Evaluation of the effect of addition of polyester fiber on some mechanical properties of heat cure acrylic resin

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ABSTRACT

Background: This study aimed to evaluate the effect addition of polyester fibers on the some mechanical properties of heat cured acrylic resin (implant strength, flexural strength and hardness)

Materials and methods: Ninety specimens were used in the study. Thirty specimens were used for impact strength measurements (80mm X 10mm X 4mm) length, width and thickness respectively. The specimens divided into three test groups (n=10), first group formed from heat cure acrylic resin without fiber reinforcement. Second group was formed from heat cure acrylic resin was reinforced with 2 mm length polyester fiber and third group was formed from heat cure acrylic resin reinforced with 4mm length polyester fiber, impact strength measured by impact testing device. 30 specimens with (65 mm X 10mm 2.5mm) length, width and thickness respectively were used in 3 groups (n=10) flexural strength test. The flexural strength was measured by using flexural testing device. 30 specimens with (65mm X 10m X 2.5mm) length width and thickness respectively were used for hardness test. The specimens were divided into 3 group (n=10) as in impact strength and flexural strength.

Hardness measured by using (shore D hardness tester TH210).

Results: revealed statistically significant increase on impact strength especially on 4mm length when compared to control group. Significant decreases in flexural strength of PMMP. When compared to control group with 4mm length fiber reinforcement. Non significant decrease when compared control group with 2mm length fiber reinforced PMMA. Significant decrease in hardness of PMMA resin after reinforcement with 2mm, 4mm lengths polyester fibers.

Conclusions: Strengthening with the polyester fiber decreased the flexural strength and hardness of the resin, but increased impact strength. Thus when high impact acrylic resins are needed, fiber reinforced resins may be the material of choice.

Keywords: Heat cure acrylic resin, polyester fibers. (J Bagh Coll Dentistry 2013; 25(Special Issue 1):23-29).

الخلاصة

الهدف من هذا البحث لتقييم تاثير اضافة الياف البوليستر للاكريلك الحراري على بعض الخواص الميكانيكية للاكريلك الحراري (مقاومة الصدمة ,قوة الطي,صلادة السطح).
استخدم في البحث 90 نموذج وقد قسمت الى 30 نموذج لكل خاصية , 30 نموذج لقياس قوة الصدمة بقياسات (80ملم*10ملم*4ملم) الطول , العرض,السمك بالتتالي النماذج قسمت الى ثلاثة مجموعات (العدد=10) للاختبار المجموعة الاولى شكلت من الاكريلك الحراري بدون اضافة الالياف ,المجموعة الثانية شكلت باضافة الالياف بطول 2ملم,المجموعة الثالثة شكلت باضافة الالياف بطول 4ملم. مقاومة الصدمة قيست بواسطة جهاز قياس الصدمة .
30 نموذج استخدمت لقياس قوة الطي بقياسات (65ملم*10ملم* 2,5ملم)الطول ,العرض,السمك بالتتالي ,قسمت الى ثلاثة مجاميع(العدد=10) لكل مجموعة وتم قياس قوة الطي بجهاز قياس قوة الطي. 30 نموذج استخدمت لقياس صلادة السطح بنفس القياسات المستخدمة لقياس قوة الطي .
عكست النتائج زيادة ملحوظة في مقاومة الصدمة وخاصة بعد اضافة الاليف بطول 4 ملم ونقصان ملحوظ في قوة الطي بعد اضافة الاليف بطول 4ملم مع نقصان غير ملحوظ بعد اضافة الالياف بطول ال2ملم. نقصان غير ملحوظ لكلا الطولين على صلادة السطح. هذه الدراسة استنتجت ان اضافة الياف البولستر تقلل من قوة الطي والصلادة ولكن تزيد من مقاومة الصدمة ولذلك عندما نريد ان نستخدم الاكريلك الحراري ذو المقاومة العالية للصدمة نستخدم الاكريلك الحراري المدعم بالياف البوليستر.

INTRODUCTION

Heat polymerized polymethly methacrylate (PMMA) is the most widly used material in prosthetic dentistry. Superior esthetic ease processing, accurate fit, used with inexpensive equipment and repairability, make PMMA as a material of choise for denture base fabrication. Despite these excellent properties PMMA is not metting all the necessary requirement, and primary proplem is its poor strength characteristics, including low impact and flexural strength[(1-3)].

Many attempts have been made to enhance the strength properties of acrylic denture base. One of the most common reinforcing technique was the use of metal wire embedded in the prosthesis [(4,5)].

In addition to this various type of fiber including carbon fiber [(6)], aramid fiber [(7)], polyetheylene fiber [(8)],and glass fiber [(9)] have been investigated as reinforcing material, and it has been shown that the fibers increase the flexural strength and impact strength of denture base polymer.

Carbon and aramid fibers strengthened PMMA but caused clinical problems, including difficulty polishing and poor esthetics[(10)].

Inclusion of metal wire and plate reinforcements resulted in poor aesthetics, restricting their use to location at which aesthetics are least important. In case of polyethylene fibers, the surface treatment to improve the adhesion between fibers and denture base polymer is complicated and has not resulted in adequate adhesion [(11)].by contrast glass fibers have better potential for provisional restoration, despite the difficulty of achieving adequate impregnation of fibers with PMMA [(12)].

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Fiber reinforcement is depending on many variables including, fiber type, length, form, and arrangement, percentages of fibers in the matrix and fiber matrix bond. Polyester fibers are available in monofilament form and belong to the thermoplastic polyester group. They are temperature sensitive and somewhat hydrophobic. Polyester fibers were used for reinforcement of acrylic denture base resin but there were little studies about the use of this fiber. Hence the purpose of this study was undertaken to determine the reinforcing effect of polyester fibers on impact strength, flexural strength and hardness of heat polymerized polymethyl mathacrylate denture base polymer.

MATERIALS AND METHODS

Heat cure acrylic resin (Triplex, Ivoclar vivadent, Germany) was used in this study. The reinforcing material was polyester fiber.

Three mechanical tests were used in this study:-

1- **Impact strength test.**

Thirty specimens were prepared for impact test and devided into three test groups which contained 10 specimens each (n=10).

Metal dies with dimensions of (80mm X10mm X4mm) length, width, thickness repectively following the ISO standared 179-1: 2000[13] were fabricated to prepare the gypsum molds. A thin layer of petroleum jelly was applied over the die and it was invested with type IV gypsum product in the lower half of dental flask when stone was set in the lower half of the flask, a layer of separating medium was applied on the stone and metal die, then upper half of the flask was seated and the flask was filled with dental stone. After one hour the dental flask was opend and the die was carefully removed from the investing material. Ten moulds were prepared. The moulds were evaluated for any porosities and roughness. The prepared moulds were immersed in hot water to remove any traces of empurities and to facilitate the application of separating medium. The mould cavities obtained were used for the preparation of test specimens. For control group, ten specimens of polymethyl methacrylate (PMMA) were fabricated. Polymer and monomer in the ratio of 2.5: 1 by weight was mixed and allowed to reach dough stage. It was kneaded and packed in the mould. The trial closures were performed and excess was removed. The two halves of the flask were pressed together by bench press. Curing was carried out by placing clamped flask in water bath at room temperature raised slowly up to 74°C and hold for 2 hours then raised to 100°C and was maintained for 1 hour [14]. After completion of polymerization cycle, the flask allowed to cool in water bath to room temperature. Specimens were finished and polished after deflsking. The dimension and quality of each specimen were verified and stored in distal water at 37°C for 24 hours in an incubator befor testing.

The second group specimens preparation:-

Before mixing of polymer and monomer. Polyester fibers were cut into 2mm length and were socked in monomer for 10 minutes in petridish for better bonding of fiber with PMMA resin[15].

After fiber were removed from the monomer, excess liquid was allowed to dry and fibers (2%by weight) were mixed thoroughly with the polymer powder to disperse the fibers by manual mixing. The polymer containing fibers and monomer was mixed in ratio of 2.5:1 by weight and allowed to reach the dough stage. The mix was packed into the prepared mould. The specimens were polymerized and retrived in the same manner as control group.

The third group specimens were prepared from the same percentage of fibers in the polymer but the length of fibers were cut into 4mm length and specimens were prepared as mention before.

Impact strength test was carried out on un-notched specimens. Testing was done on impact testing machine fig(1) with pendulum of S_2 scale in an air at 23±2°C.

Figure 1: Impact testing device

Before testing, pendulum was releated to freely swing in the air to record the air resistance (AR) encountered by free-swinging pendulum. Air resistance of 0.9 Joules was recorded. The readings were taken on S_2 scale where pointer was stabilized after swing. The specimen was clamped in position precisely. Pendulum was released and reading indicating energy absorbed (EA) to break the specimens on S_2 scale was recorded. All the specimens were tested in the same manner.

Impact strength of specimen was calculated. By using formula:-

$$I=\frac{(EA-AR)}{X.Y} X10^3$$

I=impact strength in Kj/m^2.
EA=energy absorbed in joules.
AR=air resistance in joules.
X=specimen thickness (mm).
Y=specimen width(mm).

2- Flexural strength test:-

Thirty specimens with dimension of (65mmX10mmX2.5mm) length, width and thickness respectively were prepared for flexural strength test. All the specimens were grouped and fabricatd similar to the specimens prepared for impact test. Before testing the specimens were stored in distilled water at 37°C for 48hours the flexural strength was evaluated according to ISO/DIS 1567 international standard [16] by the three-point bending test fig(2).

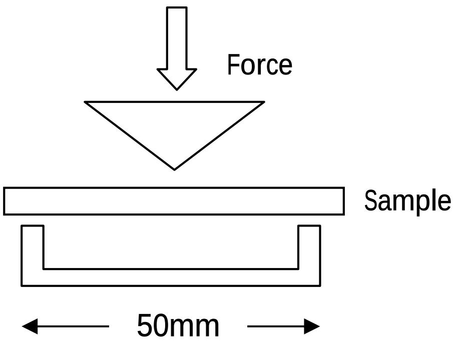

Figure 2: Schematic illustration of flexural strength test arrangement

Figure 3: Flexural testing device

The test were carried out in air at 21±1°C using flexural-testing device fig(3). Aload was applied using a centrally located rod until fracture occurred. The span of this 3-point bending was 50mm. specimens were set wet from the storage container directly onto the testing apparatus.

All the specimens were tested in the same manner. The ultimate flexural strength (MPa)) of each specimen was determind with the following formula [17].

$$\propto=\frac{3XFXI}{2XbXh^2}$$

Where α is considered as flexural strength (MPa)
F= the maximum load applied (N)
I= the span between the two supports (mm)
b=the width of specimen(mm).
h=thickness of specimen (mm).

3- Shore hardness test.

Thirty specimens were fabricated and grouped similar to the specimens prepared for flexural strength test. The tests were carried out in air at 21±1°C using electrical device (shore D hardness tester TH210) fig (4). The hardness number is based on depth of penetration and was read directly from a gauge.

The mean difference and standard deviation were calulated for each test and each group (control group, 2mm and 4mm length polyster fiber reinforcement groups) to make comparisons between the different groups tested, independent samples t-test was used for analysis.

Figure 4: Electrical device for shore hardness test

RESULTS

The mean values and standard deviation (SD) of impact strength, flexural streagth and hardness for control group and 2mm, 4mm length polyester fiber reinforced PM/MA are reported in table (1).

By using independent samples t-test, the results revealed statistically significant difference between impact strength of fiber reinforced

PMMA and control group as showing in table(2). The comparative mean values of the impact strength of control group. 2mm fiber reinforcemat and 4mm fiber reinforcement were presented in fig (5)

Table 1: Descriptive statistics of the impact strength, flexural stragth and hardness of control and reinforced PM/MA:

	Control n=10		2mm fiber n=10		4mm fiber n=10	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Impact strength Kj/m^2	7.3750	.94288	13.8400	1.04265	18.4020	1.53928
Flexural strength Map	440.300	8.96970	424.600	26.466	404.3000	12.7283
Hardness	85.3500	1.51529	82.7900	1.35355	82.5900	1.670

Table 2: Independent samples t-test: comparison of impact strength between control group and fiber-reinforced PMMA groups.

	Type	t-test for equality of mean			
		t	**Df**	**p-value**	**sig**
Impact strength	**Control and 2mm fiber**	-14.543-	18	.000	H.S
	Control and 4mmfiber	-19.318-	18	.000	HS
	2mm fiber and 4mm fiber	-7.760-	18	.000	H.S

***P <0.05 significant.**

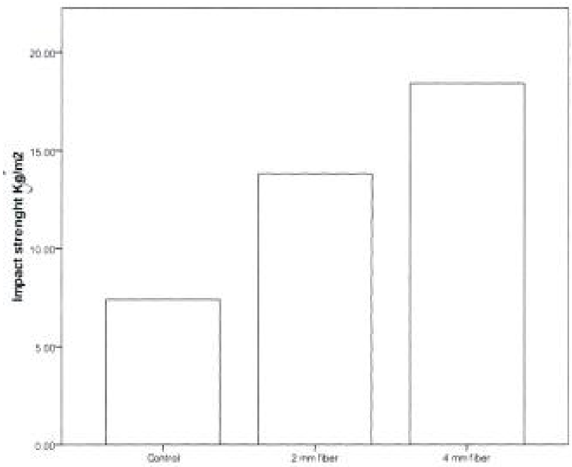

Figure 5: Graph showing mean impact strength of control and fiber-reingorced PMMA (m=10)

There was significant decrease in flexural strength of PMMA when compared control group with 4mm length fiber reinforcement but this decrease was statistically not significant when compared control group with 2mm length fiber-reinforced PMMA(table3). The comparative mean values of the flexural strength of PMMA of control group, 2mm fiber reinforcement 4mm fiber-reinforcement were presented in fig(6).

Table 3: Independent samples t-test: comparison of flexural strength between control and fiber reinforced PMMA groups.

	Type	Test for equality of mean			
		t	**Df**	**p-value**	**sig**
Flexural strength	**Control and 2mm fiber**	1.77	18	.093	NS
	Control and 4mm fiber	7.311	18	.000	S
	2mm fiber and 4mm fiber	2.186	18	.042	S

***p< 0.05 significant**

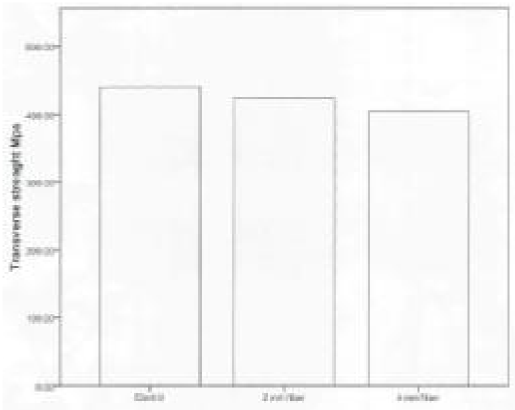

Figure 6: Graph showing mean flexural strength of control and fiber reinforced PMMA (n=10).

There was significant decrease in hardness of PMMA resin after reinforced with polyester fiber as showing in table (4). The comparative mean values of hardness of control group, 2mm fiber reinforcement and 4mm fiber reinforcement were presented in fig-7.

Table 4: Independent samples t-test: comparison of hardnes between contral group and fiber reinforced PMMA groups.

	Type	t-test for equality of mean			
		t	Df	p-value	sig
Hardness	**Control and 2mm fiber**	3.904	18	.001	S
	Control and 4mm fiber	3.869	18	.001	S
	2mm fiber and 4mm fiber	0.294	18	.772	N.S

***p<0.05 significant**

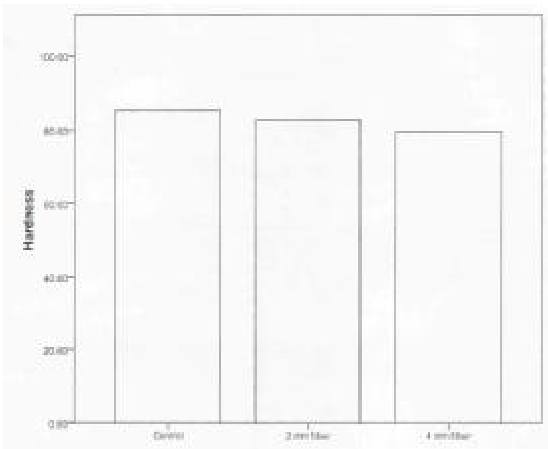

Figure 7: Graph showing mean hardness of control fiber reinforced PMMA (n=10).

DISCUSSION

This study demonstrated the effect of polyester fiber reinforcement on the impact strength, flexural strength and hardness of heat polymerized PMMA resin. Any increase in fiber incorporation beyond 3% by weight will affect the flow of the dough, 4% by weight of fibers represents a large volume of material be wetted by monomer during mixing and may produce dry friable dough (18). This will provide no beneficial effect on strength. For this reason a standard 2% by weight of fiber was added to each specimen in this study.

Many different stress were applied on denture base acrylic resin. For example intra-orally, repeated masticatory forces lead to fatigue phenomena, while extra-orally, the fracture of acrylic resin dentures as a result of being dropped is a common occurrence and research continues to produce a denture material with impact resistance which must not interfere with other properties of material [19].

Impact strength testing could be carried out on un-notched and notched specimens but notching would have cut the superficial fiber in the specimens, therefore testing was carried out on un-notched specimens.

The reinforcement groups with polyester fibers showed statistically significant increase in impact strength compared to the control group specimens as showing in table(2). This might be attributed to presence of reinforced fibers which carry the load a long their length to provide strength and stiffness to the specimen, resulting in higher absorption of energy compared with un-reinforced specimens [20].

The impact strength of the specimens reinforced with polyester fiber (4mm length) was much higher than that of (2mm length) and this was agree with study by Chen et al [21].

Specimens contain 2mm length fibers showed decrease in flexural strength which is statistically not significant when compared with control group. The decrease in flexural strength of specimens contains 4mm length fibers was statistically significant when compared with control group. The mean values of flexural strength for control group and 4mm length fiber reinforcement were 440 MPa, and 404MPa respectively. Despite the decrease was statistically significant, this decrease didn't adversely affect the miret of PMMA denture base resin. This slight decrease in flexural strength may be attributed to the random orientation of the fibers from the literature it appears that reinforcement is optimized when fibers are laid down in strategic fashion, running parallel to the surface of denture base. In this way their contribution to reinforcement is maximized as fibers at right angle to the surface produce no beneficial effect. How ever, technical difficulties of ensuring that fibers were aligned correctly might overweigh the possible advantage, by complication the technique to such an extent that it becomes impractical 18. In random orientation of fibers, some fibers are oriented to produce beneficial effect and others are of little or no benfit. The ease and simplicity of random orientation would make this technique more acceptable for widespread use, avoiding the necessity of interruption of packing procedures and time consuming placement of oriented fiber. Further investigation is required to determine the adequate direction of reinforcing materials against the applied force. The polyester fibers reinforcement showed statistically significant decrease in hardness of reinforced group when compared with control group but clinically this may be not so important because the mean values of control group, 2mm length fiber and 4mm length and 4mm length fiber reinforcement were 85.35, 82.79, 82.59, respectively. Thus these fibers can be effectively used to reinforce denture base to minimize denture fracture. This technique can be clinically for constriction of complete dentures and distal extension partial dentures, especially in cases like patients with poor neuromuscular control.

We have compared unreinforced and polyster fiber reinforced PMMA resin under conventional heat curing techniques. Strengthening with the polyester fiber decreased the flexural strength and hardness of the resin, but increased impact strength. Thus when high impact acrylic resins are needed, fiber reinforced resins may be the material of choice.

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