***ISSN:* 1812–1217**

Water sorption of heat–cured acrylic resin

Ammar Kh Al-Nori
BDS, MSc (Lect)

Ahmed MA Hussain
BDS, MSc (Assist Lect)

Lamia T Rejab
BDS, MSc (Lect)

Department of Prosthetic Dentistry
College of Dentistry, University of Mosul

ABSTRACT

Aims: To evaluate the effect of the different curing methods conventional water bath heat–curing and microwave energy curing method and different immersion periods on the water sorption and solubility of the different types of heat–cured acrylic resins. **Materials and methods**: Water sorption and solubility were measured by means of mass change in the materials after water saturation and dehydration. Two different commercial heat–cured acrylic resins Major Base 2, and Quayle Dental resins were used in this study. Specimens were divided into two groups depending on the curing method. Thirty two specimens were prepared, eight specimens for each material in each group. Specimens were immersed in distilled water, and then subsequently removed from their containers at 1 week and 1 month of immersion for evaluation. Mean values wear compared statistically with one way analysis of variance followed by Duncan's multiple range test to determined the significant different among the groups at ($p< 0.05$) level of significance. **Results**: showed that the curing method and immersion period have a significant effect on the water sorption and solubility ratios of the resins. Curing by microwave energy method and increasing immersion period caused increasing in the ratios. The type of heat–cured acrylic resin has an effect but the difference was not significant. **Conclusion**: the curing method, immersion period and types of the acrylic resin have an effect on the absorption and solubility ratios.

Key words: Water sorption, acrylic resin, conventional heat–cured, microwave .

Al- Nori AKh, Ali AA, Rejab LT. Water sorption of heat–cured acrylic resin. *Al–Rafidain Dent J*. 2007; 7(2): 186–194.

Received: 14/6/2006 ***Sent to Referees:*** 2/7/2006 ***Accepted for Publication:***19/8/2006

INTRODUCTION

The most popular denture base material is heat–cured acrylic resin poly methyl methacrylate (PMMA). Acrylic polymers have been used as facings for fixed bridges to improve the esthetic value of the restoration.[1–4] Poly methyl methacrylate possesses dimensional change during processing and in service.[5] Poly methyl methacrylate absorb water slowly over period of time. This imbibition is due primarily to the polar properties of the resin molecules.[6,7] Sorption of material represents the amount of water adsorbed on the surface and absorbed into the body of the material during fabrication or while the restoration is in service. Since both adsorption and absorption are involved the term sorption is usually used to include the total phenomena. Usually a serious warpage and dimensional change in the material are associated with a high percentage of water sorption.[8] Water sorption has detrimental effect on the colour stability and the wear resistance.[9] Solubility represents the mass of the soluble materials from polymers. The only soluble materials present in denture base resins are initiators, plasticizers, and free monomer. Any observed loss of weight of the resin is the measure of the specimen's solubility.[6] Water sorption and solubility were measured by means of mass change in the materials after water saturation and dehydration.[10–12] Curing processes have been modified in order to improve the physical and mechanical properties of those materials, and also to afford the technical work of the professionals. Different polymerization methods have been used: heat, light and microwave energy.[13,14] This last method has the advantage of reducing time of curing.[15] The major advantages of microwave heating over conventional heating are: (1) the inside and outside of substance are almost equally heated, and (2) temperature rise rapidly.[7]

The aim of this study was to evaluate the effect of the different curing methods, namely conventional water bath heat–curing and microwave energy polymerization method and also different immersion periods on the water sorption and solubility of the different types of heat–cured acrylic resins.

MATERIALS AND METHODS

The two different commercial heat–cured acrylic resins were used in this study. These were Major Base 2 (M) (Major prodotti company, Italy) and Quayle Dental (England) (QD). The resins wear mixed at powder/liquid ratio of (2.5/1) by weight.[16, 17] The resins specimens for the water sorption and solubility were prepared as disks with a dimension (50 ± 1 mm in diameter and 0.5 ± 0.1mm thikness).[18] Specimens were divided into two groups depending on the curing method, "Group I" water bath method, "Group II" microwave energy curing method, and the two different resins were used in each group. Eight specimens for each material in each group were prepared, so the final total number was thirty two. For conventional water bath technique specimens cured with the conventional denture–flasking procedure. The specimens processed at 74 ^{o}C for 1.5hours, then the temperature of the water bath increase to boiling (100 ^{o}C) for additional one hour.[8] While for the curing cycle for microwave technique, a new Iraqi Fiber Reinforced Plastic (FRP) flask was placed in the microwave oven (Samsung, Model RE–570 D, 0.6 cuft, Korea) for 30 minutes at low setting (80 watts): 15 minutes per side, followed by 1.5 minutes at the high setting (500 watts).[19] Initially, specimens were dried over silica gel in a desiccator at 37 ^{o}C and weighed to an accuracy of 0.0001 g using an electronic balance (Mettler PM 460 , Germany). This was considered to be the initial weight of the specimen (W1). Specimens then were immersed in distilled water, each specimen being in separate containers. The specimens subsequently were removed from their containers at 1 week and 1 month. Excess water was removed by blotting with filter paper and the weight of the specimen was recorded (W2) at each occasion. This represent the weight of the specimen after absorption of the distilled water. The procedure was repeated after interval of 1 week and 1 month. The amount of soluble materials lost was measured by drying the specimens in the desiccator after each absorption cycle and recorded as (W3). The percentage of absorption and solubility were determined as follows [18]:

$$\text{(1) Absorption \%} = \frac{(\text{W2 - W3})\text{ g}}{(\text{W1})\text{ g}} \times 100$$

$$= \frac{(\text{Weight after absorption - final weight after desication})\text{ g}}{(\text{Initial weight})\text{ g}} \times 100$$

$$\text{(2)Solubility \%} = \frac{(\text{W1} - \text{W3})\text{ g}}{(\text{W1})\text{ g}} \times 100$$

$$= \frac{(\text{Initial weight - final weight after desication})\text{ g}}{(\text{Initial weight})\text{ g}} \times 100$$

Mean values and standard deviation wear calculated Mean values wear compared statistically with one way analysis of variance (ANOVA) followed by Duncan's multiple range test to determined the significant different among the groups at $p < 0.05$ level of significance.

RESULTS AND DISCUSSION

The results of the mean value of the water sorption and solubility in this study are shown in Tables (1 and 2). The results of ANOVA at $p< 0.05$ level of significance are shown in Tables (3–10) and the results of Duncan's multiple range test were represented in Figures (1–3). The results in Figure (1) represent the ratios of the water sorption and solubility of the QD and M resins in the tested groups Group I (water bath method) and Group II (microwave energy curing method) after 7 days of immersion. The ratios of the QD resin were higher than that of the M resin but the difference was not significant as shown in Tables (3 and 4). Denture plastics of the same type may vary in water sorption because of the presence of additives.[11] This result come in agreement with the finding of Peter and Ernst and others [20, 21] when examined the physical properties of the different brands of heat–cured denture base resins that had different additives, the resins exhibit significant differences in residual MMA monomer, water up take and ratios of water sorption and solubility.

Table (1): Means value of the water sorption rate of the tested materials cured by two different curing methods for different immersion periods.

Tested groups	No	Water sorption ratio (weight %)			
		Quayle Dental resin		Major resin	
		7 days immersion	1 month immersion	7 days immersion	1 month immersion
		Mean ± SD	Mean±SD	Mean± SD	Mean± SD
Group I	8	1.0168±0.2075	1.8221± 0.8892	0.9864±0.1374	1.4853±0.1752
Group II	8	1.3168± 0.2085	2.9221± 0.8792	1.2436±0.1813	2.3424±0.3979

SD: Standard deviation; No: Samples number; Group I: Water bath curing method; Group II: Microwave energy curing method.

Table(2): Means value of the water solubility rate of the tested materials cured by two different curing methods for different immersion periods.

Tested groups	No	Water solubility ratio (weight %)			
		Quayle Dental resin		Major resin	
		7 days immersion	1 month immersion	7 days immersion	1 month immersion
		Mean± SD	Mean± SD	Mean± SD	Mean± SD
Group I	8	0.7192± 0.6767	0.9821±1.0689	0.2743±0.1097	0.3484±0.1351
Group II	8	1.5192±0.6778	1.5964±0.68	0.9886±0.161	1.5712±0.7251

SD: Standard deviation; No: Samples number; Group I: Water bath curing method; Group II: Microwave energy curing method.

Table (3): ANOVA for the means of the water sorption ratio of the tested materials cured by different curing methods after 7days of immersion.

Source of variance	df	Water sorption ratio (weight %)					
		Water bath (Group I)			Microwave (Group II)		
		MS	F–value	*P*–value	MS	F–value	*P*–value
***Tested materials**	1	0.0032	0.10	** 0.753	0.0188	0.49	** 0.496
Error	12	0.0312			0.0382		
Total	13						

df: Degree of freedom; MS : Mean square.
*Tested materials: Quayle Dental and Major heat cured acrylic resin .
** Means are not have significant different at P≤0.05.

Table (4): ANOVA for the means of the water solubility ratio of the tested materials cured by different curing methods after 7 days of immersion.

Source of variance	df	Water solubility ratio (weight %)					
		Water bath(Group I)			Microwave(Group II)		
		MS	F–value	*P*–value	MS	F–value	*P*–value
***Tested materials**	1	0.693	2.95	** 0.112	0.986	4.06	** 0.067
Error	12	0.235			0.243		
Total	13						

df: Degree of freedom; MS : Mean square.
*Tested materials: Quayle Dental and Major heat cured acrylic resin .
** Means are not have significant different at P≤0.05.

Table (5) : ANOVA for the means of the water sorption ratio of the different materials in the tested groups after 7 days of immersion.

Source of variance	df	Water sorption ratio (weight %)					
		Quayle Dental resin			Major resin		
		MS	F–value	*P*–value	MS	F–value	*P*–value
***Tested groups**	1	0.3150	7.24	** 0.020	0.2314	8.95	** 0.011
Error	12	0.0435			0.0259		
Total	13						

df: Degree of freedom; MS : Mean square.
*Tested materials: Quayle Dental and Major heat cured acrylic resin .
** Means are not have significant different at P≤0.05.

Table (6): ANOVA for the means of the water solubility ratio of the different materials in the tested groups after 7 days of immersion.

Source of variance	df	Water solubility ratio (weight %)					
		Quayle Dental resin			Major resin		
		MS	F–value	*P*–value	MS	F–value	*P*–value
*****Tested groups**	1	2.240	4.88	** 0.047	1.7857	94.13	*** 0.000
Error	12	0.459			0.0190		
Total	13						

df : Degree of freedom; MS : Mean square
* Group I (resins cured by water bath) and Group II (resins cured by microwave)
** Means are significant different at P≤0.05 . *** Means are highly significant different at P≤0.01 .

Table (7) : ANOVA for the means of the water sorption ratio of the different materials for different immersion periods cured by water bath method(Group I).

Source of variance	df	Water sorption ratio (weight %)					
		Quayle Dental resin			Major resin		
		MS	F–value	*P*–value	MS	F–value	*P*–value
***Immersion periods**	1	2.270	5.44	** 0.038	0.8710	35.13	*** 0.000
Error	12	0.417			0.0248		
Total	13						

df: Degree of freedom; MS: Mean square.
*Immersion periods: 7 days and 1 month immersion period.
** Means are significant different at P≤0.05
*** Means are highly significant different at P≤0.01
*** Means are significant different at P≤0.05 .

Table (8) ANOVA for the means of the water sorption ratio of the different materials for different immersion periods cured by microwave energy method (Group II).

Source of variance		Water sorption ratio (weight %)					
		Quayle Dental resin			Major resin		
		MS	F–value	*P*–value	MS	F–value	*P*–value
***Immersion periods**	1	9.019	21.63	** 0.000	4.2263	44.21	** 0.000
Error	12	0.417			0.0956		
Total	13						

df: Degree of freedom; MS: Mean square.
*Immersion periods: 7 days and 1 month immersion period.
** Means are highly significant different at P≤0.01.

Table (9): ANOVA for the means of the water solubility ratio of the different materials for different immersion periods cured by water bath method (Group I).

Source of variance	df	Water solubility ratio (weight %)					
		Quayle Dental resin			Major resin		
		MS	F–value	*P*–value	MS	F–value	*P*–value
***Immersion periods**	1	0.242	0.30	** 0.593	0.0192	1.27	*** 0.282
Error	12	0.800			0.0151		
Total	13						

df: Degree of freedom; MS : Mean square.
*Immersion periods: 7 days and 1 month immersion period.
** Means are not significant different at P≤0.05 .
*** Means are significant different at P≤0.05 .

Table (10) ANOVA for the means of the water solubility ratio of the different materials for different immersion periods cured by microwave energy method (Group II).

Source of variance	df	Water solubility ratio (weight %)					
		Quayle Dental resin			Major resin		
		MS	F–value	*P*–value	MS	F–value	*P*–value
***Immersion periods**	1	0.021	0.05	** 0.835	1.188	4.31	** 0.060
Error	12	0.461			0.276		
Total	13						

df: Degree of freedom; MS : Mean square.
*Immersion periods: 7 days and 1 month immersion period.
** Means are not significant different at $P \leq 0.05$.

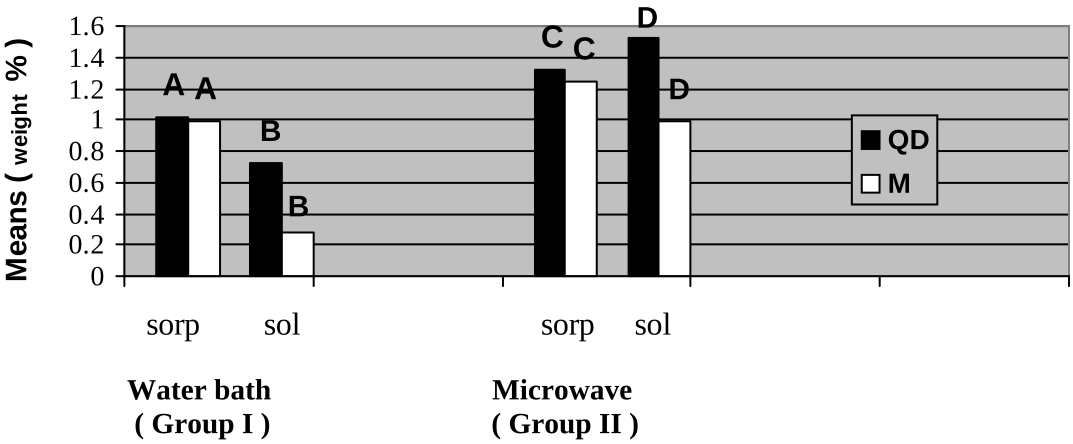

Figure (1) : Duncan multiple rang test for the water sorption and solubility ratios of the different materials(QD and M) in the tested groups after 7 days of immersion. Means with the same letter have no significant difference at $p < 0.05$; Sorp : Water sorption rate.Sol : Water solubility rate; QD: Quayle Dental heat-cured acrylic resin; M: Major heat-cured acrylic resin.

The result in Figure (2) represent the ratio of the water sorption and solubility of the tested resins after 7 days of immersion in the tested groups. The ratios for the QD and M resins in Group II (microwave energy method) were higher than that of the Group I (water bath method), the difference was significant as shown in Tables (5and 6). This finding is disagreement with the finding of Reitz *et al*., and others [22–24] in that the two polymerization methods microwave irradiation and heat activation did not cause differences in the properties of the resins. The explanation of increasing the ratios in Group II is that the microwave oven for curing resin was much faster than a conventional water bath, and degree of curing also increased a little. Microwaves act only on the monomer, which decreases in the same proportion as polymerization increases. Microwave cause the methyl methacrylate monomer molecules within the acrylic resin to orient themselves in electromagnetic field at frequency 2450 MHz, and numerous polarized molecules are flipped over rapidly and generate heat due to molecular friction. Initiating radicals are then able to react with monomers to start polymerization. Microwave processing temperatures beyond 100.3 ^{o}C caused vaporization of the monomer and produced porosity and the voids in the structure of the cured resin will increase water sorption.[7, 24, 25]

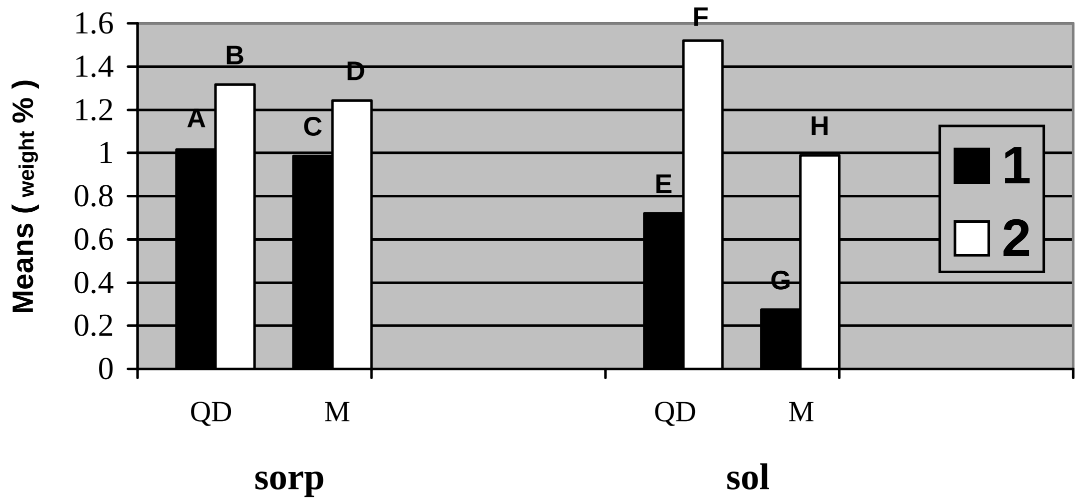

Figure (2): Duncan multiple rang test for the effect of the curing methods on the water sorption and solubility ratios of each material (QD and M) in the tested groups after 7days of immersion.
Means with the different letter have a significant difference at $p < 0.05$; (1) : Water bath curing method (Group I); (2): Microwave energy curing method (Group II); Sorp: Water sorption rate.Sol : Water solubility rate; QD : Quayle Dental heat-cured acrylic resin; M: Major heat-cured acrylic resin.

The results in Figure (3) showed the effect of the immersion period on the ratios of the water sorption and solubility of the different resins (QD and M) in the tested groups. The ratios after one month were higher than after 7 days. The difference was significant except that the difference of the water solubility ratio of the QD resin in Group I and of the two resins in Group II was not as shown in Tables (7–10). The significant differences indicated that the water uptake and leaching of the soluble mass of the resin are continues process in a period reached to 1 month. The water sorption is gradual process taking many months to complete.[9] This result come in agreement with the finding of Stafford *et al* [21] in that the resins expanded during the storage in water for one month. The result of the effect of the immersion period on the solubility disagreement with the finding of Varpu and Pekka [6] in that the largest amount of residual monomer usually leached from denture base PMMA within the first few days of water storage.

CONCLUSION

The results of this study appeared that the curing method and immersion period have an effect on the water sorption and solubility ratios of the different types of heat–cured acrylic resin, QD and M resins. The results appeared after 7 days of immersion the ratios of the water sorption and solubility of the QD were higher than that of M when cured by both conventional water bath and microwave processing. Also the ratios of the both resin were significantly higher when cured by microwave processsing method than when cured by conventional water bath method. The result also appeared that the ratios of the two resins after one month were higher than after 7 days when cured by both curing methods and the difference was significant except that the difference of the water solubility ratio of QD in Group I and that of the two the resins in Group II was not.

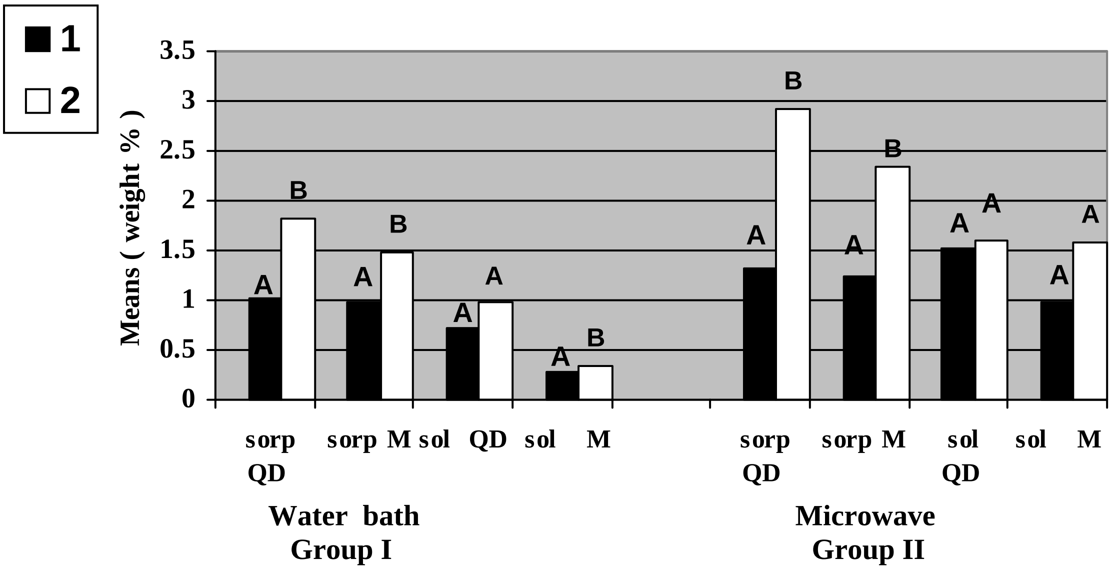

Figure (3): Duncan multiple rang test for the effect of immersion period on the water sorption and solubility ratios of (QD and M) materials in the tested groups.
Means of the ratios with different letters for each resin have a significant difference at $p < 0.05$; (1) : 7 days of immersion; (2): 1 month of immersion; Sorp: Water sorption rate; Sol: Water solubility rate. QD : Quayle Dental heat-cured acrylic resin; M: Major heat-cured acrylic resin.

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