The Effect of Two Types of Separating Medium and Investment Materials on Some Physical Properties of Acrylic and Nylon Denture Base Materials

Farah Nabeel Mohammed Tahir Al-Khayyat B.D.S.- M.Sc.*, Nagham Bahjat Kamil; BDS-M.Sc.*Suad Jafar Alnakash; B.D.S.-M.Sc.*

**Prosthodontic Department/ College of Dentistry / Al-Mustansiriya University.*

Abstract

Background: The relatively rough surface of gypsum mould may be penetrated by acrylic denture base resin and adhere to it, to prevent this, a separating medium must be employed.

Objectives: The aim of this study is to evaluate the effect of separating medium substitute and investment materials on Surface roughness, Water sorption and solubility of acrylic and nylon denture base materials.

Material and method: Two types of separating medium were chosen (Cold mold seal and glycerin). 160 specimens were prepared from heat cure and Valplast resins. Each main group was subdivided into four subdivisions according to the type of investment material and separating medium used; each group of them contains 10 specimens for each test.

After processing of both resins, some physical properties such as water sorption, solubility and surface roughness have been evaluated according to investment material and compared with those processed using cold mold seal and glycerin.

Result: In this study, the surface roughness and water solubility of both base materials are significantly higher when using cold mold seal than glycerin. Mean value of heat-cure acrylic resin shows high water sorption than that of Valplast. When compared by ANOVA test, there is no significant difference between groups in both investment materials.

Conclusion: The use of glycerin as a separating medium leads to smoother surfaces of both denture base materials, while for water sorption, neither the separating medium nor the investment material has an effect on it. Cold mold seal leads to higher water solubility of both base materials regardless of the type of investment material.

Key Word: Separating medium**,** heat cure resin, Valplast (nylon) resin**,** physical properties.

الخلاصة

السطح الخشن لقالب الجبس قد يمكن اختراقه من قبل الاكريليك ، لذلك يجب استخدام مادة عازلة. فالهدف من هذه الدراسة هو تقييم تأثيرالمواد العازلة و نوع مادة الجبس على بعض الخواص الفيزيائية لكل من مواد الاكريليك الراتنج والنايلون.

تم إعداد 160 عينة، قسمت الى مجموعتين رئيسيتين حسب نوع الاكريليك المستخدم ثم قسمت كل مجموعة رئيسية إلى أربعة أقسام فرعية وفقا لنوع مادة الجبس والمادة العازلة المستخدمة؛ كل مجموعة منها يحتوي على 10 عينات لكل اختبار.

تم مقارنة بعض الخصائص الفيزيائية للمجاميع كاملة. و اظهرت النتائج بأنه يمكن استخدام مادة الجليسيرين كمادة عازلة، حيث ادت الى نعومة سطح العينات المصنوعة من الراتنج و النايلون، ولا يوجد تأثير لنوع الجبس على الخواص الفيزيائية لجميع العينات.

مفتاح الكلمات: مادة عازلة، راتنج الاكريليك ، راتنج النايلون، الخصائص الفيزيائية

Introduction

Separating media are the materials used for filling porous surfaces for easy separation from other materials which are later poured against them (1). It is one of the important factors in dental prosthesis success due to its effect on polymerization rate as well as the optical and physical properties of the resultant denture base materials (2). Polymethylmethacrylate has been used as the main component of denture base polymer since 1930; it is a derivative of acrylic acid, referred to us as acrylic resin and it is still the most popular choice for construction of dentures (3). The development of polymer chemistry produce alternative materials to PMMA such as polyamides (nylon plastics), acetal resins, epoxy resins, polystyrene, polycarbonate resin…etc. all these resins are suited for thermoplastic processing (4), Valplast is a specialized form of nylon in the family of super polyamide (a very pure nylon). It is very flexible biocompatible with good patient comfort (5). In the process of fabrication of dental prosthesis, a separating medium should be used, as hardened plaster or stone is absorbent, the surface of the mold must be therefore made nonabsorbent, or liquid acrylic resin will soak into the stone during processing. If liquid acrylic resin penetrates the mold surface, the finished denture will have a crust of acrylic resin and stone that will have to be removed during finishing .The result is an improperly contoured, and hence an unaesthetic and poorly fitting, denture base (6).The water from the mold enters in the acrylic resin, this may affect the rate of polymerization and color. It can also result in crazing, the application of separating media help in easier retrieval of the denture from the mold (7). Separating media are either sheets, such as tin foil, rubber dam and cellophane; and this type was laid over the surface of the mould to provide the required protection, or liquids such as the alginates which are painted onto the empty mould to seal the pores of the investment (8). Many authorities consider that tinfoil is the best separating medium, but the unfortunately placement of it was time-and labor intensive. Therefore, practical substitutes were sought (2, 9)**,** these are basically solutions of soluble alginate such as sodium, potassium, or ammonium together with sodium citrate or tri-sodium phosphate (10). These solutions produce thin, relatively insoluble films which prevent direct contact of denture base resins and the surrounding dental stone (2). Other materials have been used as separating medium, such as Deteryisolant (11), glycerin also has been used for heat cure and autopolymerizing resin (12).It is a simple poly oil compound, colorless, odorless, viscous liquid that is widely used in medical, pharmaceutical formulations and personal care preparations (13). Both water sorption and solubility would lead to a variety of chemical and physical processes that may result in deleterious effect on the structure and function of dental polymers (14). Moreover, the surface properties of any denture base material is of particular concern as there is a direct link between adherent of candida albicans and surface roughness, (9, 15) .Due to the importance of these properties in clinical and material performance this study was designed to evaluate the effect of using glycerin as a separating medium on surface roughness, water sorption and solubility of polymethyl methacrylate resin and valplast denture base and compare it with cold mold seal separating medium by using stone and plaster as investment materials.

Materials and Method

A total of 160 specimens were prepared to be used in this study. They were divided into two main groups according to the type of denture base material used (conventional heat cure acrylic and nylon). Each main group was subdivided into four subdivisions according to the type of investment material (stone and Plaster) and type of separating medium (cold mold seal and glycerin) each group of them contain10 specimens for each test.

Preparation of heat cure specimens for surface roughness and water sorption and solubility tests

Metal patterns were constructed by cutting the stainless steel plates with the dimensions of (65mm x 10mm x 2.5mm) length, width and thickness respectively for surface roughness specimens and (50 ± 1mm in diameter and 0.5± 0.1mm thickness) for water sorption and solubility specimens (16).

The conventional flasking technique was followed in the mould preparation according to the required measurements of the adopted specimens. Each metal block was coated with petroleum jelly and immersed in the slurry stone (Type III hard stone, thixotropic, Zhermach/ Italy) or plaster (Al- Ahliyah Co. / Iraq) which is prepared according to the manufacturer's instruction and poured into the lower half of the dental flask as in (Figure 1, a). After setting of gypsum material, a layer of separating medium was applied on the gypsum surface and another layer of stone or plaster was poured into the second half of the flask and allowed to stand for one hour then the flask was opened and the metal block was removed 2ml of separating medium either cold mold seal (P.D. Pink color 1b separating film/ Switzerland) or glycerin (Tri-hydroxy alcohol/ Malaysia) was applied by fine brush No 0 onto the gypsum surface in each half of the flask then the mold was packed with acrylic resin dough (Ivoclar/ Germany) which was mixed according to the manufacturer's instruction (3:1) by volume and left under pressure 20 bar for 5 min before clamping was done. Curing was carried out by placing the clamped flask in a water bath and processed by short curing cycle 90min at 74C° then temperature was increased to the boiling point 100°C for 30 minutes (16) (Figure 1,b) All the tested specimens were conditioned in distilled water at 37C° for 48 hours before they were tested (16).

Mould preparation for valplast resin:

The same procedure was done as in heat cured mould preparation but with addition of wax sprues were prepared - major sprues with 6-8mm in diameter, minor sprues 2-4mm in diameter are attached to selected areas from one side of the metal pattern (17) as shown in (Figure 2). Then the upper portion of the metal flask was positioned on top of the lower portion and filled with stone or plaster, vibration was done to remove any air bubbles. The investment material was allowed to harden before the metal flask was opened.

Wax elimination was performed using boiling water then metal flask was opened and 2ml of separating medium either cold mold seal or glycerin was applied onto the mold surface in each half of the flask then injecting the Valplast denture base material (Nylon grains. USA), the procedure started with the heating cylinder inserted into the slot present inside the electrical furnace and the furnace was allowed to warm up till it reaches the preset heating which was 287°C, then the heating cylinder removed from the furnace, the Valplast cartridge, metal disc and the short solid metal cylinder was inserted into the heating cylinder and left inside the furnace for 11 minutes to allow the granules inside the cartridge to melt. Then the material was injected inside the flask by the use of the manual injection unit as in (Figure 3).

The handle of the injection unit was tightened until both springs on the top side of the unit were closed to give a pressure of 5 bars. After 5 minutes the pressure was released and the flask is removed from the injection unit and allowed for cooling at room temperature. All the tested specimens were conditioned in the same manner as in heat cure specimens.

Physical tests utilized to examine properties:

1. Surface roughness test:

The profilometer device (Surface roughness tester SRT-6210, England) is used to measure the surface roughness of the specimens. All the specimens were unpolished after flasking then each specimen was placed on a fixed and stable base then the device was adjusted in a way so that the stylus just touch the surface of the specimen, after that the stylus was traversed toward the right direction along the specimen surface for 10 mm length then the reading appeared on the digital scale as in (Figure 4).

2. Water sorption test:

The disks were dried in a desiccator containing freshly dried silica gel at 37ºC ± 2ºC for 24 hours then removed to a similar desiccator at room temperature for one hour, then weighed. The cycle was repeated until constant weight was attained, that is until the weight loss of each disk was not more than 0.5mg in every 24 hour period. The disks were then immersed in distilled water at 37ºC ± 1ºC for 24 hours (12), after that time the disks were removed from water with tweezers, wiped with a clean dry hand towel, waved in the air for 15 second and weighed 1 minute after removal from the water.

The value for water sorption was calculated as follows for each disk (5):

$$S = \frac{W2 - W1}{S.A}$$

W2= Weight after immersion (mg)

W1= Conditioned weight (mg)

S.A= Surface area (cm^2)

S= Sorption (mg/cm^2)

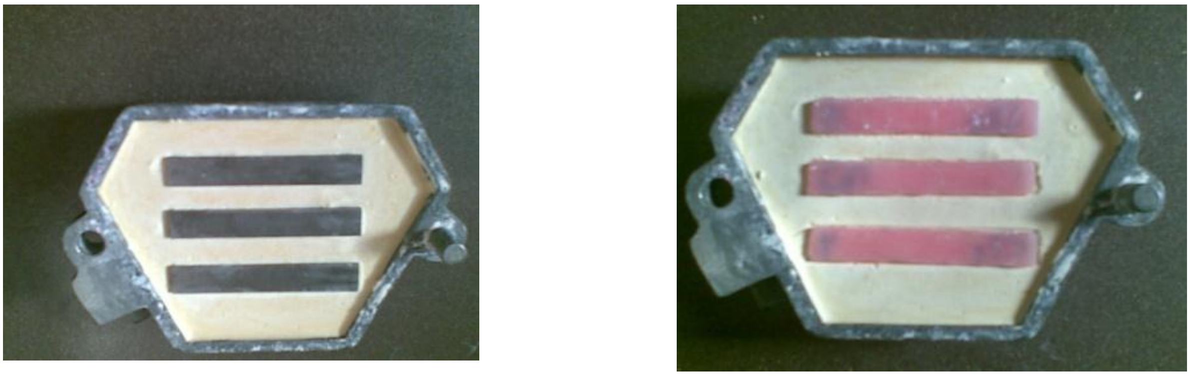
The average of the determined values for the disks was recorded to the nearest 0.01 mg/cm^2.

3. Water solubility test:

To obtain the value of solubility test, the discs were reconditioned to a constant mass in the desiccator at 37 ºC ±2 ºC as done previously for sorption test and considered as the reconditioned mass.

The values for solubility were calculated for each disc from the following equation:

Solubility (mg/cm2) = condition mass (mg) - reconditioned mass (mg)/ Surface area (cm2)



a　　　　　　　　b

Figure 1. Specimens for Surface roughness test of heat cure denture base material.
a-Metal mold.　　b-Specimens after curing

Figure 2. Metal mold with wax sprue for Valplast denture base material.

Fig 3. Manual injection unit for Valplast denture base material

Fig 4. Profilometer device for surface roughness of denture base material.

Results

The mean water sorption values and standard deviations for each studied groups are presented in Table 1. Factorial ANOVA testing (Table 2) suggested that the main effect of denture base on water sorption was significant, F (1, 72) = 7566.030, P=0. 00, as water sorption was significantly higher for conventional heat cure acrylic (M = .154045, SD = .0058440) than for Valplast nylon (M =. 007268 SD =.0048859). The main effect of Investment material on water sorption was non-significant, F (1,72) = .092, p= .762. The main effect of Separating medium on water sorption was non-significant, F (1, 72) =1.128, p=.292. The interaction of denture base and investment material was non-significant, F (1, 72) =.063, p=.803.the interaction of acrylic type and separating medium was not statistically significant, F (1, 72) =.396, P=.531. The interaction of investment material and separating medium was non-significant, F (1,72) =2.709. P=.104. Finally there was no significant interaction between acrylic type, investment material and separating medium on water sorption, F (1, 72) =1.072, p=.304. The mean water solubility values and standard deviations for each studied group are presented in Table 3. Factorial ANOVA (Table 4) yielded a significant main effect for denture base on water solubility, F (1, 72) =37.419. P= 0.00, as water solubility was significantly lower for conventional heat cure (M=.003494, SD=.0021045) than for Valplast acrylic (M=.007462, SD=.0039276). The main effect of investment material on water solubility was non-significant, F (1,72)= .092, P=.762. The main effect of separating medium on water solubility was significant, F (1.72) =4.715. P=.033, such as water solubility was significantly higher for Cold mold seal (M=.006183, SD= .0046628) than for glycerine (M=.004774, SD=.0022743). The interaction of denture base material and investment material was non-significant, F=.044, P=.834. ON the other hand the interaction of denture base material and separating medium was statistically significant, F=12.094,P=0.001. This interaction indicated that water solibility for Valplast-cold mould seal (M=0.009.SE=0.001) was higher than Valplast-glycerine (M=0.006.SE=0.001). The interaction of investment material and separating medium was non-significant F=1.323, P=.254. The interaction between acrylic type, investment material and separating medium on water solubility was non-significant statistically. F=.039. P=.843. The mean surface roughness values and standered deviations for each studied group are presented in Table 5. Factorial ANOVA (Table 6) yielded a significant main effect for denture base on surface roughness, F(1, 72) =7.102. P= 0.009, as surface roughness was significantly higher for valplast acrylic (M=1.278325, SD=.5735872) than for heat cure acrylic (M=.899675, SD=.4204470). The main effect of investment material on surface roughness was non-significant, F(1,72)= .002, P=.969. The main effect of separating medium on surface roughness was significant, F(1.72) =29.506. P=0.00, such as surface roughness was significantly higher for Cold mold seal (M=1.474900, SD= .7602340) than for glycerine (M=.703100, SD=.6788707). The interaction of acrylic material and investment material was non-significant, F=.472, P=494. ON the other hand the interaction of acrylic material and separating medium was statistically significant, F=16.712, P=0.001. This interaction indicated that surface roughness for heat cure-glycerine (M=0.223.SE=0,141) lower than for heat cure-cold mold seal(M=1.576,SE=.142). The interaction of investment material and separating medium was non-significant F=3.231, P=0.076. The interaction between acrylic type, investment material and separating medium on surface roughness was non-significant statistically. F=.821.P=.368.

Discussion

Separating medium can be defined as a coating applied to a surface and serving to prevent a second surface from adhering to the first one, they consist of Oil that dispersed in water and their action depend on the high interfacial tension of the medium that separates between the two different matrix (18) .

In the present study we have evaluated the effect of cold mold seal and glycerin on water sorption, solubility and surface roughness of Polymethylmethacrylate and thermoplastic resins against stone or plaster investment. Sorption of the materials can be represented by the amount of water absorption on the surface and into the body of the material. The results have showed that the water sorption was significantly higher for conventional heat cure acrylic than for Valplast nylon in both investment materials and this can be due to the strong hydrogen bond between amide groups and a reduction in attachment areas for water molecules. These results indicate that a majority of the thermoplastic resins have a hygienic nature that reduces the accumulation of plaque and promotes the smooth movement of the oral soft tissue (19). Also, sorption of the acrylic resin materials is facilitated by its polarity and the mechanism which is primarily responsible for the ingress of water is diffusion (20). The water sorption value of polymers may depend on the monomer composition which can influence the hydrophilicity of the polymerized resin and the filler content of resin materials. (21) .

Furthermore, It is important that the surface roughness of the materials used for dental prostheses are determined before their use in the mouth. Rougher surfaces can cause discoloration of the prosthesis, be a source of discomfort to patients and it may also contribute to microbial colonization and biofilm formation. Bacterial and fungal species have more of a propensity to adhere to rough denture base materials (9, 22). The unpolished Valplast specimens produced rougher surface than polymethylmethacrelate, this may be due to the disintegration of the mold surface which is heated to a higher temperature than conventional acrylic resin, also due to the pressure during injection moulding (23).

Table1: Mean water sorption values and std.deviation for studied groups.

Denture base type	Investment material	Separating medium type	Mean (Mg/cm²)	Std. Deviation	Std. Error	N
Conventional Heat cure acrylic	**Stone**	**Cold mould seal**	.154880	.0049213	.002	10
		Glycerine	.153120	.0084132	.002	10
	Plaster	**Cold mould seal**	.153940	.0066983	.002	10
		Glycerine	.154240	.0025185	.002	10
Total			.154045	.0058440	.001	40
Valplast	**Stone**	**Cold mould seal**	.010490	.0091402	.002	10
		Glycerine	.003110	.0019891	.002	10
	Plaster	**Cold mould seal**	.006900	.0058504	.002	10
		GLycerine	.008570	.0036985	.002	10
Total			.007268	.0048859	.001	40

Table 2: Factorial ANOVA for water sorption

Source of variation	Type III Sum of Squares	df	Mean Square	F	Sig.
Denture base type	.431	1	.431	7566.030	.000
Investment material	5.253E-6	1	5.253E-6	.092	.762
Separating medium	6.426E-5	1	6.426E-5	1.128	.292
Denbastyp * investmat	3.570E-6	1	3.570E-6	.063	.803
Denbastyp * sepmed	2.258E-5	1	2.258E-5	.396	.531
Investmat * sepmed	.000	1	.000	2.709	.104
Denbastyp * investmat * sepmed	6.108E-5	1	6.108E-5	1.072	.304
Error	.004	72	5.695E-5		
Total	.956	80			

Table 3: Mean water solubility values and std.deviation for studied groups.

Denture base type	Investment material	Seaperating medium	Mean (Mg/cm²)	Std. Deviation	Std Error	N
Conventional heat cure acrylic	Stone	Cold mould seal	.002880	.0015775	.001	10
		Glycerine	.003110	.0011846	.001	10
	Plaster	Cold mould seal	.003260	.0017709	.001	10
		Glycerine	.004725	.0031363	.001	10
Total			.003494	.0021045	.000	40
Valplast	Stone	Cold mold seal	.009370	.0038953	.001	10
		Glycerine	.004830	.0018337	.001	10
	Plaster	Cold mould seal	.009220	.0055017	.001	10
		Glycerine	.006430	.0012970	.001	10
Total			.007462	.0039276	.000	40

Table 4: Factorial ANOVA for water solubility

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Denture base type	.000	1	.000	37.419	.000
Investment material	1.484E-5	1	1.484E-5	1.762	.189
Separating medium	3.969E-5	1	3.969E-5	4.715	.033
Denbastyp * investmat	3.713E-7	1	3.713E-7	.044	.834
Denbastyp * sepmed	.000	1	.000	12.094	.001
Investmat * sepmed	1.114E-5	1	1.114E-5	1.323	.254
Denbastyp * investmat * sepmed	3.315E-7	1	3.315E-7	.039	.843
Error	.001	72	8.419E-6		
Total	.003	80			

Table5:Mean surface roughness values and standard deviation for studied groups

Denture base type	Investment material	Separating medium	Mean µm	Std. Deviation	Std. Error	N
Valplast	Stone	Cold mould seal	1.135700	.5866483	.201	10
		Glycerine	1.328900	.6673439	.201	10
	Plaster	Cold mould seal	1.611900	.4588935	.201	10
		Glycerine	1.036800	.4601011	.201	10
Total			1.278325	.5735872	.100	40
Conventiona lheat cure acrylic	Stone	Cold mould seal	1.564300	.8725710	.201	10
		Glycerine	.338300	.2690255	.201	10
	Plaster	Cold mould seal	1.587700	1.0082867	.201	10
		Glycerine	.108400	.1426863	.201	10
Total			.899675	.4204470	.100	40
Total		Cold mould seal	1.474900	.7602340	.100	40
		Glycerine	.703100	.6788707	.100	40

Table 6: Factorial ANOVA for surface roughness.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Denture base type	2.868	1	2.868	7.102	.009
Investment material	.001	1	.001	.002	.969
Separating medium	11.914	1	11.914	29.506	.000
Dentbastyp * investmat	.191	1	.191	.472	.494
Dentbastyp * sepmed	6.748	1	6.748	16.712	.000
investmat * sepmed	1.305	1	1.305	3.231	.076
Dentbastyp * investmat * sepmed	.332	1	.332	.821	.368
Error	29.071	72	.404		
Total	147.301	80			

According to the result of this study, roughness of both resins was lower when glycerin was used as a separating medium and this finding may be related to several reasons, fist one is the viscosity of glycerin which is 1.4/2 Pas permit to close any voids or porosity found due to the high coefficient of penetration of this material that permit the material to penetrate and close any porous found. The second reason may be due to the surface tension of separating medium which occur due to the adhesion force that found between its molecules, high surface tension of separating medium the higher the sealing and separation between investment material and polymers denture base materials (12, 18, 24).

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