.337±0.661
Plasticizer (15%)	5	36.556±1.263	5	41.956±0.299
Plasticizer (20%)	5	31.040±0.612	5	37.240±0.582
Flavoring agents(banana) 15%	5	25.762±0.178	5	30.562±0.416

Table 2: Analysis of variance (ANOVA) for plasticizer and flavoring agents groups with control group for tensile strength after two and seven days

	Sum of Squares	df	Mean Square	F	Sig
Two Days					
Between Groups	3238.457	4	809.614	1327.532	0.000
Within Groups	12.197	20	0.610		
Total	3250.654	24			
Seven Days					
Between Groups	2635.200	4	658.800	2000.141	0.000
Within Groups	6.588	20	0.329		
Total	2641.787	24			

df =degree of freedom. Sig =significance.

Table 3: Mean, standard deviation, and duncan's multiple range test for the effect of different flexing additives on tensile strength

Groups	Mean (N/mm2)+Sd.	Duncan Groups	Number
Two Days Tensile strength			
Control (HCAR)	54.552+1.034	B	5
Flexite(Valplast®)	63.292+0.124	A	5
Flavoring (Caramel) +plasticizer (DBP) addition to (HCAR) (20%)	27.948+0.190	D	5
Plasticizer(DBP) addition to (HCAR)	30.462+0.206	C	5
Flavoring (Caramel) addition to (HCAR)	21.704+0.162	F	5
Flavoring (Banana) addition to (HCAR)	24.506+0.380	E	5
Seven Days Tensile strength			
Control (HCAR)	54.484+1.017	B	5
Flexite(Valplast®)	61.902+0.167	A	5
Flavoring (Caramel) and plasticizer(DBP) addition to (HCAR)	31.526+0.516	D	5
Plasticizer(DBP) addition to (HCAR)	36.446+0.226	C	5
Flavoring (Caramel) addition to (HCAR)	25.020+0.403	F	5
Flavoring (Banana) addition to (HCAR)	29.512+0.252	E	5
Selected flexing additive on Tensile Strength after six months.			
Control (HCAR)	54.332± 0.636	B	5
Flexite (Valplast®)	60.845± 0.181	A	5
Flavoring (Caramel) and plasticizer(DBP) addition to (HCAR)	32.018± 1.121	C	5

HCAR= (heat cured acrylic resin). (N/mm^2)= Newton/square millimeter.

Table 4: Analysis of variance (ANOVA) for the effect of different flexing additives on tensile strength.

	Sum of Squares	df	Mean Square	F	Sig
Two Days Tensile strength					
Between Groups	7665.749	5	1533.150	1377.196	0.000
Within Groups	26.718	24	1.113		
Total	7692.467	29			
Seven Days Tensile strength					
Between Groups	5503.375	5	1100.675	780.021	0.000
Within Groups	33.866	24	1.411		
Total	5537.241	29			
Six Months Tensile strength					
Between Groups	2285.571	2	1142.785	66477.335	0.000
Within Groups	0.206	12	0.017		
Total	2285.777	14			

df =degree of freedom. Sig =significance.

Table 5: Mean, standard deviation, and Duncan multiple range tests for the effect of different flexing additives on water sorption and solubility

Groups	Mean (N/mm2)+Sd.	Duncan Groups	Number
Effect of different flexing additives on water sorption.			
Control (HCAR)	0.582± 0.150	C	5
Flavoring (Caramel) and plasticizer(DBP) addition to (HCAR)	1.006±0.251	B	5
Plasticizer (DBP) addition to (HCAR)	1.289±0.172	A	5
Flavoring (Caramel) addition to (HCAR)	0.99±0.029	B	5
Flavoring (Banana) addition to (HCAR)	0.910±0.061	B	5
Effect of different flexing additives on water Solubility.			
Control (HCAR)	0.0452±0.007	B	5
Flavoring (Caramel) and plasticizer(DBP) addition to (HCAR)	0.0878±0.012	B	5
Plasticizer(DBP) addition to (HCAR)	0.2218±0.123	A	5
Flavoring (Caramel) addition to (HCAR)	0.0546±0.011	B	5
Flavoring (Banana) addition to (HCAR)	0.0726±0.015	B	5

HCAR= (heat cured acrylic resin). (N/mm^2)= Newton/square millimeter.

Table 6: Analysis of Variance (ANOVA) for the effect of different flexing additives on Water sorption and solubility

	Sum of Squares	df	Mean Square	F	Sig
Water Sorption					
Between Groups	1.353	4	0.338	13.639	0.000
Within Groups	0.496	20	0.025		
Total	1.849	24			
Water Solubility					
Between Groups	0.104	4	0.26	8.207	0.000
Within Groups	0.063	20	0.003		
Total	0.167	24			

df =degree of freedom. Sig =significance.

Table 7: Mean and standard deviation, Duncan multiple range tests for the effect of different flexing additives on color and volumetric changes.

Groups	Mean ± Sd.	Duncan Groups	Number
Color Change (nm)			
Control (HCAR)	1.570±0.0558	B	5
Flexite (Valplast®)	1.686±0.0508	A	5
Flavoring (Caramel) and plasticizer(DBP) addition to (HCAR)	1.389±0.0840	C	5
Plasticizer(DBP)addition to (HCAR)	0.823±0.7090	D	5
Flavoring (Caramel) addition to (HCAR)	1.724±0.03626	A	5
Flavoring (Banana) addition to HCAR	1.388±0.0051	C	5
Two Days Dimensional Change (mm^3)			
Control (HCAR)	1624.9854± 0.00838	B	5
Flexite (Valplast®)	1624.9930±0.00430	A	5
Flavoring (Caramel) and plasticizer(DBP) addition to (HCAR)	1624.9716±0.00421	C	5
Plasticizer(DBP) addition to (HCAR)	1624.9114±0.00873	E	5
Flavoring(Caramel) addition to HCAR	1624.9824±0.00114	B	5
Flavoring (Banana) addition to HCAR	1624.9544±0.00114	D	5
Seven Days Dimensional Change (mm^3)			
Control (HCAR)	1624.9818±0.00597	B	5
Flexite(Valplast®)	1624.9890±0.00158	B	5
Flavoring (Caramel) and plasticizer(DBP) addition to (HCAR)	1624.9568±0.00130	C	5
Plasticizer(DBP) addition to (HCAR)	1624.8798±0.01658	D	5
Flavoring (Caramel) addition to (HCAR)	1625.0122±0.00082	A	5
Flavoring (Banana) addition to (HCAR)	1624.9500±0.00158	C	5
Six Months Dimensional Change (mm^3)			
Control (HCAR)	1624.9822+0.0005	A	5
Flexite(Valplast®)	1624.9812+0.0018	B	5
Flavoring (Caramel) and plasticizer(DBP) addition to (HCAR)	1624.9454+0.0015	C	5

HCAR= (heat cured acrylic resin), (nm) = nanometer.

Table 8: Analysis of variance (ANOVA) for the effect of different flexing additives on color and dimensional changes

	Sum of Squares	df	Mean Square	F	Sig
Color Change					
Between Groups	2.718	5	0.544	183.271	0.000
Within Groups	0.071	24	0.003		
Total	2.790	29			
Two Days Dimensional Change					
Between Groups	326.103	5	65.221	2210.620	0.000
Within Groups	0.708	24	0.030		
Total	326.811	29			
Seven Days Dimensional Change					
Between Groups	0.023	5	0.005	146.219	0.000
Within Groups	0.001	24	0.000		
Total	0.023	29			
Six Months Dimensional Change					
Between Groups	0.008	2	0.004	416.572	0.000
Within Groups	0.000	12	0.000		
Total	0.008	14			

df=degree of freedom. Sig=significance.

The greater change in tensile strength of the group with plasticizer (30.462–36.445 N/mm²) after immersion in distilled water for two to seven days could be attributed to the leach out of plasticizer to the aqueous environment from the acrylic that caused the loss of softness property of the material and left it hard and fissured [5, 18, 19], or to the increase in rigidity of material, allowing an increase in the tensile strength of the material [20, 21].

The mean of tensile strength after two to seven days for caramel group obtained (21.704 N/mm² to 25.020 N/mm²), and for group with banana flavor addition was (24.506 N/mm² to 29.512 N/mm²) due to the addition of flavors to heat cured acrylic resin which lead to an increase in the flexibility, and to divergence between the bonds of the acrylic and eventually filled the gaps that existed in the acrylic by flavors which are oily materials, that may work as a coating. Consequently, it did not show a greater change in tensile strength within seven days [22].

The group that contains a mixture of plasticizer and caramel flavor showed a smaller change in tensile strength with increasing time of storage, for two to seven days (27.948 N/mm² to 31.526 N/mm²). That is why the same group was chosen to measure its tensile strength after six months for qualification.

This group showed a flexing characteristic that remained in the acrylic even after the period of six months with a minimum change in tensile strength (32.018 N/mm²). This group showed the minimum change in tensile strength and that may be related to the effect of flavor which behaved as a flexing and a coating material at the same time lead to reduce the leaching out of the plasticizer and keep the flexibility of the acrylic for a longer period. In general, groups with flavor addition showed a lower tensile strength than control group which may be related to gaps created between acrylic bonds by the flavors [22].

Water sorption and solubility

Tables 5 and 6 provide an acceptable mean (0.582 mg/cm²) of water sorption of the control group of heat cured acrylic resin with ADA specification No.12 [11].

While the group with plasticizer addition showed higher water sorption (1.289 mg/cm²). The low molecular weight plasticizer leached out into the water and at the same time, the water was absorbed into the polymer structure. The loss of the plasticizer appears to be the most important process. This is usually a phthalate. In an aqueous environment, the plasticizer leaches out resulting in gradual hardening and limiting of the intra-oral life of the material [23, 24].

The groups with flavor addition (caramel, banana) showed lower water sorption than the plasticizer group. Mean of water sorption for caramel group was (0.99 mg/cm²) and (0.910 mg/cm²) for group with banana flavor addition. This amount of water sorption may be related to the presence of gaps that were created by flavors between polymer bonds filled with water [25, 26].

The group that contained a mixture of plasticizer and caramel flavor showed slightly higher water sorption than groups with only flavors. Mean of the water sorption of this group was (1.006 mg/cm²). This amount of water sorption may be related to the leach out of excess plasticizer later replaced by water [22, 25].

Water sorption and solubility of polymers depended on the homogeneity of the material. The more homogeneous material was the less water absorbed and the less soluble it is [26].

The group with plasticizer addition showed the highest solubility (0.2218±0.055 mg/cm²) because of leaching out of the plasticizer besides of the residual monomer that might remain dissolving in water. This result corresponds Cucci's et al. [27] while the groups with flavor addition (caramel, banana) showed lower solubility which was very close to the result of the control group. This amount of solubility may be related to the excess flavors that might leach out from the acrylic, in addition to the residual monomer that leached out [17].

Solubility of heat cured acrylic resin mixed with plasticizer and caramel flavor showed significant effect than groups with flavors alone. This could be attributed to the effect of flavor that may work as a coating agent reducing the leaching out of plasticizer. This amount of solubility could be indicated to the small amount of residual monomer, plasticizer and flavors that were unable to incorporate.

Color change

In vitro's study, the color changes value ($\Delta E \leq 3.7$) was considered to be acceptable. While in vivo's study, the color changes value ($\Delta E \leq 6.8$) was considered to be acceptable [28, 29].

The result of color change test showed that the mean of the control group of heat cured acrylic resin was (1.570 nm) which matches Sadoon's result [10] while the result of color change of Flexite thermoplastic material group was equal to 1.686 nm. No previous studies results are identical to ours for this group, however, its color property is accepted and is close to control group of heat cured acrylic resin.

The color changes of HCAR have been investigated by many authors they have found that the color changes accompanied by changes in the properties of materials are due to its absorption of water or solubility in water [30].

Mean of color property (absorbance) (0.823 nm) of group with plasticizer addition showed a lower absorbance than control groups. This had to do with colorless property of plasticizer that was added to the acrylic which reduced the amount of light absorbed. The mean value (1.724 nm) of caramel flavor addition group showed the highest color change, this was perhaps related to the thick yellowish milky colored caramel flavor that contained xanthan and Arabic gum.

The color change of the group of banana flavor addition (1.388 nm), and mean (1.389 nm) of group that

contained a mixture of plasticizer and caramel flavor (CP-HCAR) showed a slight difference from the control group. These findings could be ascribed to the transparent color of banana flavor and plasticizer that were added, and which made the absorbance lower than control group of heat cured acrylic resin.

Dimensional change

The control group of heat cured acrylic showed the highest dimensional accuracy during the periods of two to seven days, and six months. This result is in accord with Hatim's et al. [16].

The group of Flexite thermoplastic material showed a significant change in dimensional accuracy during the periods of two to seven days and after six months). The result of this group showed high accuracy during the period of two days, which is attributed to the injection molding which was used for samples construction that was more accurate than water bath procedure. But after the samples were left in distilled water for seven days to six months, the material showed an obvious change in dimensions because of the hydrophilic property of nylon that caused water sorption and affected the dimensions of samples. This result matches with those of Parvizi's et al. [31], but disagrees with Pronych's et al. [32] who concluded that the thermoplastic resin showed dimensional changes in service compared to the conventional resins, but less dimensional change caused by dehydration.

The group of plasticizer addition showed the highest dimensional changes in two to seven days. The reason behind that was the leach out of the plasticizer and the percentage of water sorption which might cause undesirable dimensional alterations that, in turn, compromise denture clinical success and longevity [33, 34].

The groups with flavor addition (caramel, banana) showed dimensional changes that were close to the control group. These slight changes in dimensions can be justified that the water sorption between the gaps of polymer that are created by flavors.

The group that contained a mixture of plasticizer and caramel flavor showed an acceptable dimensional accuracy after six months where it was left in distilled water, since the coating effect of flavors that reduced the leach out of the plasticizer, consequently reduced the dimensional changes in this group.

CONCLUSION

Within the limitation of the experimental methods employed in the present study, the following conclusions can be drawn:

All prepared samples with additives (caramel, banana, and plasticizer) showed lower tensile strength than the heat cured acrylic resin, except the Flexite thermoplastic material group, which showed a higher tensile strength than the control group during the periods of two and seven days. The groups (control, Flexite thermoplastic material), flavoring (caramel) and plasticizer (DBP) addition to (HCAR)) that left for six months in distilled water showed a change in tensile strength. Plasticizer group showed the higher water sorption, solubility, and dimensional change, but were reduced by the addition of flavoring agent (caramel). Finally, there was no difference between groups in color properties, where all groups experienced close absorbance to the control group.

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Nadira A. Hatim – Substantial contributions to conception and design, Acquisition of data, Analysis and interpretation of data, Revising it critically for important intellectual content, Final approval of the version to be published
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Sufian Ahmed Yassin – Analysis and interpretation of data, Drafting the article, Final approval of the version to be published

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The corresponding author is the guarantor of submission.

Conflict of Interest
Authors declare no conflict of interest.

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