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The Effect of Adding Different Types and Concentrations of polymers on the Water Solubility of Heat Cured Acrylic Resin

Nada Z. Mohammed *, Radhwan H. Hasan

Department of Prosthetic Dentistry, College of Dentistry, University of Mosul.

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***Correspondence:**

E-mail:
nada2005@uomosul.edu.iq

Abstract

Aims: To evaluate the effect of adding different types and concentrations of polymers on the water solubility of heat cured acrylic resin. **Materials and Methods:** Heat cured acrylic resin specimens were prepared and divided into: Control group (without additives) and experimental group (with additives). Three kinds of additives (Styrene Butadiene Rubber (SBR), Poly ethylene glycol (PEG) and Poly urethane (PU)) were incorporated with acrylic resin in three concentration s 1%, 3% and 5% by weight. The water solubility was tested, calculated and the data were statistically analyzed by SPSS Version 19 by mean of Descriptive statistics, analysis of Variance (ANOVA), and Duncan multiple range tests at $p \leq 0.05$. **Results:** The results showed that the water solubility of experimental group was less than that of the control group and its values decreased as the additives concentration increased. The lowest mean value of water solubility was achieved by the incorporation of SBR polymer at 5% concentration (0.018 µg/mm^3). **Conclusions:** The type and concentration of additives directly affected the water solubility of heat cured acrylic resin. The control group has higher mean value of water solubility than that the experimental group. The additives were significantly decreased the amount of water solubility of heat cured denture base resin.

الخلاصة

الأهداف: تهدف الدراسة إلى تقييم تأثير إضافة أنواع وتراكيز مختلفة من المواد المضافة على قابلية الذوبان في الماء للراتنج الاكريلي المبلمر حراريا . **المواد وطرائق العمل**: تم تحضير عينات من الراتنج الأكريلي المبلمر حراريا وقسمت إلى مجموعتين. مجموعة السيطرة (بدون إضافات) مجموعة التجربة (مع الإضافات). كانت الإضافات هي ثلاثة أنواع من البوليمرات (ستايرين بوتادين ربر (SBR) ، بولي إيثيلين كلايكول (PE) وبولي يوريثين (PU)) تمت إضافتها بثلاث تركيزات ١٪ ، ٣٪ و ٥٪. تم اختبار وحساب قابلية الذوبان و استخدام SPSS الإصدار ١٩ للتحليل الاحصائي 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 ذوبان المجموعة التجربة في الماء مقارنة بمجموعة السيطرة. اقل قيمة للذوبان في الماء تم الحصول عليها (0.018µg/mm3) عند اضافة ستايرين بوتادين ربر بتركيز ٥٪. يتناسب الانخفاض في ذوبان المجموعة التجربة في الماء تناسبا طرديا مع تركيز المواد المضافة. **الاستنتاجات**: ان نوع و تركيز الإضافات يؤثر وبشكل مباشر على قابلية الراتنج الاكريلي المبلمر حراريا للذوبان في الماء. ذوبان مجموعة السيطرة في الماء اكثر من ذوبان المجموعة التجربة في الماء. تنتج الإضافات انخفاضًا معنويا في في ذوبان المجموعة التجربة في الماء والذي يناسبً طرديًا مع تركيز الإضافات المستخدمة.

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INTRODUCTION

Partial or complete dentures are the most common treatment modalities that are used to replace missing teeth. Since, the cost of dental implants and metallic dentures are much higher [(1)]. Acrylic resin polymer is one of the most popular polymeric materials used for the fabrication of denture base [(2& 3)].

The Water solubility of denture base materials considered as an essential physical property that influences their biocompatibility and clinical success [(4&5)]. During clinical use, the denture base resin is immersed in an aqueous medium like saliva, nasal secretion and cleansing agents or water. The denture base acrylic resins are insoluble in water and in most fluids that encounter the resin in the oral cavity. However, the substances within the resin matrix that may leak out from the polymer matrix are unreacted monomer, plasticizers and other soluble components [(6, 7& 8)]. The water solubility of denture base materials are affected by many factors. It has been found that soaking acrylic resin material in water at 67ºC increasing its solubility and attributed this finding to the structural changes or expansion of the polymeric matrix that modify its solubility behaviour as compared to that at lower temperatures[(9)]

The polar carbonyl groups of acrylic resins 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 [(10, 11& 12)]. The chemical composition of denture base material among one of the most important factors that affect its water solubility. It has been concluded that the water solubility of conventional heat cured denture base resin was statistically significantly higher than that of recent polyamide denture base resin [(13)]. Curing method also influence water solubility of acrylic resin. It has been proved that the polymerization of heat cured denture base acrylic resins material by infrared radiation method would give better results regarded their water solubility comparing with conventional water bath method[(14)].

MATERIALS AND METHODS

Fifty specimens of heat cured acrylic resin were prepared and divided into the following groups: control group (without additives) and nine experimental groups (with additives) i.e five specimens for each group. The additives were three kinds of polymers manufactured by Sigma Aldrich Chemical Company, Germany (Styrene butadiene rubber (SBR), Poly ethylene glycol (PE) and Poly urethane (PU)) that incorporated with three concentrations 1%, 3% and 5% by volume. The conventional flasking, packing and curing procedures were used in the processing of all specimens of this study.

Biostar sheet were cut as a pattern

form, with the dimensions of 10×12×4±0.02mm (length, width and height respectively) [15].

The investing dental stone was mixed in a water/ powder ratio of 100:23 according to instructions of the manufacturer. Hand spatulation up to 10-20 seconds was done and to get rid of air bubbles an electrical vibrator was used for about 2 minutes.

The molds were made up by pouring the mixed dental stone into the lower half of the dental flask and then the master mold was invested after being coated with a thin layer of an alginic insulator (cold mold seal). After the final setting of the stone (about 1 hour), its surface was coated with a thin layer of alginic insulator, then the upper counterpart of the flask was placed and filled with a freshly mixed stone and vibrated till the flask was totally filled with some excess. Then the upper lid of the flask was positioned in its place and the clamp was secured tightly and left final setting. After one hour, the two halves of the flask were opened and the master mold was removed carefully, all exposed stone surfaces were coated with a thin layer of an alginic insulator and left to dry. Heat polymerized acrylic resin ProBase Hot (EN,ISO, 20795, Ivoclar vivadent, Liechtenstein) was used in this study. According to manufacturer instruction, the powder mixed to liquid at ratio of 23.4g powder (PMMA) to 10 ml liquid (monomer). Composites with varying amounts of additives were prepared by replacing a weight of the pre-mixed MMA monomer with an equal volume fraction of additives at concentrations of 1%, 3% and 5%.

Firstly, the measured amount of MMA monomer was poured into a glass bottle and the calculated amount of the additive was added to it then mixed by glass rod until a consistent mixture is obtained. After that, the powder was added gradually and mixed, the mixture was covered until it reached the dough stage to avoid evaporation of monomer, and then the dough mass was packed into the flask. The flasks pressed up to 200 MPa pressure for 10 minutes by using the hydraulic press. After that, the flasks transferred to a clamp that should be secured tightly for processing.

A short curing cycle (heat up to at 100°C for 90 min and left boil for 45 min) according to manufacturer's instruction was used using a water bath that was thermostatically controlled. At the end of the curing cycle, the flask was removed from the water bath and left for bench cooling.

After specimens' preparation, finishing and polishing, they dried in freshly dried silica gel in a desiccator (at 37 °C) until weight constant has been achieved. The specimens were weighted by using an electronic balance (of 0.0001 gm accuracy); this weight is considered as initial weight (m_1). At this stage, the volume (V) of each specimen was evaluated by a digital vernier (0.01mm accuracy). Three measurements were taken

of each dimension at three locations around the borders and the means of the three measurements were calculated.

The specimens were then immersed in deionized distilled water in a thermostatically controlled incubator at 37 ± 1 °C for 7 days ± 2 hours. After this period, each specimen was flapped in the air for 15 seconds and weighed 1 min after its removal from the water. This weight (m_2) was recorded. Then, the specimens were dried in freshly dried silica gel in a desiccator (at 37°C) until a constant weight is obtained that, was recorded as (m_3).

The water solubility (W_{sol}) value for each specimen was calculated and expressed in microgram per cubic millimeter ($\mu g/mm^3$) from the following equations [16]:

$W_{sol} = m_1 - m_3 / V$

Where: $W_{sol:}$ Water solubility, m_1: The conditioned (dried) mass of the specimen, m_3: The reconditioned mass of the specimen, V: The volume of the specimen.

After data collection, the results of this study were statistically analysed by using SPSS Version 19 by mean of descriptive statistics including means, standard deviations, Duncan multiple range tests and analysis of Variance (ANOVA) at $p \leq 0.05$

RESULTS

The mean and standard deviations of the water solubility of the control group and experimental groups were revealed in Figure (1). The results disclosed that the mean value of water solubility of experimental group was less than that of control group. The mean value of water solubility of experimental group decreased as the concentration of additives increased.

One way ANOVA test Table (1) demonstrated that there was a statistically significant reduction at $p \leq 0.05$ in the water solubility of the experimental group as compared to that of control group. Duncan's multiple range test Figure (1) showed that the water solubility of experimental group reduced significantly as compared to that of control group at $p \leq 0.05$. Except for experimental group of 1% SBR, the water solubility was not significantly reduced.

Figure (2) revealed that the measured amount of water solubility varied concerning the type of additive materials being incorporated with heat cured denture base resin. The most pronounced decrease in the amount of water solubility (0.018 $\mu g/mm^3$) was observed with the addition of styrene butadiene rubber polymer at a concentration of 5% polymer.

DISCUSSION

One of the most important properties of denture base acrylic resin is its water solubility as it represents the mass of soluble materials that leak out from the polymer matrix and it influences the quality of prosthesis and consequently the quality of the patient's life [4&8].

The measured amount of water groups (Figure 1) of this study are within standard ADA value [16] for water solubility of heat cured acrylic resin that is 1.6 μg/mm^3. The mean values of the water solubility of the control and experimental groups showed that the water solubility of experimental group with the additives (SBR, PEG and PU polymers) is less than that of control group that could be explained according to the fact that when two polymers blended together they form cross-linked three -dimensional interpenetrating polymer network (IPN) which, may impede or reduce the potential sites for water exchange [17&18].

One way ANOVA test Table (1) showed that the water solubility of experimental group was significantly lesser than that of control group at $p \leq 0.05$. Except experimental group of 1% SBR polymer the reduction in the mean value of water solubility was not significant at $p \leq 0.05$ Figure (1). Incorporation of various additives with acrylic resin responsible for the observed differences in the water solubility [6&10]. The IPNs involve physical cross-linking especially when the incorporated polymers are homogenous [19].The solubility of polymeric material depended on the homogeneity of its polymeric structure. The higher the homogeneity; the less soluble it is. This comes in accordance with Zidan *et al*.(2020)[20] who attributed the reduction in the water solubility of PMMA reinforced with zirconia nanoparticles to solubility of control and experimental the improved homogeneity of the polymer composite resulted from uniform dispersion of zirconia nanoparticles with acrylic resin matrix .

The measured amount of water solubility varies concerning the type of polymer being incorporated with heat cured denture base resin Figure (2). The most pronounced decrease in the amount of water solubility (0.018 μg/mm^3) was observed with the addition of styrene butadiene rubber polymer at a concentration of 5% polymer. The incorporation of some additives with denture base acrylic resins resulted in changing their water solubility. This was came in agreement with Mohammed (2010) [21]. The solubility of denture base materials affected by the chemical structure of each type [22]. The amount of water sorption depend on the type, size and distribution of the fillers particle within resin matrix as well as the interfacial bonding between filler and resin matrix[5]. The nature of interlocking is one of the major controlling factors in the physico-mechanical properties of the polymer. As the cross-linking level in PMMA enhances, it provides further retardation in its water solubility [23].

By comparing the effect of concentration of added polymers into denture base acrylic resin, the results of this research demonstrated that water solubility of experimental group decreased as the concentration of incorporate

polymers increased Figure (1). This may be due to increased physical cross-linking within polymeric structure as the concentration of added polymers increased which, in turn impeded the leaking of plasticizers [24] or due to reduction in the porosity formation within polymeric matrix [25&26] that could be result from lower content of the unreacted monomer as a consequent to higher degree of conversion and [5&9]. The result of this study was in line with the result of research done by Bacali *et al*. (2019) [27] who related the enhanced mechanical properties of acrylic resin material incorporated with various concentrations and types of fillers to the reduced amount of eluted residual monomer.

CONCLUSIONS

The type and concentration of additives directly affected the water solubility of heat cured acrylic resin. The control group has higher mean value of water solubility than that the experimental group. The additives were significantly decreased the amount of water solubility of heat cured denture base resin.

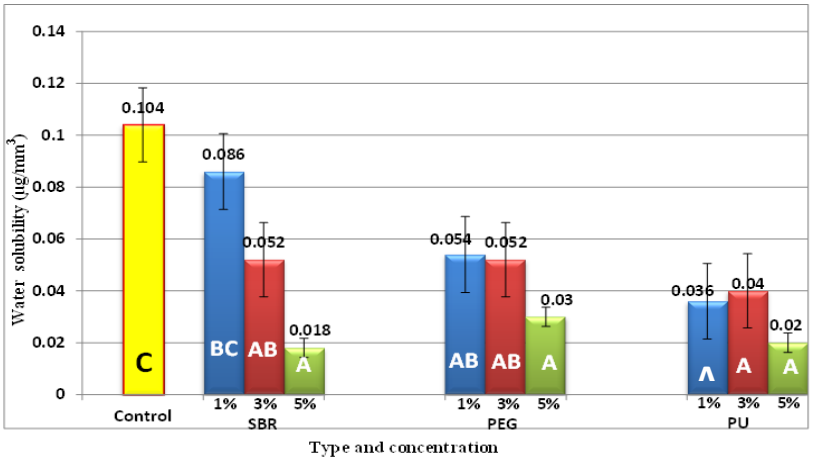

Figure (1): Mean, standard deviation and Duncan's multiple range test for the effect of the concentration of incorporated polymer on the water solubility experimental group

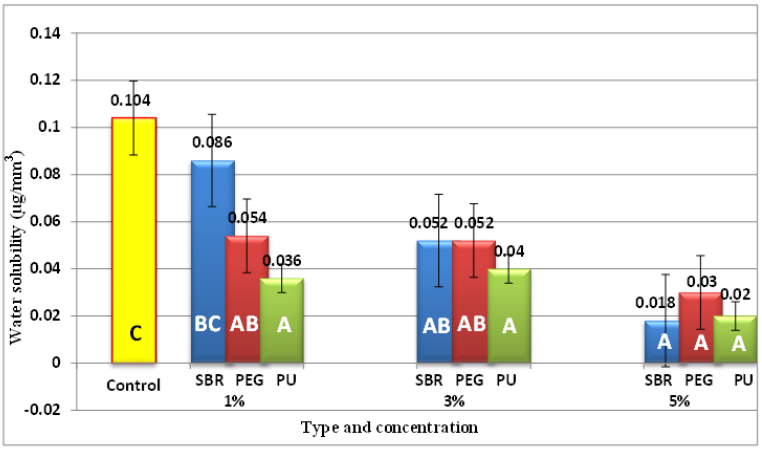

Figure (2): Mean, standard deviation and Duncan's multiple range test for the effect of the type of incorporated polymer on the water solubility experimental group

Table (1): One way ANOVA test for water solubility of control and experimental group incorporated with SBR, PEG and PU polymers**.**

	SS	**Df**	**MS**	**F**	***P***
Between Groups	0.034	9	0.004	5.801	0.000
Within Groups	0.026	39	0.001		
Total	0.060	48			

REFERENCES

1. Baghani MT, Yahyazadehfar N, Zamanian A, Abbasi K, Shanei F, Shidfar S and Zohri Z. Factors Affecting Bonding Strength of Artificial Teeth: A Literature Review, J Res Med Dent Sci. (2018);6 (1): 184-191.
2. Alla RK, Sajjan S, Alluri VR, Ginjupalli K and Upadhya N. Influence of Fiber Reinforcement on the Properties of Denture Base resins. JBNB. (2013); 4, 91-97.
3. Chen SG,Yang J, Jia Y, Lu B and Ren L. A Study of 3D-Printable Reinforced Composite Resin: PMMA Modified with Silver Nanoparticles Loaded Cellulose Nanocrystal. MDPI. (2019); 11: 1-14.
4. Agarwal B, Patel CBS, Singh BP, Kumar A, Singh M and Singh N. Water Sorption and Solubility of Denture Base resins-An Evaluation. IJAR. (2015); 5(8):41-44.
5. Dehis WM, Eissa SM, Elawady AF and Elhotaby MM. Impact of nano-TiO_2 particles on water sorption and solubility in different denture base materials. J Arab Soc Med Res. (2018); 13:99–105.
6. Engelbrecht MA. Factors Influencing Sorption, Solubility and Cytotoxicity of A Heat Cured Denture Base Polymer. MSc. Thesis. University of the Western Cape. (2010)
7. Salih SE, Oleiwi JK and Mohammed AT. Effect of Water Absorption on the Compressive Strength for PMMA Nano Composites and PMMA Hybrids Nano Composites Reinforced by Different Nanoparticles Used in Dental Applications. Eng. &Tech.Journal. (2016); 34(14): 4562- 4552.
8. Narayanan S. Comparative study of sorption of heat cure and self-cure acrylic resins in different solution. IJCR. (2019); 11(2):1567-1580.
9. Latief A. Sorption and Solubility of a Denture Base Acrylic. M.Sc. Thesis, Cape Peninsula University of Technology. (2012).
10. Özdemir H and ALadağ Lİ (2013): The effect of different polymerization periods on water sorption of acrylic resins. J Dent Fac Atatürk Uni; 21(2): 214-219.
11. Jang DE, Lee JY, Jang HS, Lee JJ and Son MK (2015): Color stability, water sorption and cytotoxicity of thermoplastic acrylic resin for non-metal clasp denture. J Adv Prosthodont; 7: 278-87.
12. Chandrahari N, Kumar CR, Salgar AR, Prathibha N, Singh M and Singh S (2019): Comparison of Fracture Resistance of Heat Cure Resins Polymerized by Conventional and Microwave Methods after Immersion in Artificial Saliva. J Contemp Dent Pract; 20 (1):71-77.
13. Nguyen LG, Kopperud HK and Øilo M. Water sorption and solubility of polyamide denture base materials. Acta Biomater Odontol Scand. (2017); 3(1): 47–52.
14. AL-Omari AW, kassab NH and Mohammed NZ. Water Sorption and

Solubility of Two Acrylic resin Denture Base Materials Polymerized by Infrared Radiation. Al–Rafidain Dent J. (2019); 19 (1):20-31.

15. Taqa AA, Nazhat MNY and Basshi TY. The Effect of Autoclave on the Powder of (PMMA) on the Water Sorption, Solubility and Porosity. Int. Res.J. Basic Clin. Stud. (2014); 2(7):87-91.
16. ADA (American Dental Association) Specification No. 12 Denture Base Polymers. Council on Scientific Affairs, Approval date: September 13. (2002).
17. Panteli PA and Costas S. Patrickios CS. Multiply Interpenetrating Polymer Networks: Preparation, Mechanical Properties, and Applications. Gels (2019), 5, 36:1-21.
18. Lohani A, Singh G, Bhattacharya SS, and Verma A. Interpenetrating Polymer Networks as Innovative Drug Delivery Systems. J. Drug Deliv. (2014); 27:1-11.
19. Das R S and Barhate AN. Interpenetrating Polymer Network: A Novel Biomaterial and Carrier Systems in Drug Delivery. Indo Am. J. P. Sci. (2019); 6(06): 13479-13489.
20. Zidan S, Silikas N, Haider J and Yates J. Long-Term Sorption and Solubility of Zirconia-Impregnated PMMA Nanocomposite in Water and Artificial Saliva. Mater. (2020); 13(17):1-12.
21. Mohammed NZ. The Effect of Thickness of Heat Cured Acrylic Resin with Additives on Water Sorption and Solubility. Al–Rafidain Dent J. 2010; 10(1):167-174.
22. Helaly MN, Alam-Eldein AM and El-Sheikh AM. Effect of Two Cleansing Agents on Water Sorption and Solubility of Two Thermoplastic Denture Base Materials. Univers J Mater Sci (2018); 6(4): 115-118.
23. James J, Thomas GV, Pramoda KP and Thomas S. Transport Behaviour of Aromatic Solvents through Styrene Butadiene Rubber/Poly [Methyl Methacrylate] (SBR/ PMMA) Interpenetrating polymer network (IPN) membranes. Polymer. (2017); 116: 76-88.
24. Hamouda IM. Linear Dimensional Changes and Water Sorption of Acrylic resin Denture Base Material Reinforced with Chopped Glass Fibers or Metal Fillers. Journal of Rehabilitation Robotics. (2018); 6: 1-7.
25. Laura MO, Paulina ROJ, Jizhel BCM and Alvaro GP. Sorption and Solubility of Acrylic resin Self polymer by 3 Process Techniques in Orthodontics. Dent Pract. (2019); 2(1): 001-005.
26. Figuerôa RMS, Bruna CO, César AG, Carolina C, Vanessa MU and Karin HN. Porosity, Water Sorption and Solubility of Denture Base Acrylic Resins Polymerized Conventionally or in Microwave. J Appl Oral Sci. (2018); 26:1-7.
27. Bacali C, Constantiniuc M, Moldovan M, Nastase V, Badea M and Constantin A. Reinforcement of PMMA Denture Base Resins: From Macro to Nano Scale. Int J Med Sc. (2019); 23 (3): 374-378.