Effect of sodium fluoride on the properties of acrylic resin denture base material subjected to long-term water immersion

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ABSTRACT

Background: Fluoridated acrylic resin material can present more stable properties when compared with conventional one.The most widely used fluoride –containing substance added to dental resin materials is sodium fluoride (Naf). This study evaluated the effect of Naf in different concentration to the acrylic resin denture base material and its effect on tensile strength ,modules of elasticity with long –term water immersion (after 4 months immersion in de-ionized water)

Materials and methods: Eighty specimens from dumbbells shaped metal pattern for tensile strength test were preparedaccording to ISO 527: 1993 plastic –Determination tensile properties ,in dimensions(60mm, 12mm, 3 ± 0.2mm) length, width and depth respectively were allocated to two groups according to water immersion there were 40 specimens before immersion and 40 specimens after water immersion for 4 months in de-ionized water(the de-ionized water was changed every day),these two groups were sub divided in to four groups according to the concentration of Naf,Naf powder were added to monomer of acrylic in concentrations of 1%,2%and 5% Naf .0% Naf(control group) ,then mixing were done with polymer according to manufacture instructions ,the conventional flasking ,packing procedure were used following that (fast cycle). For tensile strength test the measuring was done by Instron machine, the values of modulus of elasticity were obtained from tensile test.

Results: Results showed that the addition of sodium fluoride to acrylic resin material werelower the tensile strength and modules of elasticity with highly significant differences p<0.01 when compared to control group regardless the concentration of Naf,But after immersion (for 4 month) the tensile strength and modules of elasticity increased in comparison to groups before immersion (with highly significance differences p <0.01), highly significance differences (p <0.0)were found between groups after and before immersion in all concentrations except for tensile strength between 1%Naf and 2%Naf after immersion there was no significant differences(p>0.05), and for modules of elasticity between control and 1%Naf, 1% Naf and 2%Naf(after immersion),there was only significant differences between them(p<0.05).

Conclusions: Addition of fluoride to acrylic resin material lower the tensile strength and modules of elasticity when compared to control group regardless the concentration of Naf, But after immersion (for 4 months) the tensile strength and modules of elasticity increased in comparison to groups before immersion (with highly significance differences p <0.01)

Key words: Fluoride, acrylic, properties, water immersion. (J Bagh Coll Dentistry 2014; 26(4):14-21).

الخلاصة

المقدمة:مادة الراتنج الاكريليك المفلوره يمكن أن تقدم خصائص أكثر استقرارا بالمقارنة مع المادة التقليدية للاكريليك. الأكثر استخداما على نطاق واسع مواد الفلورايد المضافة الى الموادالراتنجية هو فلوريد الصوديوم.

الهدف من الدراسة:دراسة تأثير اضافه تراكيز مختلفة من صوديوم الفلورايد للاكريليك الراتنج ومعرفة تأثيره على قوة الشد ،معامل المرونة مع الغمر في الماء الايوني لمدى طويل (بعد 4 أشهرغمر في الماء الأيوني)

المواد وطريقة العمل:80عينة من شكل عظمة الكلب على نمط معدني حضرت لأختبار قوة الشد وحسب الابعاد (60,12,0,2 ±3) عرض طول و عمق.قسمت الى قسمين حسب الغمر بلماء الايوني ,40عينة قبل الغمر و40 عينة بعد الغمر بلماء الايوني لمدة اربعة اشهر مع تغيير الماء الايوني المغمورة فيه يومياوقسمت هاتين المجموعتين الى إلى أربعة مجموعات فرعية وفقا لتركيز ماده صوديوم الفلورايد ، أضيفت مسحوق صوديوم الفلورايد لسائل الاكريليك بنسبة 1 ٪ ، 2 ٪ ، 5٪, 0٪(مجموعة السيطرة عدم احتوائها على صوديوم فلورايد), ثم خلط مع بودر الاكريلك (البوليمر)وفقا لتعليمات الصنع.

لأختبار قوة الشد تمت بواسطة جهاز الانسترون .أما معامل المرونة تم قياسها من نتائج اختبار قوة الشد.

النتائج :تظهر النتائج أن إضافة الفلوريد إلى مادة الراتنج الاكريليك قد خفض قوة الشد و معامل المرونة, مع وجود فروق معنوية عالية (p <0.01) مقارنة مع مجموعة السيطرة بغض النظر عن تركيز صوديوم فلورايد, أما بلنسبة للقياس بعد الغمر بلماء الايوني(لمدة اربعة اشهر) تظهر النتائج بزيادة قوة الشد ومعامل المرونة مقارنة مع المجموعة قبل الغمر مع وجود فروق معنوية عالية(p <0.01).هناك فروق معنوية عالية (p <0.01)بين جميع المجاميع والتراكيز قبل الغمر وبعده ماعدا في قياس قوة الشد بين تركيز 1 ٪ ، 2 ٪ صوديوم فلورايد (بعد الغمر) فلايوجد فروق معنوية(p>0.05)وبلنسبة لقياس معامل المرونة بين:تركيز 1 ٪ و 2 ٪ صوديوم فلورايد ,و مجموعة السيطرةو1 ٪صوديوم فلورايد(بعد الغمر) توجد فقط فروق معنوية(p<0.05).

الاستنتاجات:نستنتج بأن اضافة الفلورايد الى مواد الاكريلك الراتنج يؤدي الى انخفاضقوة الشد و معامل المرونةمقارنة مع مجموعة السيطرة بغض النظر عن تركيز صوديوم فلورايد, لكن بعد الغمر بلماء الايوني(لمدة اربعة اشهر) تزداد قوة الشد ومعامل المرونة مقارنة مع المجموعة قبل الغمر مع وجود فروق معنوية عالية(p <0.01)

INTRODUCTION

Patients have to wear appliance made by acrylic resin all day (orthodontic retainer or removable appliance), so controlling oral hygiene is very important especially for dental caries which the bacteria is the pathological factor for it [(1)]. Acrylic resins have been used for the fabrication of denture bases for over 50 years.

Despite the advantages of acrylic, most notably the ease of fabrication with very simple equipment, some limitations have been documented in previous studies such as, high water sorption and solubility of denture base acrylic resins can alter their mechanical properties [(2)] such as reducing their flexural strength and fatigue limit [(3,4)].

Moreover, discoloration and consequently with the esthetic acceptability of dental prostheses [(5)] in addition to these limitations, their potential to support and promote microbial adherence [(6)]

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because conventional denture cleaning methods are unable to completely eliminate micro-organisms from dentures.

Specific materials when used in the manufacture of dentures such as the use of fluoridated acrylic can overcome some of these limitations of conventional denture base resins in addition to their potential resistance to microbial adherence [7]. These fluoridated denture base resins have shown more stable properties such as decrease water sorption, good resistance to stain and solubility when compared with conventional one [8].The aim of this study was to investigate the influence of sodium fluoride addition on some properties (tensile strength, modulus of elasticity) of heat acrylic denture base material, and its effect with long term water immersion (after4 months immersion).

MATERIALS AND METHODS

Preparation of mould

-Tensile strength

Preparation of mould**:** Eighty specimens from dumbbells shaped metal pattern were prepared, specimens from heat acrylicdenture base material (type: Clear hot- cure acrylic resin. Germany) were prepared according to ISO 527: 1993 plastic –Determination tensile properties [9] as shown in figure (1). The measuring of the tensile strength was done in the University of Technology by using Instron machine (Instron, corporation- 195 canton, mass-U.S.A).

A_1: Overall length 60±2mm.

A_2: Length of narrow parallel – sided portion 16 ± 1mm.

B_1: Width at end 12 ± 1mm.

B_2: Width of narrow parallel – sided portion 3 ± 0.2mm

C: Thickness 2 ± 0.2 mm.

r: Large radius 12 ± 1mm

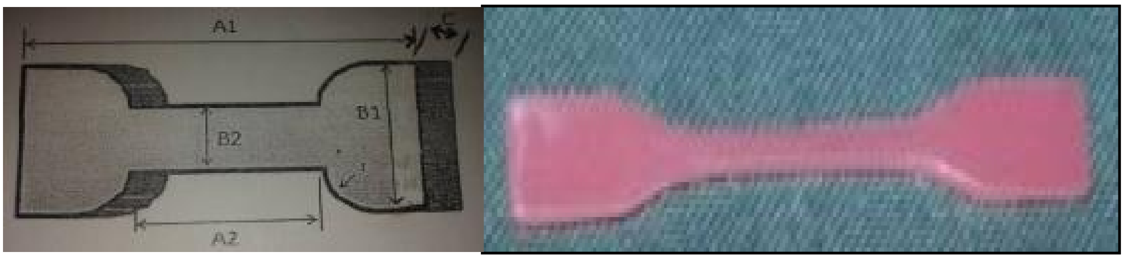

Figure 1: Dimensions of the specimens of tensile strength test

Concentration of Naf in acrylic samples

Sodium fluoride powder (BHD chemicals Ltd .Poole England) was weighed by Electronic balance(AND. Co., Japan) and added to the monomer [10] according to the concentration in this study :1%, 2%, 5%, for 1% concentration 1gram of Naf powder was dissolved in 100 ml monomer, for 2% concentration 2 gram of Naf powder was dissolved in 100 ml monomer and for 5% concentration 5 gram of Naf powder was dissolved in 100 ml monomer ,then mixed with monomer ,the mixed was done bystirrer (Magnetic stirrer Janke and Kunkel, Germany).The suspension of monomer with Naf was immediately mixed with acrylic powder according to manufacture instructions to reduce the possibility of particle aggregation and phase separation.

Distribution of the sample

Eighty samples from heat acrylic resin denture base material were prepared for Tensile strength testanddivided according to water immersion into two groups:

First group; 40 sample (before immersion in deionized water) and second group: 40 sample (after immersion in deionized water for 4 months the deionized water which was changed every day)each groups(before and after immersion)was subdivided into four groups according to Naf concentration(10 samples for each concentration) :-1% concentration of Naf ,2% concentration of Naf , 5% concentration of Naf and0% concentration of Naf which is control group (with out adding Naf)

Proportioning and Mixing of the acrylic resin

The proportion for mixing of acrylic resin was (2.5/1 by weight) (P/L). The mixing and manipulation was according to manufacturer's instructions. Table (1) shows the percentages and amounts of polymer, monomer, and Naf powder used in the study [11], for control group:40ml monomer mixed with 100g powder, for 1%Naf: 1gm of Naf powder dissolved in 100ml monomer, take 40ml from these 100ml and mixed with 99g polymer, for 2% Naf: 2gm of Naf powder dissolved in 100ml monomer, take 40ml from these 100ml and mixed with 98g polymer and for 5%Naf: 5gm of Naf powder dissolved in 100ml monomer, take 40ml from these 100ml and mixed with 95g polymer.

Table 1: Mixing ratio of acrylic resin

Naf percentage	Amount of Naf	Amount of polymer	Amount of monomer
0%	0	100g	40ml
1%	1g	99g	40ml
2%	2g	98g	40ml
5%	5g	95g	40ml

Methods

The conventional flasking, packing procedures were followed in the preparation of the specimens [12].

Polymerization

All specimens from heat cured acrylicwere polymerized by water bath (fast procedure), polymerization was carried out in case of water bath by placing the clamped flask in water bath and processed by heating at 74 ˚C for 1, 1/2 an hour and the temperature was then increased to the boiling point for half an hour according to ADAS, No. 12 [13].

After completion and curing the acrylic specimens were removed carefully from the stone mold. All the acrylic resin specimens were finished and polished according to conventional procedure till glossy surface was obtained. The final measurements were obtained using the micrometer and vernier.

Methods of evaluation

-Tensile strength

The tensile strength was tested using Instron testing machine equipped with grips suitable for holding the test specimen. Set at across head speed of 0.5mm/min, with a chart speed 20mm/min. The load was measured by a tensile load cell with a maximum capacity (200 Kg).The recorded force at failure was measured (Kg) which were converted into (N) [14]. The values of tensile strength were calculated by the following formula [12]:

$$T.S.\frac{F}{A}$$

Where:
T.S. = Tensile strength (N/mm).
F. = Force at failure (N).
A = Area of cross section at failure (mm).

-Modulus of elasticity: The values of modulus of elasticity were obtained from a chart get from the tensile Testing machine. The resultant graphs of stress versus strain from the Tensile strength test were used. Therefore, the modulus of elasticitywas calculated from the slope of the tangent drawn to the steepest initialstraight line portion of the stress strain curve. The following equationwas used to measure the modulus of elasticity [15]

E. = stress / strain
E. = Modulus of elasticity (N/mm^2).
Stress= force (N). /cross sectional of specimen (mm).
Strain=original length (mm)/ change in the length (mm).

RESULTS

Table 2 and figure 2 showed the descriptive of groups: mean, SD, SE, min., max.values of the tensile strength test of all groups. The mean value of tensile strength test were varied according to the concentration of Naf ,the tensile strength decreased when concentration of Naf were increased, the maximum mean value of tensile strength test recorded by control group before immersion 53.3Mpa,while the minimum mean value of tensile strength test recorded by 5% Naf before immersion which was equal to26.22Mpa, in all groups the mean value of tensile strength were higher in groups after immersion than groups before immersion except for control the mean value of tensile strength test were higher in groups before immersion in comparison to groups after immersion.

Table 2 Descriptive of tensile strength (Mpa) test

	Control		1% Naf		2% Naf		5% Naf	
	Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Mean	53.3	51.72	38.28	44.92	33.04	44.52	26.22	41.26
SD	1.602	0.545	3.025	0.875	1.679	0.418	4.834	1.163
SE	0.506	0.172	0.957	0.277	0.531	0.132	1.529	0.368
Min	51	51.3	35.5	43.5	31.3	44.1	18.9	40.1
Max	54.5	52.5	43	46.1	36	45	32	43

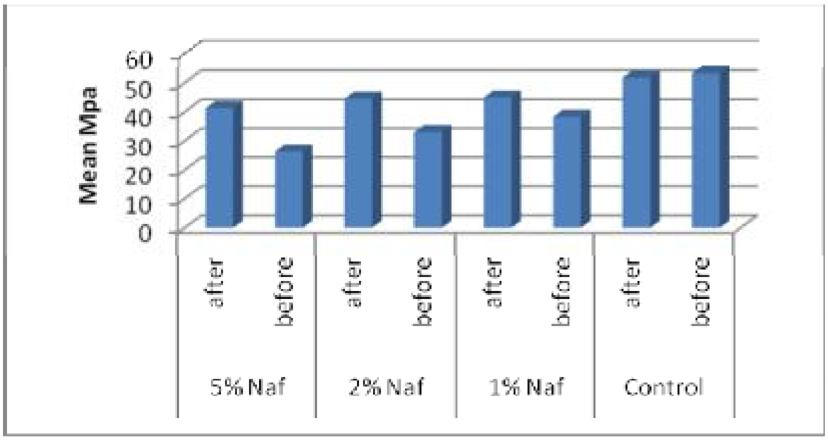

Figure 2: The mean value of tensile strength test

Table 3 showed t-test of tensile strength test between groups (control, 1%Naf, 2%Naf, 5%Naf) before and after immersion, there were highly significant differences of tensile strength test (p<0.01) between Naf groups (1%Naf, 2%Naf, 5%Naf) before and after immersion except for control there was only significant differences (p<0.05).

Table 3: t-test between groups before and after immersion of tensile strength test

Control		1% Naf		2% Naf		5% Naf	
t-test	p-value	t-test	p-value	t-test	p-value	t-test	p-value
2.327	S p<0.05	6.682	HS P<0.01	19.2	HS P<0.01	8.386	HS P<0.01

ANOVA test of tensile strength test among groups before immersion and groups after immersion show in table (4), for both groups there highly significant differences (p<0.01).

Table 4: ANOVA of tensile strength test

	F-test	P-value	Sig
Before	139.681	P<0.01	HS
After	297.885	P<0.01	HS

Table 5 showed the LSD of of tensile strength test between groups ,there were highly significant differences (p<0.01) between all groups (control, 1%Naf, 2%Naf, 5%Naf) after immersion and before immersion except between 1% Naf and 2%Naf after immersion there was no significant differences (p>0.05).

Table 5: LSD of tensile strength test

	Groups	Mean difference	P-value	Sig
Before	**Control&1%Naf**	15.020	P<0.01	HS
	Control&2%Naf	20.260	P<0.01	HS
	Control&5%Naf	27.080	P<0.01	HS
	1%Naf&2%Naf	5.2400	P<0.01	HS
	1%Naf&5%Naf	12.060	P<0.01	HS
	2%Naf&5%Naf	6.8200	P<0.01	HS
After	**Control&1%Naf**	6.8000	P<0.01	HS
	Control&2%Naf	7.2000	P<0.01	HS
	Control&5%Naf	10.460	P<0.01	HS
	1%Naf&2%Naf	0.4000	0.274	NS
	1%Naf&5%Naf	3.6600	P<0.01	HS
	2%Naf&5%Naf	3.2600	P<0.01	HS

Pearson's correlation of tensile strength test show in Table (6) there were positive relation between all groups(control, 1%Naf, 2%Naf, 5%Naf), but after immersion there were negative relation between all groups except between (1% Naf and 5%Naf), (control and 5%Naf).

Table 6:Pearson's correlation of tensile strength test

	Groups	Control	1%Naf	2%Naf	5%Naf
Before	Control	-	0.477	0.348	0.102
	1%Naf	0.477	-	0.390	0.377
	2%Naf	0.348	0.390	-	0.034
	5%Naf	0.102	0.377	0.034	-
After	Control	-	-0.103	0.310	-0.128
	1%Naf	-0.103	-	-0.123	0.154
	2%Naf	0.310	-0.123	-	-0.610
	5%Naf	-0.128	0.154	-0.610	-

Table 7 and figure 3 showed the descriptive of groups: mean, SD, SE, min., max. values of modulus of elasticity (N/mm^2) test, in all concentration(1%Naf, 2%Naf, 5%Naf), the mean value of modulus of elasticity test were higher in groups after immersion than groups before immersion the mean value of modulus of elasticity test were varied according to the concentration of Naf the modulus of elasticitywas decreased when concentrations of Naf were increased, also table show the maximum mean value of modulus of elasticity test was recorded by control group before immersion 1.65 N/mm^2,while the minimum mean value of modulus of elasticity test was recorded by 5% Naf before immersion which was equal to0.7 N/mm^2.

Table 7: Descriptive of modulus of elasticity (N/mm^2) test

	Control		1% Naf		2% Naf		5% Naf	
	Before	After	Before	After	Before	After	Before	After
Mean	1.65	1.62	1.38	1.5	1.16	1.38	0.7	0.98
SD	0.135	0.131	0.168	0.066	0.157	0.078	0.094	0.154
SE	0.042	0.041	0.053	0.021	0.049	0.024	0.029	0.049
Min	1.5	1.5	1.2	1.4	0.9	1.3	0.6	0.8
Max	1.8	1.8	1.6	1.6	1.3	1.5	0.8	1.2

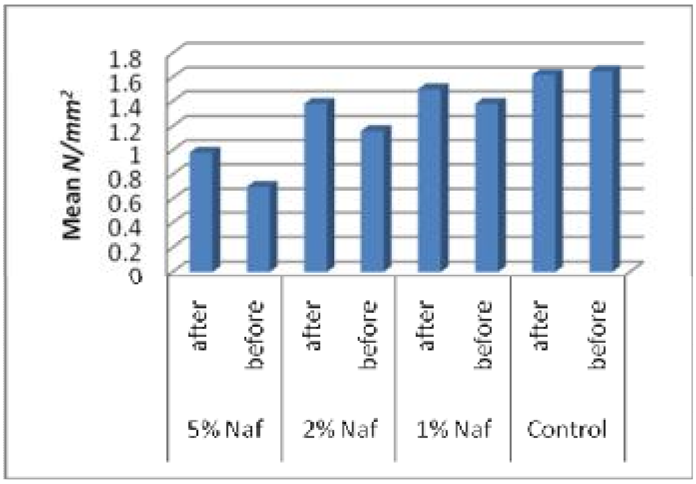

Figure 3: The mean value of modulus of elasticity test

Table 8 showed t-test of modulus of elasticity test between groups (control, 1%Naf, 2%Naf, 5%Naf) before and afterimmersion there were highly significant differences of modulus of elasticitytest ($p<0.01$) between all groups (1%Naf, 2%Naf, 5%Naf)before and after immersion except for control there was no significant differences ($p>0.05$).

Table 8: t-test between groups before and after immersionof modulus of elasticity test

Control		1% Naf		2% Naf		5% Naf	
t-test	p-value	t-test	p-value	t-test	p-value	t-test	p-value
0.758	NS p>0.05	3.087	HS P<0.01	4.957	HS P<0.01	4.332	HS P<0.01

ANOVA test of modulus of elasticity test among groups before immersion and groups after immersion is shown in table (9), for both groups there werehighly significant differences (p<0.01).

Table 9: ANOVA of modulus of elasticity test

	F-test	P-value	Sig
Before	80.189	P<0.01	HS
After	59.359	P<0.01	HS

Table 10 showed the LSD of modulus of elasticity test between groups there were highly significant differences (p<0.01) between all groups (control, 1%Naf, 2%Naf, 5%Naf) after immersion and before immersion, except between control and 1%Naf, 1% Naf and 2%Naf (after immersion), there was only significant differences between them (p>0.05).

Table 10: LSD of of modulus of elasticity test

	Groups	Mean difference	P-value	Sig
Before	**Control&1%Naf**	0.27000	P<0.01	HS
	Control&2%Naf	0.49000	P<0.01	HS
	Control&5%Naf	0.96000	P<0.01	HS
	1%Naf&2%Naf	0.22000	P<0.01	HS
	1%Naf&5%Naf	0.66000	P<0.01	HS
	2%Naf&5%Naf	0.46000	P<0.01	HS
After	**Control&1%Naf**	0.12000	P<0.05	S
	Control&2%Naf	0.24000	P<0.01	HS
	Control&5%Naf	0.64000	P<0.01	HS
	1%Naf&2%Naf	0.12000	P<0.05	S
	1%Naf&5%Naf	0.52000	P<0.01	HS
	2%Naf&5%Naf	0.4000	P<0.01	HS

Pearson's correlation of modulus of elasticitytest show in table (11) there were positive relation between all groups (control, 1%Naf, 2%Naf, 5%Naf) before immersion except between control and 1%Nafthere was negative relation, but after immersion there were negative relation between all groups except between (1%Naf and 2%Naf), (1%Naf and 5%Naf) and (2%Naf and 5%Naf) there were positive relation between them.

Table 11: Pearson's correlation of modulus of elasticity test

	Groups	Control	1%Naf	2%Naf	5%Naf
Before	**Control**	-	-0.195	0.208	0.000
	1%Naf	-0.195	-	0.468	0.699
	2%Naf	0.208	0.468	-	0.747
	5%Naf	0.000	0.699	0.747	-
After	**Control**	-	-0.127	-0.171	-0.087
	1%Naf	-0.127	-	0.845	0.430
	2%Naf	-0.171	0.845	-	0.509
	5%Naf	-0.087	0.430	0.509	-

DISCUSSION

Specific materials when used in the manufacture of denture care enhance the elimination of micro-organisms to promote oral hygiene [16], fluoride is widely used for caries controland in same way to improve the properties of acrylic resin [9,17].

In the present study the tensile strength and modulus of elasticity tests of acrylic denture base material were evaluated after the addition of sodium fluoride with different concentrations which may supposed to improve the properties of acrylic resin, butthe tensile strength and modulus of elasticity of all samples containing fluoride is lower than tensile strength in comparison to the control with highly significant differences (p<0.01) the possible explanation for lower mean tensile strength and modules of elasticity reside in the intermolecular interaction .The presence of fluoride in methacrylat polymers results on different intermolecular distances [18], fluoride acrylic usually have lower mechanical strength than conventional materials due to decrease cohesive energy that reduce the effect of polymer chain entanglement [7]; however part of this decline can be explain by the dilution of other components of the liquid , such as the cross linking agent [19] there is association between increasing concentrations of cross linking agent and increased tensile strength and modules of elasticity [20], so addition of Naf will dilute this component(that responsible for increasing tensile strength) which lead to lowering the tensile strength, this results agreement with others studies [9,17,18]. Another explanation for decreasing the tensile strength was related to the primary problem with incorporation of inorganic fluoride into dental resins is an inherent incompatibility caused by a large difference in polarity between the ionic fluoride and the low-polarity dental resin, the latter being an organic material. Incompatibility usually causes phase separation with the resin, loss of mechanical integrity of the resin and rapid fluoride ion release within the first few hours of use. Incorporation of low molecular weight organic fluoride species has a plasticizing effect which leads to similar undesirable results [7]

After immersion for four months in de-ionized water the tensile strength and modules of elasticity was increased ,this may be due to release of fluoride and decreased its effect ,in previous studies [9,21] show the fluoride release was observed with first 2 day then decrease fluoride level after 2 day and the release of fluoride become in small concentration and it is duration of release depend on the types of fluoride used,example for Caf_2, fluoride release up to six months ,but for Naf the release continue up to four months, so in this study the immersion time was 4 months depend on previous results after fluoride release its effect become negligible ,so the tensile strength and modules of elasticity was increased this result was disagreement with Srithongsuk et al. [17] study that show the tensile strength decreased over time during fluoride release.

Concentrations of fluoride used in this study was 1 %, 2%, 5%, according to previous studies [9,16,20] that study different concentrations of Naf fluoride. High concentrations of fluoride were studied [9,17] 10%, 20% but the maximum concentrate for Naf was 20% ,because dough stage was not reached for 25% or more.

The concentration release in the in vitro experiment may be presumed to occur in vivo at some higher level due to larger size of dental appliances, using Naf because it is the most elevated release of fluoride compounds than other types of fluoride following by Caf $_2$then amine fluoride this may be related to the solubility's of the compounds [21]. Other limitations should be stated, the scarce literature on this subject, since no Iraqi study was found describing the incorporation of Naf in acrylic resin proprietary materials, with only a small number assessing the use of fluoridated polymers for dental applications.

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