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Water Sorption and Solubility of Two Acrylic Resin Denture Base Materials Polymerized by Infrared Radiation

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الخلاصة

الأهداف : يهدف البحث الى معرفة تاثير الاوقات المختلفة للتبلمر في الطريقة الجديدة وهي الاشعة تحت الحمراء على قابلية الامتصاص والذوبان في الماء لقاعدة الطقم من الراتنج الاكريلي. **المواد وطرائق العمل**: استخدم في هذه الدراسة نوعين من مادة طقم الاسنان المبلمرة حراريا(Traditional و High Impact) وكان العدد الكلي للعينات المحضرة هو (٨٠) والتي صنفت الى :A- مجموعة السيطرة :تتالف من عينات نوعين من الراتنج الاكريلي البلمرة بالحمام المائي ، B- مجموعة التجربة : تتالف من عينات نوعين من الراتنج الاكريلي المبلمرة بواقع ثلاث دورات مختلفة بالاشعة تحت الحمراء. قسمت العينات في كل مجموعة بالتساوي،بعضها تعود لاختبار قابلية الامتصاص في الماء والاخرى تعود لاختبار قابلية الذوبان فيه. استخدمت طريقة التغير الكتلي للمادة بعد التشبع والتجفيف من الماء ومن ثم تم التحليل الاحصائي باستخدام تحليل (التباين) ومقياس دنكن .**النتائج**:احصائيا لايوجد اختلافات بين نوعي الراتنج الاكريلي المبلمر بالحمام المائي (Traditional and High Impact) وفي كلا الاختبارين(قابلية الامتصاص في الماء والذوبان فيه). ان قيم معدل الاختبارين المذكورين سابقا وفي كلتا المادتين انخفض وبشكل معنوي عالي عند تغيير طريقة البلمرة من الاعتيادية بالحمام المائي الى الاشعة تحت الحمراء. **الاستنتاجات**: ان الاختيارالصحيح لزمن ونوع التبلمر له تاثيرواضح في التقليل من قابلية الامتصاص والذوبان في الماء للمواد الانفة الذكر.

ABSTRACT

Aims: To determine the effect of different curing times of a new method of polymerization by infrared radiation on the absorption and solubility in water of acrylic resin materials for denture base. **Materials and Methods:** In this study two types of denture base materials cured by heat were used (Traditional or Conventional and High Impact), the entire number of prepared specimens were (80) which grouped into: A- Control group: Consisted of two types of acrylic resin specimens polymerized by conventional water bath .B- Experimental group: Consisted of two types acrylic resin specimens polymerized by infrared radiation (IR) at different times of curing cycles. In each group; specimens were divided equally, some related to water sorption test others for solubility test. The mean of mass change of the material after they saturated with water and dried out of it was used, then analysis of data was done using one-way analysis of variance and Duncan test. **Results**: Statistically, no differences existed between Traditional and High Impact acrylic resin cured by water bath in water sorption and solubility tests. The mean values for previously mentioned tests in two types of acrylic resin had been decreased significantly by changing type of curing from conventional water bath to (IR) method. **Conclusions**: The selection of appropriate time and type of curing method may optimize the level of absorption and solubility in water for previously mentioned materials.

Key words Water sorption and solubility, polymethylmethacrylate, infrared radiation .

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INTRODUCTION

The curing procedures had been altered through years to get better advantages for both mechanical and physical characteristics of polymer materials. Various methods of polymerization had been used; chemical curing, heat curing, light curing and curing using microwave energy.[1] The selection of correct polymerization method includes following criteria: availability of material, its internationality, power of matter, also applicability which includes: Speed of heating, treating complexity, controlling, capability of penetration and cost. All these need to be understood [2]. Great advantages are provided by the water bath method which is the most conventional polymerization process, but a long processing time required is the major disadvantage .[3] Electromagnetic energy is converted into a heat according to the radiation heating theory. Infrared radiation heating is based on it. This is done by a resonance vibration of molecules in certain radiation wave length. It is substantial to mention that the output ionization in the resin material for both of infrared and microwave radiation are impossible due to the low energy, so curing is yet driven by heat modified by the radiation energy. Thus, the basilar mechanism of curing by infrared and microwave radiation is as yet thermal curing, even if curing is done with electromagnetic radiation but the difference between them is in their frequencies thus heating process by infrared differs from microwave radiation due to different energy of absorption. [4] Thermal curing and curing by infrared radiation were identical to each other in which there was reduction in curing time to extent of (40) percentage which had it's advantages to the practicing engineers and increasing the production rate in industry [5]. Many couplings such as CH, CH2, CH3, CC are present in polymers, these molecules are vibrating at fixed or specified frequencies, wide majority of these molecular frequencies correspond to short wave and medium infrared zone over 1.5 μm, the advantages of Infrared and laser origins considering their high pliability and controllability, therefore they were rather likable for heating, soldering of thermoplastics and identical implementation. [6,7] Water has been absorbed by acrylic resin polymer through a period of time. This is due to firstly to polar characteristics of resin [8]. The amount of absorbing water on surface and absorbed into body of the material during manufacturing or renovation in service is water sorption. [9] The property of acrylic resin that representing the not interacted materials releasing residual monomer, plasticizers and initializers is known as solubility which is identified as an unfavorable feature of resins, since they should be indissoluble in oral fluids. The tissue reactions from using prosthesis results from residues releasing from a polymerized resin base. [10] The purposes of the this study was the evaluation of the effectiveness of a new method of

polymerization by infrared radiation at three distinct times of curing cycles on water absorption and solubility of two types of hot cured acrylic resin denture base material compared with traditional water bath polymerization method.

MATERIALS AND METHODS

In this study, two types of hot cured acrylic resin materials for denture base were used: Prothyl Hot Curing and Prothyl Hot High Impact Zhermack-UNI EN ISO 14001 Badia Polesine -Italy acrylic resin and two types of polymerization process. Traditional water bath and infrared radiation (IR) which was used for the first time as a new polymerization method. Three different curing cycles with three different times of infrared radiation polymerization were chosen. The first time of IR cycle T1: 70C° for 10 min. followed by 100C° for 30 min. The second T2: 70C° for 30 min. followed by100C° for 10 min. and the last oneT3:70C° for 20 min. followed by 100C° for 20 min. respectively for two kinds of previously mentioned materials. The name of infrared radiation oven was Flavor Wave Turbo Halogen Oven, from GS, TUV ,220-240 ,V-50-60, HZ-1300W, UK,listed 39ZO,E112026 .

The entire number of samples prepared were eighty specimens. These grouped into: **A-controlling group**: Consisted of twenty specimens, ten samples for water sorption test and the same number for water solubility test. Then every ten samples were divided equally into five samples for each type of acrylic resin were used Traditional and High Impact. The samples of this group were cured by water bath 74C° for 1.5 hrs., then temperature of water bath was increased the boiling 100C° for additional three hrs.[(11)]

B - Experimental group: Consisted of sixty prepared specimens were divided equally into two large subgroups, thirty samples for water sorption test and the same number for water solubility test. Then every thirty samples for each test were divided equally into two subgroups, each one representing one type of acrylic resin material were used in this study Traditional and HI hot cured acrylic resin which consisted of fifteen samples, which also divided into three another small subgroups representing three different times of curing by IR which mentioned before, these are: T1, T2,T3. Each one consisted of five samples . The specimens were prepared as disk like, with dimension 50 mm in diameter and 1mm ± 0.05mm. A stainless-steel matrix with a diameter of 50 mm had been used to prepare the specimens [(12)]; as shown in Figure (1).

Figure (1): Acrylic Resin Sample and Matrix

After completing the polymerization, the deflasking and finishing of all samples were done using drill made of tungsten and aluminum oxide sand papers 180#, 220#, 400# at low speed. A silica gel was used then for drying specimens in a desiccator which was stored in an incubator at 37±1 ℃ for 24 hours and then removed and weighted to a fineness of 0.0001 gram, this done by using an electrical electronic sensitive scale device Germany, Mettler. This considered as the preliminary reading of weightiness of specimens W1, then all samples were sunken in deionized filtered water, every specimens being in separated container at 37±1°C for seven days ±2 hours, then specimens removed from water, wiped with pure dried hand towel till freeing them from visual moisture, flagged in air for 15 seconds, weighed 1 min. after removal them from water. This was recorded as W2. This represented the weight of specimen after distilled water absorption. [13] Specimens were dried by placing in the desiccator. It placed in recipient consists of dry, fresh silica gel stored at 37±1C° through 24 hours, afterward recipient is dropped out bench cooling about one hour till attaining room temperature, then followed by analytical weighting of specimens in balance having an accurate reading to 0.0001 gm. This was repeated every 24 hours till all samples reached the last weight W3 [14]. The following equations were used to determine sorption and solubility values. [15,16,17,18]

$$\text{Absorption is equal to } \frac{W2 - W3}{W1} \times 100$$

$$\text{Solubility is equal to } \frac{W1 - W3}{W1} \times 100$$

means and standard deviations were calculated then analysis of data carried using one-way analysis of variance and Duncan Test to determine the level of significant difference among these tested groups at level of significant $P \leq 0.05$.

RESULTS

The result of this study showed that there were statistically no differences existed between Traditional and HI acrylic resin denture base materials were polymerized by conventional water bath in water sorption and solubility tests; the Means and Standard Deviations for two tests of the studied materials were shown in Tables 1and 2 which represent Duncan Test.

Table (1): Duncan Test for Water Sorption of Heat Cured Acrylic Resin Denture Base Materials Polymerized by Water Bath

	Type of Heat Cured Acrylic Resin Denture Base Material (control)	Means of water sorption	Standard Deviation	Duncan's Grouping*
Water Sorption	prothyl hot heat curing acrylic resin for dentures	2.975	0.450	A
	prothyl hot -high impact resin(Zhermack)	2.530	0.0891	A

Table (2): Duncan Test for Water Solubility of Heat Cured Acrylic Resin Denture Base Materials Polymerized by Water Bath

	Type of Heat Cured Acrylic Resin Denture Base Material (control)	Means of water solubility	Standard Deviation	Duncan's Grouping*
Water Solubility	prothyl hot heat curing acrylic resinfor dentures	1.5750	0.1708	A
	prothyl hot-high impactresin(Zhermack)	1.455	0.1008	AB

* The share with a letter mean no significant difference exist

It is necessary to mention that Infra-red radiation was used for the first time in Prosthetic Department\ College of Dentistry\Mosul University as a new method of polymerization for acrylic resin denture base materials cured by heat. It seems clearly through the result in ANOVA Table 3

Table (3): ANOVA for the Effect of Time of Polymerization by Infrared Radiation on Water Sorption of Two Types of Acrylic Resin Denture Base Materials

Source	DF	SS (TR)	MS (TR)	F (TR)	P (TR)	SS (HI)	MS (HI)	F (HI)	P (HI)
Tested Group	3	3.985	1.328	10.66	0.001	0.9521	0.3174	9.94	0.001
Error	12	1.495	0.125			0.3832	0.0319		
Total	15	5.480				1.3353			

Traditional Acrylic Resin (TR)=Blue colour, High Impact Acrylic Resin (HI)=Red colour

High significant differences at level of significance $p < 0.01$ in water sorption of Traditional acrylic resin that cured by IR at different times T1,T2 and T3 compared with control group, also the result of Figure 2 which represented Duncan Test showed that both of T1and T2 of Traditional acrylic resin that cured by IR were at the same level of Duncan grouping ;while T3 was nearly to the previously mentioned times and control group in Duncan Grouping.

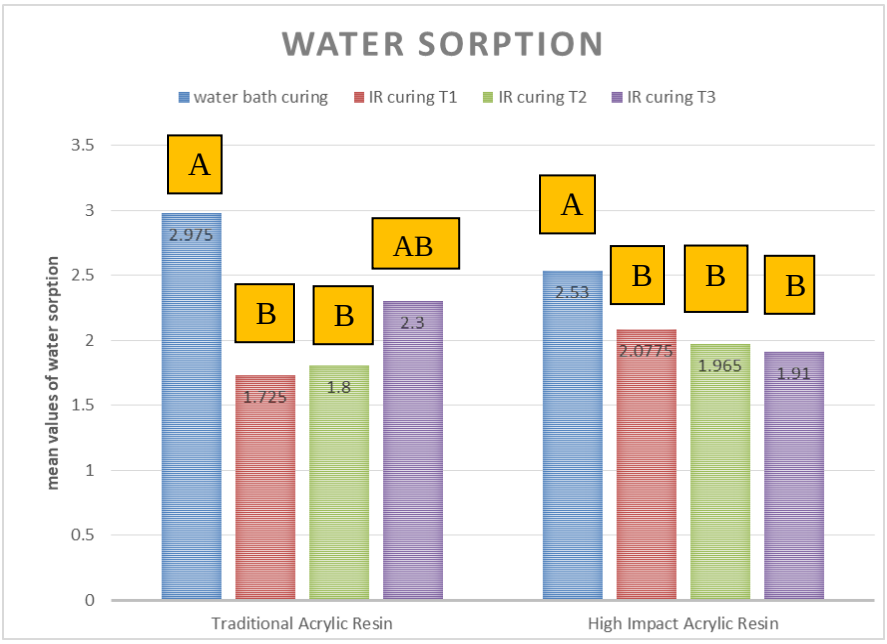

Figure (2): The Effect of Time of Polymerization by Infrared Radiation on Water Sorption of Two Types of Acrylic Resin Denture Base Materials

The result of ANOVA Table 3 also showed high differences significantly existed at level of significance p < 0.01in water sorption of HI acrylic resin polymerized byIR at T1,T2 and T3of curing cycle when compared them with control group ;the Figure 2 , also revealed that all times of polymerization T1,T2 and T3 were at the same level of Duncan Grouping .in this Figure, the least mean values of water sorption had been obtained at T1 in Traditional type while T3 for High Impact hot cure acrylic resin denture base material .For water solubility test of Traditional hot cured acrylic resin polymerized by IR at different times of polymerization cycle T1,T2 and T3, high significant differences existed at level of significance P≤ 0.01 for all times compared with control group as shown in ANOVA Table 4 .

Table (4): ANOVA for the Effect of Time of Polymerization by Infrared Radiation on Water Solubility of Two Types of Acrylic Resin Denture Base Materials

Source	DF	SS (TR)	MS (TR)	F (TR)	P (TR)	SS (HI)	MS (HI)	F (HI)	P (HI)
Tested Group	3	**3.3689**	**1.1230**	**34.22**	**0.000**	**0.5231**	**0.1744**	**3.62**	**0.045**
Error	12	**0.3938**	**0.0328**			**0.5773**	**0.0481**		
Total	15	**3.7626**				**1.1004**			

Traditional Acrylic Resin (TR)=Blue color, High Impact Acrylic Resin (HI)=Red color

The same mean values had been obtained at T1 and T2 and both of them were less than the mean at T3 as shown in Figure 3 which represented Duncan Grouping of Traditional heat cured acrylic resin polymerized by IR at different times of polymerization. For water solubility of HI hot cured acrylic resin polymerized by IR at different times of polymerization cycle, there were statistically significant difference existed at level of significance P < 0.05 when compared with control group. these results showed in ANOVA Table 4 , also Figure 3 which represented Duncan Grouping revealed that the least mean values of water solubility test for both Traditional and HI hot cured acrylic resin denture base material had been obtained at T1 of IR polymerization.

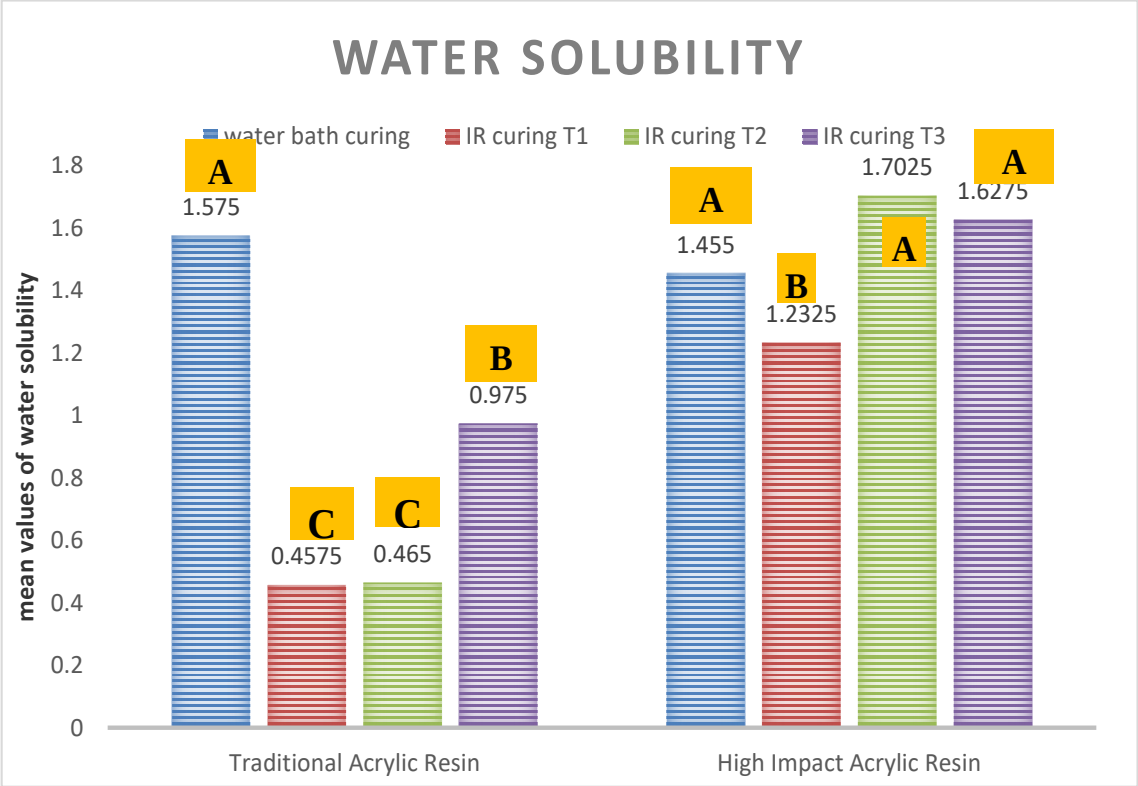

Figure (3): The Effect of Time of Polymerization by Infrared Radiation on Water Solubility of Two Types of Acrylic Resin Denture Base Materials

DISCUSSION

Once denture base acrylic resins had polymerized, they were far from stable and constantly be interacting with their surrounding environment. The important reaction occurred with water since the dentures were continually bathed in saliva or soaked in aqueous disinfectant solutions. Water diffused into the matrix causing two opposing phenomena to take place, water leaches out free nonreacted monomers and ions. [2] Since the processing of acrylic resin denture bases, one of their major disadvantages was that they undergo a sequence of some components filtering out and water uptake during and following curing and placement. These changes considered being one of the main reasons for failures of dentures. Therefore, acrylic resin denture base materials were subjected to sorption and solubility. [19] It

was clearly obvious that a high solubility is not appropriate properties for denture material. [20] as these characteristics influence allergy susceptibility of these materials. [21]

In this study, for both mentioned tests, statistically no differences existed between means of both types of denture base materials which they were polymerized by conventional water bath and with same immersion period ,this result would be in agreement with the result of Al-Nori,et al [22] who stated that the curing method and immersion period can affect ratios of water sorption and solubility in acrylic resin and also agreed with the study of Oliveira,et al [23] who stated that type of resin used do not affect the water sorption, but disagree with study of Meloto, et al[24] who stated that degree of polymerization is related directly to resin's ability of water absorption. In addition to that water sorption for both types of denture base materials had been decreased significantly by changing type of polymerization process from water bath to infrared radiation polymerization process, this result would be in agreement with study that carried out by Ozdemir and Aladagthe [25] who stated that values for sorption and solubility in water of polymers, the rate at which they happened depend considerably on the type of the polymer, polymerization procedure, also with previous studies by Al-Hachem and Al-Khafaji [26] who had the same conclusion to the previous authors, in addition to that ,they found that the temperature and period of immersion in aqueous environment and thickness of the tested polymer specimens and the solution in which they are immersed affect this value for both water sorption and solubility, as all these factors which mentioned before were standardized in our study ,so the result of our study would be affected by changing type of polymerization process from water bath to infrared radiation.

For two types of heat cured acrylic resin denture base materials which polymerized by IR ,the least mean value of water sorption test was obtained at T1 for Traditional type andT3 for High Impact acrylic resin, while other times had a higher mean, which could be due to the least amount of non-reacted residual acrylic acid. This result would be in agreement with Jawad [13] thesis who stated that the lesser water sorption means may be related to the least amount of residual methyl methacrylate acid estimated in the tested group and with Philips and Khalil [8,27] studies who stated that the high water solubility expected to be the result of presence of non-reacted residual acrylic acid which is highly soluble in water . This would be in agreement with Debby et al and Jagger [28,29] studies who stated that the stage of polymerization is immediately related to resin's ability of water absorption because best acrylic resin polymerization reduces residual monomers, sorption of water values and increases crosslinking. While disagreed with

Dixon [30] result who stated that an inadequate curing of mass of the acrylic resin result in increasing amount of the residual monomer, these influences sorption of water because instead of water ,no polymerized monomer occupies gaps in polymerized mass. It leads to a lower water sorption. Our study was the first one proved that the polymerization of heat cured acrylic resin denture base material by infrared radiation method would give better results for both water sorption and solubility comparing with conventional water bath method.

CONCLUSIONS

Water sorption and solubility for denture bases were inevitable, and they were critical problems that may affect denture durability. Statistically no differences appeared between Traditional and High Impact acrylic resin denture base materials were polymerized by conventional water bath in water sorption and solubility tests. Water sorption had been decreased significantly by changing the method of polymerization from water bath to IR method for Traditional hot curing acrylic resin and High impact resin Zhermack for dentures. The best time of polymerization by IR for Traditional type which had the least mean values was T1 while T3for High Impact acrylic resin. On the other hand, the least mean values of water solubility in Traditional and HI acrylic resin denture materials was T1 which considered the best time of polymerization by IR in water solubility test.

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