



The Impact of the Type and Concentration of Different Additives on the Water Sorption of Denture Base Resin

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Abstract

Aims: To evaluate the effect of incorporation of different types and concentrations of additives on water sorption denture base acrylic resin. **Materials and Methods:** Heat polymerized acrylic resin samples were prepared and divided into two groups; control group (without additives) and experimental group (with additives). The additives were three types of polymers (Styrene Butadiene Rubber (SBR), Poly Ethylene Glycol (PE) and Poly Urethane (PU)) being added with three concentrations 1%, 3% and 5%. SPSS Version 19 was used to analyze and to assess the results of the present study by mean of Descriptive statistics, analysis of Variance (ANOVA) and Duncan multiple range tests at $p \leq 0.05$. **Results:** The results reveal that there is statistically significant reduction in the amount of water sorption of experimental group as compared to that of control group at $p \leq 0.05$. The reduction in the amount of water sorption of experimental group is directly proportional to the concentration of incorporate additives. **Conclusions:** Water sorption of experimental group is less than that of control group. The additives produce statistically significant reduction in the amount of absorbed water of denture base resin and this reduction was directly proportional to the concentration additives material being used.

الخلاصة

الأهداف: تهدف الدراسة الى تقييم تأثير اضافة انواع وتراكيز مختلفة من الاضافات التي يتم دمجها مع الراتنج الاكريلي المستخدم في قاعدة طقم الاسنان على قابليته لامتناس الماء. **المواد وطرائق العمل:** تم تحضير عينات من الراتنج الاكريلي المبلر حراريا وقسمت الى مجموعتين. مجموعة السيطرة (بدون إضافات) مجموعة التجربة (مع الإضافات). كانت المواد المضافة عبارة عن ثلاثة أنواع من البوليمرات (ستايرين بوتادين ربر (SBR) ، بولي إيثيلين كلايكول (PE) وبولي يوريثين (PU)) تمت إضافتها بثلاث تراكيز 1% ، 3% ، و 5%. تم استخدام SPSS الإصدار 19 لتحليل وتقييم نتائج الدراسة الحالية عن طريق الإحصاء الوصفي وتحليل التباين (ANOVA) واختبارات Duncan متعددة المدى عند $p \leq 0.05$. **النتائج:** أظهرت النتائج وجود انخفاض في كمية المياه الممتصة لمجموعة التجربة مقارنة بمجموعة السيطرة. يتناسب الانخفاض في كمية امتصاص المياه لمجموعة التجربة تناسباً طردياً مع تركيز المواد المضافة. **الاستنتاجات:** امتصاص الماء لمجموعة التجربة أقل من امتصاص الماء لمجموعة السيطرة. تنتج المواد المضافة انخفاضاً معنوياً في كمية الماء الممتص للراتنج الاكريلي لقاعدة طقم الأسنان والذي يتناسب طردياً مع تركيز الإضافات المستخدمة.

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INTRODUCTION

Complete or partial dentures are the most popular treatment modalities used to replace lost teeth; since the cost of metal base denture and dental implants are considerably higher ⁽¹⁾. Polymethyl methacrylate (PMMA) or acrylic resin is one of the most commonly used polymeric materials for this purpose ^(2&3).

During the time service of denture in patient mouth, it absorbs water and saliva. Water sorption of acrylic resin depend on its chemical composition and intrinsic strength in addition to the amount of adsorbed water ⁽⁴⁾. The polar carbonyl groups of acrylic resin pull water molecules and as the interpolymer chain distance was greater than the size of water molecules; they diffuse between the interpolymer gaps and gradually penetrate deeper into the polymer matrix and reduce the frictional forces in between the polymer chain that causes deterioration of the mechanical properties of the denture base resin ^(5&6).

It has been reported ⁽⁷⁾ that the polymerization shrinkage of acrylic resin partially compensates by water sorption. Hence, it improves the fitness of prosthesis. In contrast, it may cause dimensional change that give rise to change the previously determined occlusal vertical dimension of occlusion ^(8&9) and internal stress that in turn leads to the formation of crack and decrease the fatigue and fracture resistance of the denture base material. In addition to the

fact that water, molecules act as plasticizer that may negatively affect the mechanical properties of dental resin ⁽¹⁰⁾.

Water sorption of heat polymerized acrylic resins was more than that of self-cured resin ⁽¹¹⁾. Water sorption of denture base resin affected by the chemical composition and polymerization technique ^(12&13). It has been proved that curing of conventional and high impact heat polymerized denture base resins by infrared radiation significantly reduces their water sorption as compared to that when they cured by water bath ⁽¹⁴⁾.

The addition of filler into acrylic resin affects the amount of it's water sorption as it depend on the interfacial bonding between filler and resin matrix as well as the type, size and distribution of the fillers particle within resin matrix ^(15,16&17). Water sorption of PMMA nano composite is higher than that of PMMA hybrid Nano composite. The incorporated Nano particles lead to further fill or diminish of the micro voids in the PMMA hybrid Nano composite ⁽¹⁸⁾.

MATERIALS AND METHODS

The total number of heat polymerized acrylic resin samples (50) were divided into two groups; control group (5 samples without additives) and experimental group (45 samples with additives). The additives were three types of polymers (Styrene Butadiene Rubber (SBR), Poly Ethylene Glycol (PE) and Poly Urethane (PU)) being added with three concentrations 1%,

3% and 5%. All the samples of heat polymerized denture base resin used in this study were prepared by conventional flasking, packing and curing procedures. The molds were prepared by cutting the Biostar sheet as master mold, with the following dimension $12 \times 10 \times 4 \pm 0.02$ mm (long, width and height respectively)⁽¹²⁾.

The investing stone was mixed with water powder ratio of 100:23 according to manufacturer's instructions. A manual spatulation up to 10- 20 seconds and to get rid of possible air bubbles in the mixtures, an electrical vibrator for about 2 minutes was used.

The molds were prepared by pouring the dental stone mixture into the base half of the metallic dental flask and investing the master mold after being lubricated with a thin layer of separating medium to ensure their easy separation and removal from the stone molds after stone setting and flask opening. After complete set (about 1 hour), the set stone surface was coated with alginic insulator (cold mould seal). The upper half of the flask was put and filled with a newly mixed stone and vibrated until the flask was completely filled with some excess. Then the counterpart (upper lid) of the dental flask was put in its place and the clamp was screwed tightly and left for one hour for final setting. After this time the two halves of the dental flask were opened and the master plastic mold pieces were removed carefully to avoid damaging the stone molds, all exposed stone surfaces of

the flask were coated with alginic insulator (cold mould seal) left it to dry. This process was repeated until three layers were applied and left to be completely dry. Heat polymerized acrylic resin (Triplex Hot technical, Ivoclar vivadent, Liechtenstein) was used in this study. The manufacturer's recommendation for powder to liquid mixing ratio was followed (23.4g powder to 10 ml liquid). Composites with varying amounts of polymers were prepared by replacing a weight fraction of the pre-mixed MMA liquid with an equal weight of polymer. The weight fractions of substituted pre-mixed MMA by the polymer were 1%, 3% and 5%.

At the beginning, the specific amount of MMA was poured into a glass bottle and the particular percent of the polymer was added to it and mixed together by glass rod until a homogenous mixture liquid is obtained. The powder was then added slowly and mixed together. The mixture was covered and left until it reached dough stage, and then acrylic resin dough was packed into the stone mold. The flasks were pressed to 200 MPa pressure for 10 minutes using hydraulic bench press. After that, the flasks were transferred to a spring-loaded clamp ready for processing.

The heat curing process was carried out using a thermostatically controlled water bath. Short curing cycle was achieved at 73°C for 90 min. Then after, the water bath temperature was raised to

100°C and left boiled for 30 min. the flasks removed and left to cool down slowly on bench before opening the flask. After one day, the heat polymerized acrylic resin specimens were extracted out from the molds, cleaned; the traces of stones carefully removed and the excess margins were eliminated. The proposed dimensions of the specimens were confirmed by finishing the margins.

After specimens' preparation, they dried over silica gel in a desiccator at 37°C until their weight become constant. An electronic balance device with accuracy of 0.0001 gm was used to weight the specimens; this was considered initial weight of specimens (m_1). At this point, the volume (V) of each specimen was measured by an electronic digital vernia (accuracy of 0.01mm) and calculated using the means of three measurements of each dimension taken at three spaced locations around the borders.

Then, the specimens immersed in deionized distilled water, at $(37 \pm 1) ^\circ\text{C}$ for $7 \text{ days} \pm 2 \text{ hours}$ in a thermostatically controlled incubator. After this time, the specimens were removed from the water with tweezers, wiped with clean dry towel until freeing them from visible moisture, waved in the air for 15 seconds and weighed 1 min after removal from the water. This mass (wet mass) was recorded as (m_2). After that, the specimens were dried by placing in the desiccator that contain freshly dried silica gel at 37°C until a final constant mass is obtained

which was recorded as (m_3).

The water sorption (W_{sp}) value for each specimen were calculated and expressed in microgram per cubic millimeter ($\mu\text{g}/\text{mm}^3$) from the following equations ⁽¹⁹⁾:

$$W_{sp} = m_2 - m_3 / V$$

Where:

W_{sp} : water sorption.

m_2 : the mass of the specimen after water immersion.

m_3 : the reconditioned mass of the specimen.

V: the volume of the specimen.

After data collection, SPSS Version 19 was used to analyze and to assess the results of the present study by Descriptive statistics (means and standard deviations), analysis of Variance (ANOVA) and Duncan multiple range tests at $p \leq 0.05$.

RESULTS

The mean and standard deviations of the water sorption of control group and experimental groups are shown in figures (1,2 and 3) The results reveal that there are decrease in the water sorption of experimental groups as compared to that of control group. The reduction in the amount of water sorption of experimental group is directly proportional to the concentration of incorporate additives.

One-way analysis of variance (ANOVA) tables (1,2 and 3) show a statistically significant decrease in the water sorption of experimental group as

compared to that of control group at $p \leq 0.05$. Duncan's multiple comparison test figures (1,2 and 3) reveals that the water sorption of all experimental group decreased significantly in as compared to

that of control group at $p \leq 0.05$. Except for experimental group of 1% SBR the water sorption none significantly decreased as compared to that of control group at $p \leq 0.05$

Table (1): One-Way analysis of variance (ANOVA) for water sorption of control and experimental group of SBR polymer.

	SS	Df	MS	F	P
Between Groups	0.039	3	0.013	4.474	0.018
Within Groups	0.046	6	0.003		
Total	0.085	9			

Table (2): One-Way analysis of variance (ANOVA) for water sorption of control and experimental group of PEG polymer.

	SS	df	MS	F	P
Between Groups	0.051	3	0.017	7.411	0.002
Within Groups	0.037	6	0.002		
Total	0.088	9			

Table (3): One-Way analysis of variance (ANOVA) for water sorption of control and experimental group of PU polymer.

	SS	Df	MS	F	P
Between Groups	0.064	3	0.021	9.185	0.001
Within Groups	0.037	6	0.002		
Total	0.101	9			

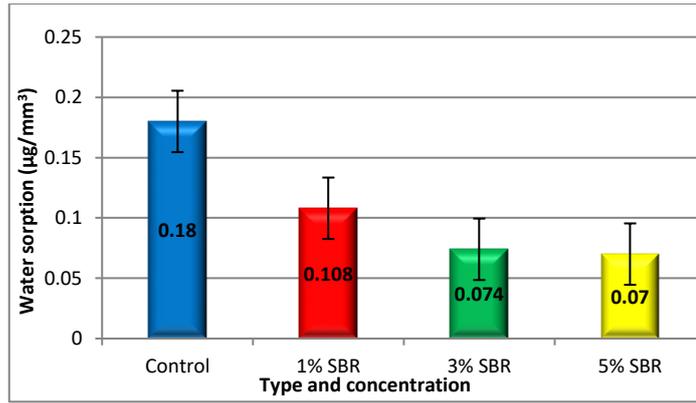


Figure (1): Mean, standard deviation and Duncan's multiple comparison test for water sorption of control and experimental group of SBR polymer

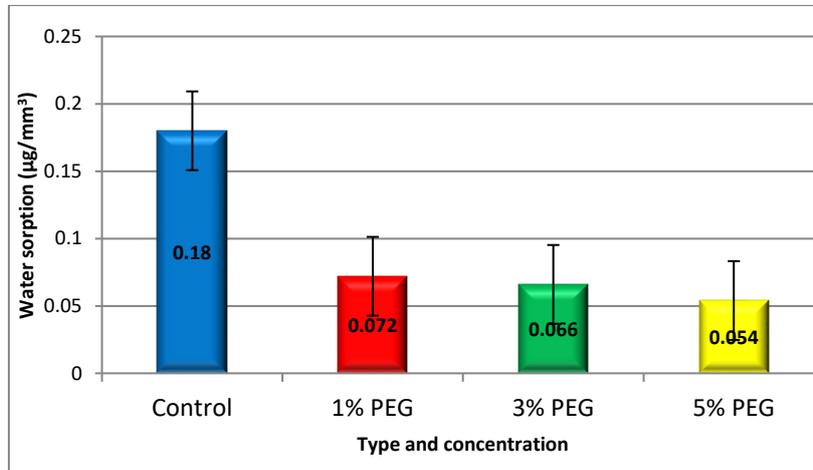


Figure (2): Mean, standard deviation and Duncan's multiple comparison test for water sorption of control and experimental group of PEG polymer.

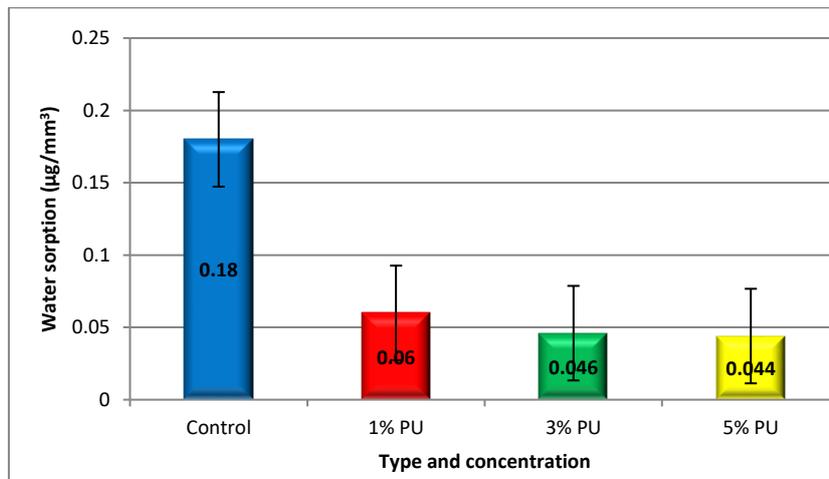


Figure (3): Mean, standard deviation and Duncan's multiple comparison test for water sorption of control and experimental group of PU polymer

The mean and standard deviations for water sorption of control and experimental groups of 1% concentration of additives (SBR, PEG and PU polymers) figure (4) reveals that the water sorption of experimental group of 1% concentration of additives is less than that of control group.

One-way analysis of variance (ANOVA) table (4) shows a statistically significant decrease in the amount of water sorption of experimental group of 1%

concentration of additives (SBR, PEG and PU polymers) as compared to that of control group at $p \leq 0.05$. While the Duncan's multiple comparison test figure (4) indicates that the significant reduction in the water sorption of experimental group of 1% concentration of PEG and PU polymers and none significant reduction in the amount of water sorption of experimental group of 1% concentration SBR polymer as compared to control group at $p \leq 0.05$.

Table (4): One way analysis of variance (ANOVA) for water sorption of control and experimental group of 1% concentration of additives (SBR,PEG and PU polymers).

	SS	Df	MS	F	P
Between Groups	0.044	3	0.015	4.669	0.016
Within Groups	0.05	16	0.003		
Total	0.094	19			

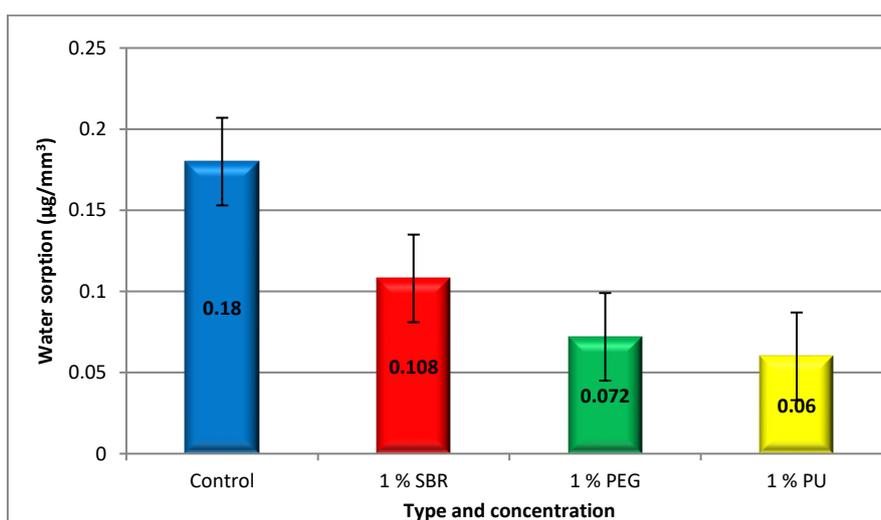


Figure (4): Mean, standard deviation and Duncan's multiple comparison test for water sorption of control and experimental group of 1% concentration of additive materials (SBR,PEG and PU polymers).

The mean and standard deviations for water sorption of control and experimental groups of 3% concentration of additives (SBR, PEG and PU polymers) figure (5) reveals that there are reduction in the amount of absorbed water of experimental group of 3% concentration of additives (SBR, PEG and PU polymers) as compared to that of control group.

Duncan’s multiple comparison test figure (5) and One-way analysis of variance (ANOVA) table (5) show a statistically significant decrease in the amount of water sorption of experimental group of 3% concentration of additives (SBR, PEG and PU polymers) as compared to that of control group at $p \leq 0.05$.

Table (5): One way analysis of variance (ANOVA) for water sorption of control and experimental group of 3% concentration of additive materials (SBR,PEG and PU polymers).

	SS	df	MS	F	P
Between Groups	0.054	3	0.018	7.83	0.002
Within Groups	0.037	6	0.002		
Total	0.091	9			

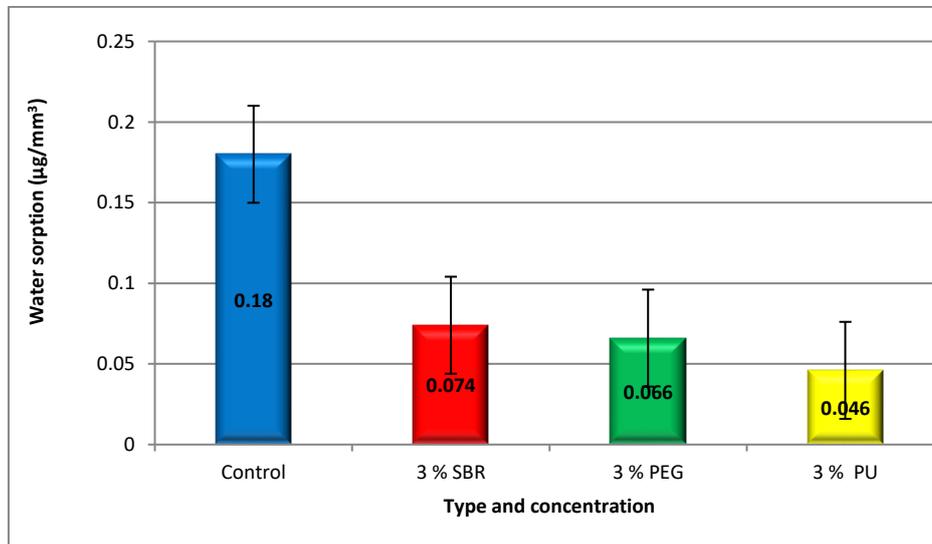


Figure (5): Mean, standard deviation and Duncan’s multiple comparison test for water sorption of control and experimental group of 3% concentration of additive materials (SBR,PEG and PU polymers).

The mean and standard deviations for water sorption of control and

experimental groups of 5% concentration of additives (SBR, PEG and PU polymers) figure (6) revealed that the water sorption

control group higher than that of experimental group of 5% concentration of additives (SBR, PEG and PU

polymers). Duncan's multiple comparison test figure (6) and One-way analysis of

variance (ANOVA) table (6) show a statistically significant decrease in the water sorption of experimental group of 5% concentration of additives (SBR, PEG and PU polymers) as compared to that of control group at $p \leq 0.05$.

Table (6): One way analysis of variance (ANOVA) for water sorption of control and experimental group of 5 % of additive materials (SBR,PEG and PU).

	SS	Df	MS	F	P
Between Groups	0.059	3	0.02	9.414	0.001
Within Groups	0.034	16	0.002		
Total	0.093	19			

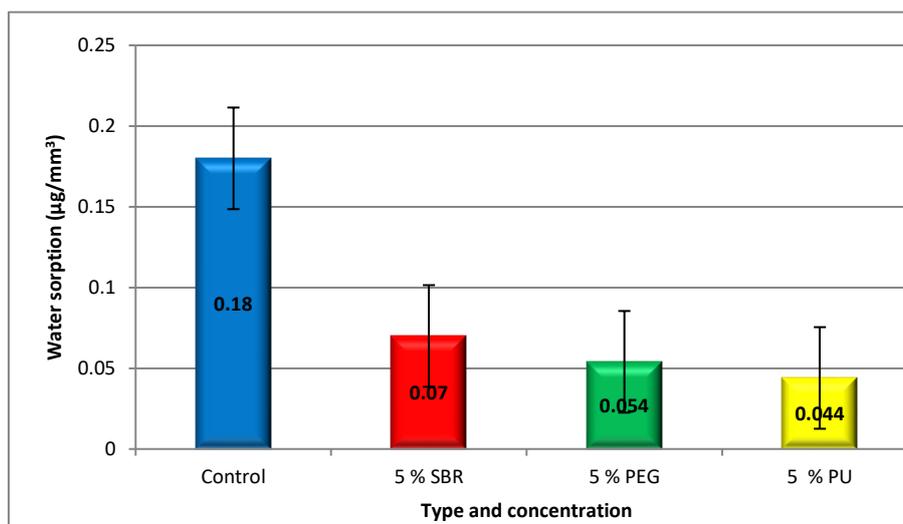


Figure (6): Mean, standard deviation and Duncan's multiple comparison test for water sorption of control and experimental group of 5% concentration of additive materials (SBR,PEG and PU polymers).

DISCUSSION

Water sorption is one of the most critical properties of denture base resin

that affects the quality of prosthesis and patient's life^(20&21). The measured amount

of water sorption of both control and experimental groups used in this study are within ADA standard value of water sorption for denture base materials which are $32\mu\text{g}/\text{mm}^3$ ⁽¹⁹⁾.

The mean and stander deviation values of the measured water sorption of

the control and experimental groups are listed in figures (1,2 and 3). These figures expose that there is reduction in the amount of absorbed water of experimental group being blended with the additive materials (SBR, PEG and PU) as compared to that of control group. When two polymers are blended together, they form what's called interpenetrating polymer network (IPN) that involves physical crosslinking rather than chemical bonding ⁽²²⁾. The cross-linking of the polymer chains increases their molecular weight, so that their resistance to solvents and water sorption are also increased ⁽²³⁾.

According to the results of this research, one way analysis of variance (ANOVA) tables (1,2 and 3) indicates statistically significant decrease in the water sorption of all experimental group as compared to that of control group at $p \leq 0.05$. While Duncan's multiple comparison test figure (1) confirms that water sorption of experimental group incorporated with 1% SBR polymer decreased none significant as compared to that of control group at $p \leq 0.05$. This was in agreement with Nguyen et al ⁽²⁴⁾, modifications in the manufacturing techniques or incorporation of different additives into denture base resin may cause the observed differences in this evaluated property.

In this study, the measured amount of water sorption varies with respect to the type of the additive materials being incorporated with heat

polymerized denture base resin figures (4,5, and 6). Water molecules are absorbed into polymer due to the polarity of the polymers' molecules, unsaturated chemical bonds or unbalanced intermolecular forces of polymer ^(25,26&27). This is in agree with Özdemir and Aladağ⁽⁴⁾ who reported that, the same type of denture base resins incorporated with some additives, show different amount of water sorption. This can be related to the improvement in the degree of conversion of experimental group with additives, water sorption of polymeric material is influenced by its degree of conversion ⁽³⁾ or it may be due to the reduction in the amount of eluted residual monomer. Heat polymerized acrylic resins that had different types of additives exhibit significant differences in amount of eluted residual monomer and ratios of water sorption ⁽²⁸⁾.

The most pronounced reduction in the amount of water sorption is recorded with the incorporation of polyurethane polymer figure (3). The amount of water sorption of polymeric materials mainly affected by their chemical composition and structural configuration ⁽¹³⁾.

The reduction in the amount of water sorption of experimental group is directly proportional to the concentration of incorporate additives figure (1,2 and 3). This may be related to the increase in physical cross-linking between polymers chains ⁽²⁹⁾ or to the reduction in the porosity within resin matrix ⁽³⁰⁾.

Incorporation of Various types and concentrations fillers reduces porosity and water absorption of acrylic resin material⁽³¹⁾.

CONCLUSION

Water sorption of experimental group is less than that of control group. The additives produce statistically significant reduction in the amount of absorbed water of denture base resin and this reduction was directly proportional to the concentration additives material being used.

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