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The Effect of Thermal Cycling on The Fitness of Modified Heat Cured Acrylic Resin Maxillary Denture Base

Nada Z Mohammed
BDS, MSc (Lec.)

Department of Prosthodontics
College of Dentistry, University of Mosul

الخلاصة

الأهداف: لتحديد تأثير الدورات الحرارية على تطابق قاعدة الطقم العلوية للراتنج الاكريلي المحور المعالج حراريا. **المواد وطرائق العمل:** تم تحضير مئة قاعدة لطقم الأسنان العلوي من الرتنج الاكريلي المعالج حراريا وقسمت إلى مجموعتان: مجموعة مع دورات حرارية و مجموعة بدون دورات حرارية. قسمت كل مجموعة إلى : عينات سيطرة (١٠ عينات) وعينات محورة (٤٠ عينة مع إضافة ١ % كلوروهيكسيدن كلوكونيت، 1.5 % زيت حبة السودا ، ١.٥ % زيت الزعتر و٢٠ % ملين و كاراميل) . تم استخدام عشر دورات حرارية في اليوم بدرجة حرارة (٥–٥٥ ^{o}س). قيست دقةِ التطابق بعد ١٨٠٠،٩٠٠،٣٠٠،٧٠ دورة حرارية خلال فترات خزن (١إسبوع ، ١شهر ، ٣ شهورِ و٦ شهورِ) بالتعاقب . تم قياسِ دقةِ التطابق بواسطة حساب المساحة السطحيّة للفجوةِ المتكونة بين الحدودِ الخلفيةِ لقاعدةِ طقمَ الأسنان العلوي والقالب والمسُجّلة بآلةِ التصوير الرقميةِ والمدروسِ ببرنامجِ أوتوكأد . أُخضعتْ نتائج دقة التطابق إلى التحليلِ الوصفيِ(المتوسط والإنحراف المعياري)، تحليل طريقِ واحد مِنْ التباينِ (ANOVA) ، اختبار t ثنائي العينة، و اختبار دنكن. **النتائج:** دقة تطابق مجموعةِ الدورات الحراريةِ كَانتْ أقل مِنْ دقة تطابق مجموعة بدون الدورات الحرارية. القيمة الأعلى لدقة تطابق مجموعة الدورات الحرارية كانت بعد ٦ أشهرِ مِنْ الغمرِ للعيناتِ المحورة ، بينما لعينات السيطرةِ كانت قبل الغمر. **الاستنتاجات:** الدورات الحرارية أثرت سلبيا على دقة تطابق عينات السيطرة والعينات المحورة . دقة تطابق العينات المحورة أعلى من دقة تطابق عينات السيطرة مع أو بدون الدورات الحرارية •

ABSTRACT

Aims: To determine the effect of thermal cycling on the fitness accuracy of modified heat cured acrylic resin maxillary denture base. **Materials and Methods:** One hundred samples of heat cured acrylic resin maxillary denture base (Major base 2) were prepared and divided into two groups; Thermal cycling group and without thermal cycling group, each group contain; Control samples (10 samples of heat cured acrylic resin without additives) and modified samples (40 samples of heat cured acrylic resin with additives: 1% Chlorohexidine gluconate , 1.5% Nigella oil , 1.5% Thyme oil and 20% Plasticizer& caramel). The thermal cycling employed in this study was 10 cycle per day at (5-55C°). The fitness accuracy measured after 70,300,900,1800 cycle at immersion periods of (1 week, 1,3,6 months) respectively. For fitness accuracy measurement , the surface area of the gap occurred between the posterior border of the maxillary denture base and the posterior margin of the stone cast were recorded by digital camera and measured with AutoCAD program . The collected data of fitness accuracy were subjected to the descriptive analysis(mean and standard deviation) , one way analysis of variance (ANOVA), 2 sample *t*-test and Duncan Multiple range test. **Results:** The fitness accuracy of thermal cycling group was less than that of without thermal cycling. For thermal cycling group, the highest value of fitness was achieved after 6 month of immersion for modified samples, while for control samples the highest value was achieved before immersion. **Conclusion:** Thermal cycling adversely affect the fitness accuracy of control and modified samples. The fitness accuracy of modified samples was better than that of control samples either with or without thermal cycling.

Keywords: Thermal cycling , fitness, denture base

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INTRODUCTION

Acrylic resin is widely used in dentistry for various purposes like orthodeontic appliances, denture bases and provisional restoration. [1-2] Since the introduction of acrylic resin in dentistry in 1937, a certain lack of dimensional accuracy has been accepted as one of disadvantages of complete denture construction. [3-6] The greatest dimensional changes was found on the posterior palatal area. [7] Discrepancies in the adaptation on the cast at the posterior border of the maxillary record base have been reported by several investigators and have attributed to the linear dimensional change and volumetric shrinkage. [8] A variety of methods have been used to evaluate adaptation accuracy of a denture base[9] as weighing impression material cim-pressed under a denture base[10&11] and measuring the posterior border gap. [12-17]

The temperature of the mouth varies considerably by the intake of hot and cold food and drinks resulting in fatigue or stress on the denture base from the cumulative effect of shrinkage and expansion, which might lead to impair some material properties such as cohesive, compressive, and shear strength, as well as hardness and roughness. [18] The thermal changes are simulated in the researches through thermocycling, the effect of thermal cycling on the hardness, roughness, color stability , microleakage, water sorption and solubility and bond strength of acrylic resin denture base to soft lining material have been discussed by many scientist, [19-27] however little was known about the effect of thermal cycling on the fitness accuracy of acrylic resin denture base.

This study aimed to determine the effect of thermal cycling (10 cycle per day (5-55C°)) on the fitness accuracy of the modified samples (after the addition of 1% Chlorohexidine gluconate , 1.5% Nigella oil , 1.5% Thyme oil and 20% Plasticizer and caramel) of heat cured acrylic resin maxillary denture base compared to that of the control samples (without additive materials) . The fitness accuracy measured after 70,300,900,1800 cycle at immersion periods of (1 week, 1,3,6 months) respectively and compared to that of without thermal cycling.

MATERIALS AND METHODS

One hundred samples of heat cured acrylic resin maxillary denture base (Major base 2) were prepared and divided into two test groups :

1. Thermal cycling group (50 samples)
2. Without thermal cycling group (50 samples).

The samples, within each group are divided into:

❖ Control samples: 10 samples of heat cured acrylic resin maxillary denture base without additives.

❖ Modified samples: 40 samples of heat cured acrylic resin maxillary denture base with the addition of :

a- 1% Chlorohexidine gluconate [28] (10 samples).
b- 1.5% Nigella oil [29] (10 samples).
c- 1.5% Thyme oil [29] (10 samples).
d- 20% Plasticiser (dibutylphthalate) and caramel [30] (10 samples).

A master model of an edentulous maxilla was duplicated using a ready made rubber mold and dental stone type III (Elite, Seienor, industria, Italy, GSGIA0702) to fabricate 100 stone cast. The thickness of all denture bases was standardized by using 2mm hard thermoformed material and then a Biostar thermoforming equipment (Duran,Scheu/Dental, Germany) was used in the fabrication of denture base, [31] then the casts with denture base were invested using conventional methods. Acrylic resin samples were mixed and manipulated according to manufacturer directions. Care was taken to avoid porosities due to entrapment of air bubbles. Trail closure was performed. The specimens were cured in water bath with conventional curing cycle, the specimens processed at 74°C for 90 minutes, then the temperature of water path raised to boiling 100°C for 30 minutes(according to manufacturer instructions). [29] The flasks left for bench cooling to room temperature, the flasks were opened and the resin excesses trimmed from the edge of resin denture base, then the resin denture base placed on respective cast and trimmed to a horizontal line 5-mm away from the posterior end using a vertical trimmer under water cooling, then the cut surfaces were cleaned to allow a visual distinction.[9] The two groups (with and without thermal cycling) were stored in a water bath containing tap water at a controlled temperature of 37 ± 1°C for 1 week, 1, 3 and 6 months respectively. The group of thermal cycling were subjected to an alternating manual thermal cycling of +5 ±2°C and +55±2° for 10 cycle per day , the duel time at each temperature was 30 seconds and the transport time between the water baths was 15 second . [22-27&32] The fitness accuracy measured after 70,300,900,1800 cycle at the immersion periods of (1 week, 1,3,6 months) respectively.

For fitness accuracy measurement, a digital camera (Sony, Japan) with a very high degree of resolution (20 mega pixel) was used and placed at constant distance

(30 cm) away from each specimen using stable horizontal stand, the images then captured and the surface area of the gap occurred between the posterior border of the maxillary denture base and the posterior margin of the stone cast were recorded and measured in graph using the AutoCAD computerized program with (00.0000)mm degree of accuracy. [17]

For statistical analysis, the collected data of fitness accuracy were subjected to the descriptive analysis(mean and standard deviation), one way analysis of variance (ANOVA), 2 sample *t*-test and Duncan Multiple range test.

RESULTS

The result in Table (1) showed the decrease in the fitness accuracy of control and modified samples after thermal cycling as compared to that without of thermal cycling at the same period of time. For thermal cycling group, the highest value of fitness accuracy of control samples was achieved before thermal cycling (before immersion). While for modified samples, the highest value of fitness accuracy was achieved after 6 month of immersion . For without thermal cycling group ,the highest value of fitness accuracy of control and modified samples was achieved after 6 month of immersion.

Table (1): Mean and standard deviation of fitness accuracy of control and experimental groups with and without thermal cycling

Immersion media	Material	No.	Before immersion mean	±SD.	1 week immersion + 70 cycle mean	±SD.	1 month immersion + 30 cycle mean	±SD.	3months immersion + 900 cycle mean	±SD.	6 months immersion + 1800 cycle mean	±SD.
With thermal cycling	**control**	5	10.69	0.01	15.64	0.016	20.88	0.13	12.45	0.047	11.45	0.09
	1%chlorohexidine gluconate	5	10.36	0.089	12.03	0.01	14.12	0.09	11.03	0.014	10.3	0.049
	1.5% nigella oil	5	10.40	0.004	11.35	0.22	12.49	0.026	10.56	0.015	9.26	0.001
	1.5% thymol oil	5	10.48	0.001	12.18	0.11	14.47	0.12	10.08	0.012	9.9	0.01
	20% plasticizer & caramel	5	10.22	0.001	13.24	0.17	15.69	0.21	12.48	0.03	9.75	0.118
	Material	**No.**	**Before immersion mean**	**±SD.**	**1 week immersion mean**	**±SD.**	**1month immersion mean**	**±SD.**	**3months immersion mean**	**±SD.**	**6 months immersion mean**	**±SD.**
Without thermal cycling	**control**	5	10.61	0.003	13.14	0.012	16.13	0.012	10.75	0.053	9.76	0.038
	1%chlorohexidine gluconate	5	10.32	0.102	11.93	0.011	12.01	0.011	9.96	0.06	9.399	0.005
	1.5% nigella oil	5	10.37	0.083	10.31	0.027	11.00	0.027	9.85	0.011	9.22	0.001
	1.5% thymol oil	5	10.45	0.282	11.27	0.034	12.39	0.034	9.72	0.08	9.55	0.255
	20% plasticizer & caramel	5	10.20	0.081	11.74	0.234	12.88	0.238	9.19	0.17	8.94	0.035

No: number of samples .SD: Standard deviation

Statistical analysis Table (2) revealed a statistical significant difference in the fitness accuracy of modified samples as compared to that of control samples either with or without thermal cycling.

Table (2): ANOVA for the fitness accuracy of modified samples as compared to the control samples for with and without thermal cycling groups.

	After 1 week+70 cycle					**After 1 month +90 cycle**				
	Source	**DF**	**SS**	**MS**	**F***	**Source**	**DF**	**SS**	**MS**	**F***
With thermal cycling	factor	9	56.4372	14.1093	731.36	factor	9	204.961	51.2403	2911.12
	Error	40	0.3858	0.0193		Error	40	0.3520	0.0176	
	Total	49	56.823			Total	49	205.3133		
	After 3 months +300cycle					After 6 months +180cycle				
	Source	DF	SS	MS	F*	Source	DF	SS	MS	F*
	factor	9	24.20659	6.05165	977.27	factor	9	12.2080	3.05201	3333.48
	Error	40	0.1582	0.00619		Error	40	0.18304	0.00915	
	Total	49	533.5894			Total	49	12.39107		
Without thermal cycling	After 1 week					After 1 month				
	Source	DF	SS	MS	F*	Source	DF	SS	MS	F*
	factor	4	21.3266	5.3316	453.14	factor	4	75.3247	18.8312	1417.72
	Error	20	0.12385	0.0118		Error	20	0.2657	0.0133	
	Total	24	24.33044			Total	24	75.5903		
	After 3 months					After 6 months				
	Source	DF	SS	MS	F*	Source	DF	SS	MS	F*
	factor	9	4	5.79458	1.4486	257.85	4	1.1194	0.2798	14.32
	Error	40	20	0.11236	0.0056		20	0.3909	0.0195	
		24	5.90694				24	1.5103		

*Statistically Significant at $p \leq 0.05$

Two sample *t*-test analysis for the mean values of the fitness accuracy control and modified samples with thermal cycling revealed a statistical significant difference (at p<0.05) in their fitness accuracy as compared to that of without thermal cycling Table (3), except that there was no statistically significant difference in the fitness accuracy of modified samples of 1.5% nigella oil with thermal cycling after 6 months of immersion as compared to that without thermal cycling.

Table (3): Two sample *t*-test for the effect of thermal cycling on the fitness accuracy of control and modified samples as compared to that without thermal cycling**.**

Material	**DF**	**After 70 cycle (1 week immersion)**		**After 300 cycle (1 month immersion)**		**After 900 cycle (3months immersion)**		**After 1800 cycle (6 months immersion)**	
		t	***p***	***t***	***p***	***t***	***p***	***t***	***p***
control	8	-89.4	0.000	-79.31	0.000	-75.76	0.000	-30.39	0.000
1%chlorohexidine gluconate	8	-6.26	0.000	-52.45	0.000	-111.94	0.000	-13.43	0.000
1.5% nigella oil	8	-10.43	0.000	-56.00	0.000	-14.87	0.000	0.3	0.78
1.5% thymol oil	8	-17.14	0.000	-16.49	0.00.	-5.87	0.000	-6.15	0.000
20% plasticizer & caramel	8	-11.49	0.000	-92.47	0.000	-43.24	0.000	-14.27	0.00

Considering the effect of thermal cycling on the fitness accuracy of control and modified samples, ANOVA analysis Table(4) revealed a statistical significant difference (at $p<0.05$) in the fitness accuracy of these samples among the different thermal cycles (70,300,900,1800 cycle) that used in this study as compared to that without thermal cycling.

Table (4): ANOVA for the effect of thermal cycling on fitness accuracy of control and modified samples.

Control

Source	**DF**	**SS**	**MS**	**F***
factor	9	533.4312	59.2701	1543.53
Error	40	0.1582	0.004	
Total	49	533.5894		

1% chlorohexidine gluconate

Source	DF	SS	MS	F*
factor	9	86.82465	9.64718	2103.27
Error	40	0.18347	0.00459	
Total	49	87.00812		

1.5% nigella oil

Source	DF	SS	MS	F*
factor	9	39.9587	4.4399	443.51
Error	40	0.4004	0.0100	
Total	49	40.3592		

1.5% thymol oil

Source	DF	SS	MS	F*
factor	9	108.667	12.0741	566.37
Error	40	0.8527	0.0213	
Total	49	109.5201		

20% plasticizer & caramel

Source	DF	SS	MS	F*
factor	9	205.5712	22.8412	1293.30
Error	40	0.7064	0.0177	
Total	49	206.2776		

DMRT analysis Figure (1-5) revealed a statistical significant difference for the mean value of fitness accuracy of control and modified samples with and without thermal cycling after 1 week, 1,3,6 months of immersion, except that for modified samples of 1% chlorohexidine gluconate, there was no Statistical significant difference in their fitness accuracy either with or without thermal cycling after 1 week of immersion.

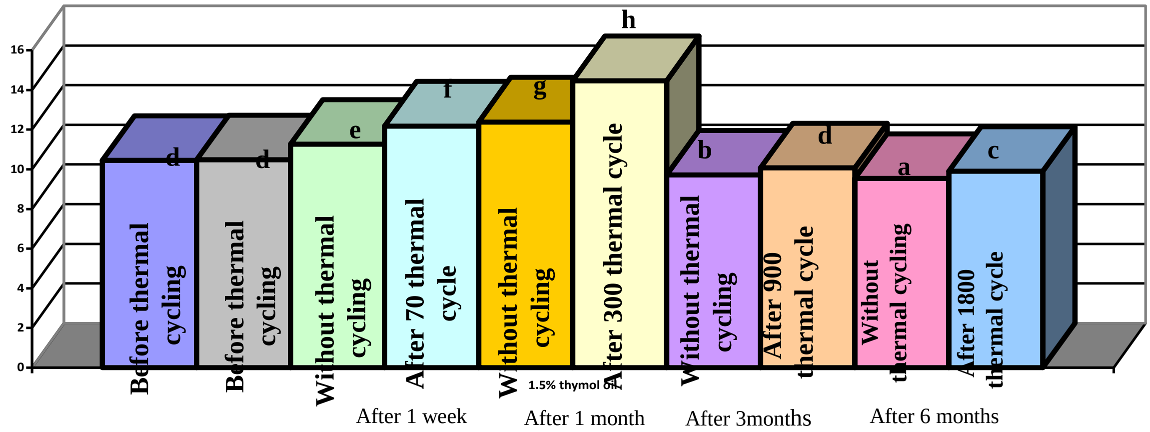
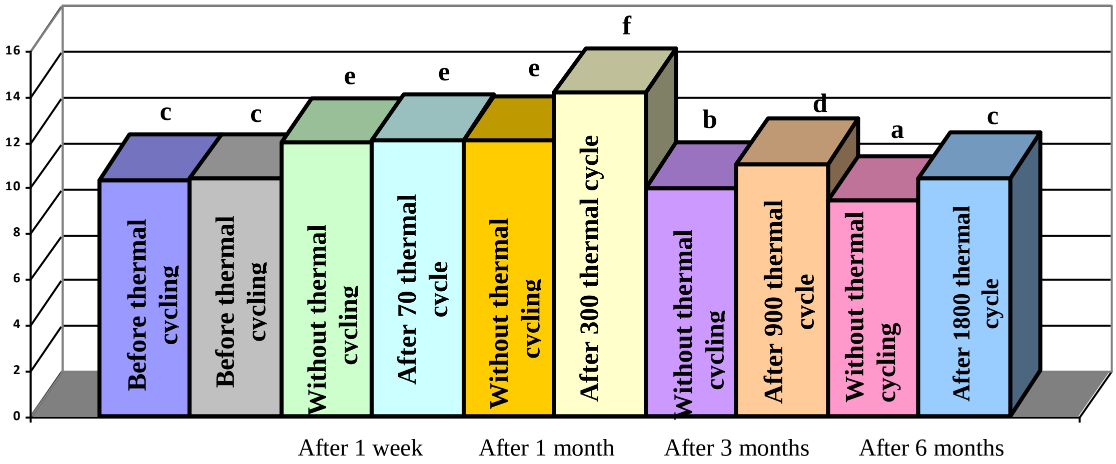


figure (1): DMRT for the effect thermal cycling on fitness accuracy of control group.



Figure(2): DMRT for the effect of thermal cycling on fitness accuracy of modified samples of 1% chlorohexidine gluconate.

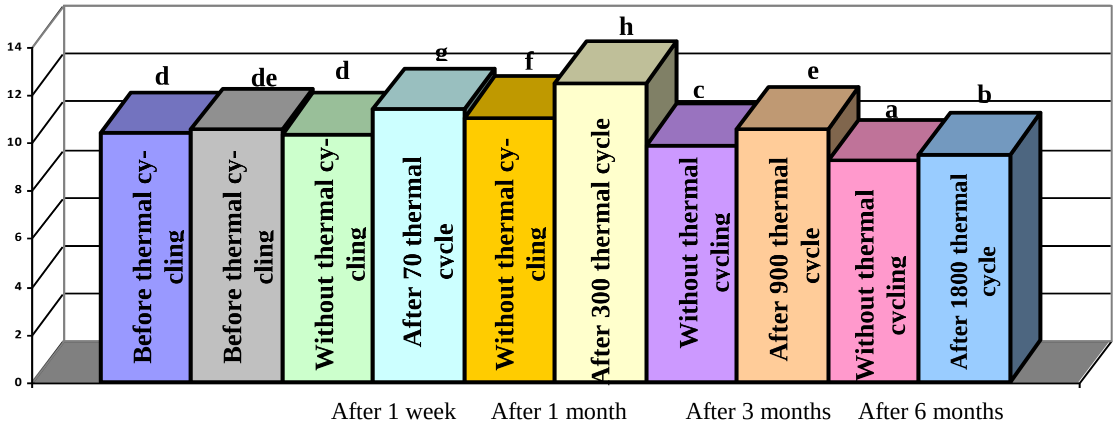


Figure (3): DMRT for the effect of thermal cycling on fitness accuracy of modified samples of 1.5% nigella oil.

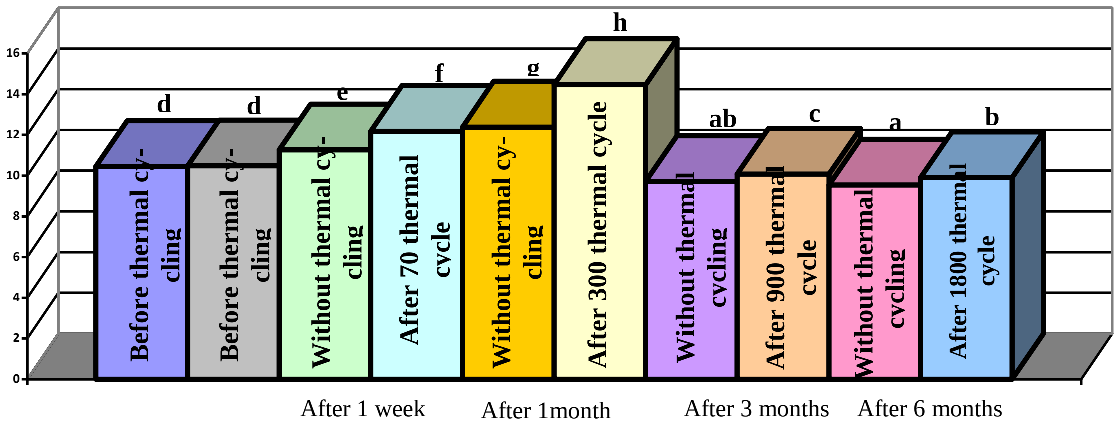


Figure (4): DMRT for the effect of thermal cycling on fitness accuracy of modified samples of 1.5% thymol oil.

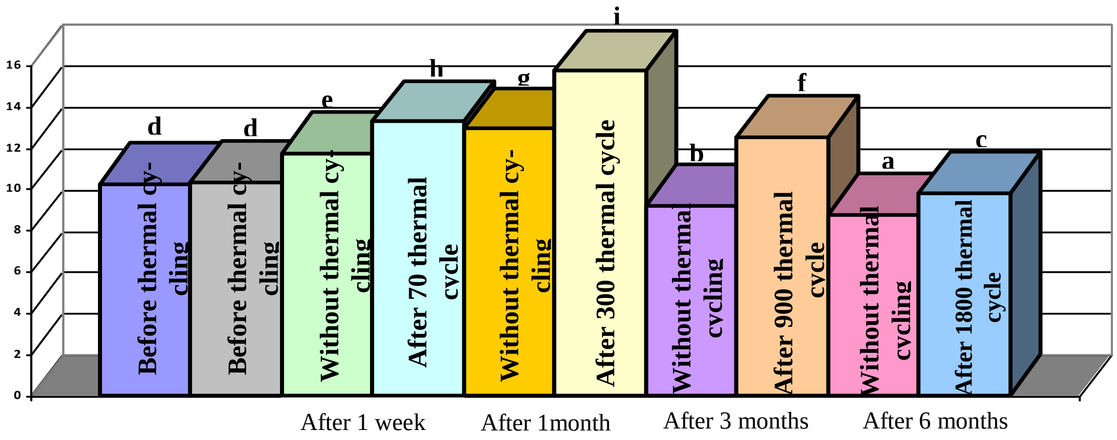


Figure (5): DMRT for the effect of thermal cycling on fitness accuracy of modified samples of 20% plasticizer & caramel.

DISCUSSION

The close contact between the denture base and the cast results in better adaptation of the tissue surface of the denture to the oral tissues which will result in a more retentive denture[6] .During clinical use, the temperature of a dental prosthesis may vary considerably because of the intake of hot and cold food and drinks[33], and the use of warm or hot water in cleaning the prosthesis . [34]

The results in Table (1) showed that the fitness accuracy of modified samples is higher than that of control samples either with or without thermal cycling. This can be explained by the fact that the addition of chemical materials cause alteration in molecular resin chain (modify the magnitude of inter polymeric gaps) and consequently alter water sorption. [35] For modified (with and without thermal cycling) and control samples (without thermal cycling)Table (1) ,the highest value of fitness accuracy was achieved after 6 month of immersion, while for control samples of thermal cycling group, the highest value of fitness accuracy was achieved before thermal cycling(before immersion). This may be explain by the fact that the cumulative effect of shrinkage and expansion as a result of temperature changes induces a fatigue or stress in the material[18] and thereby decreases its fitness accuracy . Statistical analysis (Table 2) revealed a statistical significant difference in the fitness accuracy of modified samples as compared to that of control samples either with or without thermal cycling. Different commercial types of acrylic resin exhibit significant differences in residual monomer, water uptake and ratios of water sorption and solubility [36,37]which can change the adaptation of the denture base.[16]

Two sample T test analysis revealed a statistical significant difference (at p<0.05) in the fitness accuracy of thermal cycling group as compared to that of without thermal cycling group Table (3), except that there was no statistically significant difference in the fitness accuracy of modified samples of 1.5% nigella oil with thermal cycling after 1800 cycles as compared to that without thermal cycling. One of the possible explanations for the decrease in the fitness accuracy of control and modified samples of thermal cycling as compared to that of without thermal cycling may be the continuous polymerization reaction where residual monomer molecules are progressively consumed, [38] leading to more complete polymerization, the other possible explanation is that thermal changes may be responsible for biodegradation(release of unbound/uncured monomers or and additives from the polymer network)[39-41] of acrylic resin denture material, in addition to the fact that as temperature increases, molecular mobility speeds up. [42] which may explain the increase in the solubility of acrylic resin samples which accounted for the decrease in fitness accuracy of control and modified samples of thermal cycling group as compared to that of without thermal cycling group.

Statistical analysis revealed a statistical significant difference for the mean value of fitness accuracy of control and modified samples among the different thermal cycles(70,300,900,1800 cycle) that used in this study as compared to that without thermal cycling (Table 4 and Figures 1-5). This can be related to the release of residual stress as a result of difference in thermal coefficient of expansion (due to cooling and heating). (7&43) Gap formation between the denture base and cast are generally attributed to polymerization shrinkage of resin material and the release of internal stress that produced thermal expansion of denture base (13) in addition to tendency of cooling shrinkage. (9)

CONCLUSION

Thermal cycling adversely affects the fitness accuracy of control and modified samples. The fitness accuracy of modified samples is better than that of control samples either with or without thermal cycling.

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