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Visible Light Cure Fiber Frame Work Reinforcement of Acrylic Resin Denture Base Material. A Comparative Study.

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الخلاصة

الأهداف: تعتبر المادة الراتنجيةالاكريلية الحرارية المادة المفضلة لصناعة قاعدة طقم الأسنان. بسبب خواصها المفضلة، ولكنها تملك بعض الخصائص السلبية مثل قابليتها على الكسر. هناك عدة طرائق ومواد تستخدم لتقوية قاعدة طقم الأسنان الراتنجيةالاكريلية. واحدة من هذه الطرائق هي طريقة التقوية باستخدام الألياف. في هذه الدراسة تم استخدام شبكة الالياف الاكريلية الضوئية كتقوية ومقارنتها مع التقوية باستخدام الألياف الزجاجية. **المواد وطرائق العمل**: في هذه الدراسة تم تحضير (128) عينة لدراسة قوة الانثناء و قوة الصلادة وصلادة السطوح ومقدار المونيمر المتبقي. قسمت العينات إلى أربع مجاميع، (8) عينات في كل مجموعة: مجموعة السيطرة بدون تقوية و مجموعة التقوية باستخدام شبكة الألياف الاكريلية الضوئية و مجموعة التقوية باستخدام الألياف الزجاجية العشوائية الترتيب و مجموعة التقوية باستخدام شبكة الألياف الزجاجية. **النتائج**: أظهرت نتائج هذه الدراسة إن شبكة الألياف الاكريلية الضوئية حسنت بصورة معنوية قوة الانثناء وقوة الصلادة لمادة الراتنجالاكريلي الحراري ولم تؤثر على صلادة سطح المادة ومقدار المونيمر المتبقي. **الاستنتاجات**: إن شبكة الألياف الاكريلية الضوئية تزيد من مقاومة قاعدة طقم الأسنان للكسر.

ABSTRACT

Aims: Heat cured acrylic resin is the material of choice for construction of complete dentures due to its desirable properties, although it has some disadvantages as its susceptibility to fracture. Several methods and materials are used to reinforce acrylic resin denture base. One of these methods is reinforcement by using fibers. In this study, visible light cure fiber frame work is used as reinforcement material and compared with reinforcement with glass fiber. **Materials and methods**: in this study, 128 samples were prepared for evaluation of transverse strength, impact strength, surface hardness, and residual monomer tests. The samples were divided into four groups 8 sample for each group; control group without reinforcement, reinforcement by using visible light cure fiber frame work, random glass fiber reinforcement, and mesh glass fiber reinforcement. **Results**: the results of this study showed that visible light cure fiber frame work system significantly increase the transverse strength and impact strength of the heat cured acrylic resin, and it didn't affect the surface hardness and amount of residual monomer of heat cured acrylic resin. **Conclusions**: visible light cure fiber frame work system increase acrylic resin denture base resistance to fracture.

Key words: reinforcement, glass fiber, visible light cure, impact strength, transverse strength, surface hardness, residual monomer.

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INTRODUCTION

Poly methyl methacrylate is the most widely used denture base material, because it is economical, stable in oral environment, easily constructed and repaired. However it is exposed to different types of stresses that may lead to its fracture. Therefore, many researchers have attempted to improve its mechanical properties. As incorporation of zirconia(1), tin or aluminum powder(2), or blending of polymers.(3) Also reinforcement of denture base by using metal wires(4,5), metal plate and metallic mesh(6), but this method had limited application because of the corrosion in the metal and unaesthetic appearance.

Reinforcement by using fibers is widely used for strengthening acrylic resin denture base.(6) Many types of fibers are used for reinforcement including, carbon, aramid, polyethylene, nylon and glass fibers.(7-10) Many forms of fibers are used, woven type, straight and unidirectional oriented fibers.(5,6) The carbon and aramid fibers had unaesthetic appearance and difficult to polish.(7) The polyethylene fibers need difficult application approaches so limited its use.[8-9] Glass fibers were used widely because of its great strengthening properties and easy manipulation that can be done in the dental lab. The new system of light cured fiber frame work reinforcement is used to reinforce acrylic resin denture base. The aim of this study was to compare between light cured fiber frame work reinforcement system and glass fiber reinforcement on the transverse, impact strength, surface hardness and residual monomer of heat cured acrylic resin denture base material.

MATERIALS AND METHODS

In this study (128) samples were prepared from heat cured acrylic resin (RESPAL NF/Italy) for evaluation of transverse strength, impact strength, surface hardness, and residual monomer tests. The samples were divided into four groups 8 sample for each group:

1. Control group without reinforcement (C).
2. Reinforcement by using visible light cure fiber frame work (LM).
3. Random glass fiber reinforcement (FR).
4. Mesh glass fiber reinforcement (FM).

Sample preparation:

The samples of control group were prepared in the conventional technique for heat cured acrylic resin.

The samples were prepared by placing a sheet of wax against a glass slab, the sheets were cut by using a sharp wax knife to the desired length and width specified for each test, according to ADA specification no.12. The surface of wax smoothed by piece of tissue nylon type. [11]

The stone was mixed with water in ratio of 28-32 ml of water : 100 gm of stone [12] and poured in the lower half of the flask and vibrated , the samples are placed over the stone in the flask. After the stone was set a separating medium was applied over the stone. Then the upper half of the flask was placed over and filled by stone.

After complete setting of stone, wax elimination was done. Then the two halves of the flask opened and boiling water with soap detergent was used to clean the surface of stone from remnants of the wax.

After drying a separating medium was applied to both halves of the flask. The polymer was applied to the monomer placed in glass jar and mixed together, in ratio of 2.5:1 by weight according to manufacturer instructions, after the mixture reached dough stage, the two step packing technique was done. Then curing according to manufacturer instructions and deflasking of the samples were proceeded.

Visible light cured fiber frame work reinforced samples prepared by sandwich technique, the frame was cut for the desired dimensions for each test and cured in light cure cabinet for 4 minutes then placed in the middle of the sample mold by using stoppers. The height of the stoppers is half the depth of the mould. Then acrylic resin is mixed, packing and curing proceeded as usual manner.

Randomly distributed glass fiber samples prepared by cutting the fibers to 6 mm length. Then theses short rod fibers were added to the polymer powder in a random orientation at a concentration of 5% by weight using an electronic balance. The monomer was added to the polymer in ratio of 1/2 to produce a workable dough.[6]

Mesh glass fiber reinforced samples prepared by cutting the woven mat to the desired dimensions specified for each test, the mat is soaked in monomer for 10 minutes then allowed to dry and placed in the middle of the sample mold by using stoppers (sandwich technique). Then acrylic resin is mixed, packing and curing proceeded as usual manner .[6]

Transverse strength test:

Samples with dimensions of 65×10×2.5×0.03mm (length, width and thickness) respectively were prepared according to ADA specification no.12. The samples stored in distilled water at 37°C for 48 hr. before testing. The test was done in air by using a 3 points bending on an Instron testing machine. The devise was supplied with a central loading plunger and two supports ,with polished cylindrical surfaces of 3.2 mm in diameter and 50 mm between supports. The supports should be parallel to each other and perpendicular to the central line. The tests were carried out with cross head speed of 5mm/min. The test samples held at each end of the two supports, and the loading plunger placed mid-way between the supports.(13,14)wa

The transverse strength were calculated using the following equation:-

$$S = \frac{3PI}{2bd^2}$$ (Craig and Ward 1997)[12]

S = transverse strength (N/mm2)
b= width of specimen (mm)
d = depth of specimen (mm)
I= distance between supports (mm)
P= maximum force exerted on specimen(N)

Impact strength test:

Samples with dimensions of 64×13×3×0.03mm (length, width and-thickness) respectively were prepared. The samples stored in distilled water at 37^{o}C for 7 days before testing. The test was done on Izod impact testing machine with a pendulum of S2 scale in air. Before testing, pendulum was released to freely swing in the air to record the air resistance (AR) encountered by free-swinging pendulum. The specimen was clamped in position precisely. Pendulum was released and reading indicating energy absorbed (EA) to break the specimens on S2 scale was recorded.[6,15]

Impact strength of specimen was calculated by using following formula:

Impact strength =Corrected Readings/W
where:
Corrected readings = (EA - AR) in Joules
W = Test specimen width in meter
Impact strength = J/m

Indentation Hardness Test :

Samples were prepared with dimensions of 30×15×3×0.03 mm.

The samples stored in distilled water at 37^{0}C for 48hr. before testing.

The sample were tested for hardness at five different locations then the mean is taken for each sample surface.

The test was done by using Rockwell hardness tester, equipped with an indenter in the form of round steel ball of 6.350mm in diameter. The sample was first subjected to a fixed minor load of 10 kg, then load of 50 kg was applied to the sample and the Rockwell hardness number was recorded after application of this load by 15 sec.[6,13]

Residual Monomer Test :

Samples were prepared with dimensions of 20×20×3 mm (length, width and thickness) respectively. Each sample was introduced in a sealed glass flask containing 10 ml. of distilled water at 37^{o}C . At the end of 7 days the supernatants were removed and the time dependence of the monomer concentration was followed by monitoring the amount of monomer present in the supernatant medium using a (CECIL 2000) ultraviolet-visible spectrophotometer (λ=254 nm).[16]

A linear calibration curve of methyl methacrylate (MMA) concentration as a function of absorbance at 254 nm. was obtained using MMA standard aqueous solutions in the range 0.025-0.5 mg/ml.

The results were expressed as a percent of released residual monomer mass with respect to the weight of the specimen.[13,16-18]

The statistical analysis of the results done by using one way analysis of variance and Duncan's multiple range test.

Results and discussion

The results of the study showed that the transverse and impact strength of acrylic resin denture base material were significantly increased after reinforcement with glass fiber and visible light cure fiber frame work system (at p=0.05), Figures (1,2) and Tables (1,2).

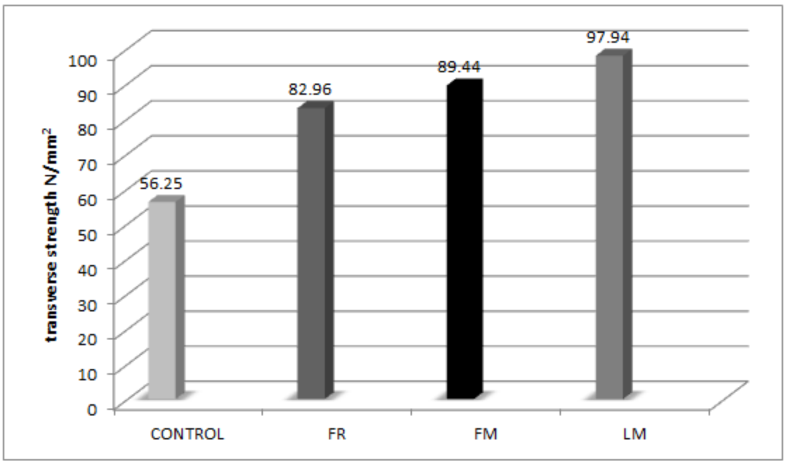

Figure (1): Duncan's Multiple Range Test of the transverse strength of the experimental groups.

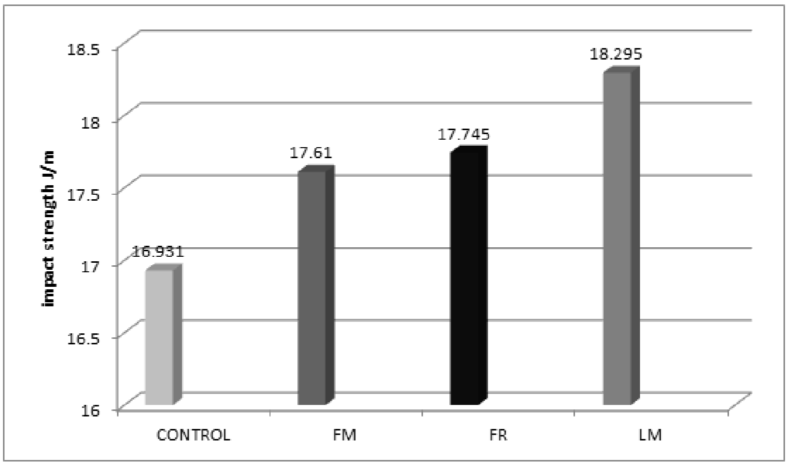

Figure (2): Duncan's Multiple Range Test of the impact strength of the experimental groups.

Table (1): One – Way analysis of variance (ANOVA) of the transverse strength of the experimental groups.

Source	DF	SS	MS	F-value	P-value
Factor	3	7777	2592	12.94	0.000
Error	28	5610	200		
Total	31	13388			

DF: Degree of freedom
SS: Sum of square
MS: Mean square

Table (2): One – Way analysis of variance (ANOVA) of the impact strength of the experimental groups.

Source	DF	SS	MS	F-value	P-value
Factor	3	7.545	2.515	18.88	0.000
Error	28	3.730	0.133		
Total	31	11.276			

DF: Degree of freedom
SS: Sum of square
MS: Mean square

The flexural strength of a material is a combination of compressive, tensile, and shear strengths.[7,19] As the tensile and compressive strengths increase, the force required to fracture the material also increases. Compared with conventional polymer materials, fiber reinforced polymers are successful in their application primarily because of their high specific modulus and specific strength.[7,20]

The increase in transverse and impact strength attributed to the direction of fiber in the polymer matrix and the aligned orientation of glass fiber, fibers placed perpendicular to the loading force provide the most effective reinforcement of acrylic resin.[6]

Negrutiuetal stated that the best reinforcement was the unidirectional glass fiber reinforcement, followed by glass fiber net reinforcements; the worst bond was between the denture resin and the metal net. [21] As expected, unidirectional glass fibers strengthen polymer material more successfully than net shaped glass fibers, because fibers were positioned perpendicularly across the applied force (opposite to the net shaped glass fibers positioned at an angle of 45^o, thus giving better strengthening effect). Therefore they are more appropriate to be used, but in cases when the direction of the braking force is known. [22] The effects of short rod fiber reinforcement are controlled by the amount distribution, diameter and aspect ratio of glass fiber used. The disadvantage of using short rod fiber was the presence of protruding ends in the finished specimen.[23]

Fiber orientation and interfacial adhesion play a significant role.[24] A significant effect is produced by random orientation of fibers in the specimens. Presumably, some fibers are oriented to produce beneficial effect and others are of little or no benefit. The ease and simplicity of their inclusion would make this technique more acceptable for widespread use, avoiding the necessity of interruption of packing procedures and time consuming placement of oriented fibers or woven filaments .[15.25]

Unidirectional glass fibers equally strengthen polymer material as net shaped glass fibers due to the larger volume amount of fibers used in net shaped reinforcements. Both of these reinforced specimens have flexural strength values similar to those of high impact strength resin specimens.[26,27] The reinforcing effect of unidirectional fibers is only in one direction anisotropic whereas randomly oriented fibers tend to reinforce in all directions and the mechanical properties are isotropic. [28] Reinforcement of heat cured acrylic with glass fiber increase the impact strength of material specially when fibers placed parallel to long axis of the specimen perpendicularly to impact force.[29] Woven fibers are able to reinforce the denture base polymers in two directions. Denture fracture in clinical use occurs from a large transitory force caused by an accident or a small force during repeated chewing. [30]

Glass fibers are not very resistant to impact but their strength can be improved by using many glass unidirectional glass fibers or by using woven glass fiber. Heat-polymerizing PMMA is a brittle material in the temperature of the oral cavity and the denture has low impact strength. The differences between the two types of reinforcements are probably due to the number of glass fibers per section area of test specimen.[31]

The SEM of unreinforced specimens showed larger cracks for causing the specimen fracture compared to all the fiber reinforced groups where cracks were small. This might be because of presence of fibers preventing the crack propagation and change in direction of cracks resulting in smaller cracks between the fibers. This can be correlated to the increased impact strength of fiber-reinforced specimens compared to the unreinforced specimens where there is unobstructed crack propagation,[15]

The bond between the glass fiber and polymer matrix depends on the mechanical retention by polymerization shrinkage and roughness caused by longitudinal threads and transverse threads, that is, on the frictional force between the glass fiber and polymer matrix.[30] However, these fibers break-up the homogeneous matrix of acrylic resin due to poor interface between fiber and resin affecting the mechanical properties.[6] In order to avoid this problem, many studies advocating the surface treatment of fibers have been reported. In this study treatment of the glass fibers done by soaking in the monomer for 10 minutes, If fibers are to be used to strengthen a polymer material, optimal adhesion between the fibers and the polymer matrix is essential. Impregnation of reinforcing fibers with resin allows fibers to come into contact with the polymer matrix. This is prerequisite for bonding of fibers to polymer matrix and thus for strength of the composite. [32]

Internal voids formed in the acrylic resin-fiber composite are assumed to be caused by polymerization shrinkage of the acrylic resin monomer liquid inside the fiber strand or poor wetting of the fibers with acrylic resin. [32] The monomer in which the fiber strand is dipped before incorporation into the acrylic resin has a volumetric shrinkage of 21% and the acrylic resin that surrounds the fibers shrinks only 8%. [33] However, the increase in the acrylic monomer liquid in the fiber seems to reduce the surface area of void space. As a result, the poor wetting of the fibers might result in formation of void space in the acrylic resin-glass fiber composite. Poorly impregnated regions in the composite decrease mechanical properties of the composite[5,34].

The specimens containing light cured glass fibers showed an increase in impact and transverse strength, it is possibly attributed to the fact that fibers are pre polymerized and contain a highly porous polymer that provides a chemical bonding to the denture base resin.[35] Glass fibers are favorable for denture base polymer when used in light curing type resin because they have excellent transparency compared to the other fibers. In dental work, it has been difficult to introduce continuous long glass fibers into the dough of liquid methyl methacrylate (MMA) monomer and polymethyl methacrylate (PMMA) powder, and glass rods are limited to application on thin palatal areas of denture base polymer. Woven glass fiber has a suitable form as a reinforcing material for the so-called partial fiber reinforcement(PFR), because the woven glass fiber is a tape with various widths. Further, glass fiber is easy to cut with scissors, however, glass fibers frayed when the fiber is bent excessively. Polymer-pre impregnation eliminates this problem. [30]

The results of surface hardness test ,Figure(3), and Table (3).

Table (3): One – Way analysis of variance (ANOVA) of the hardness of the experimental groups.

Source	DF	SS	MS	F-value	P-value
Factor	3	1373.3	457.8	29.63	0.000
Error	28	432.6	15.5		
Total	31	1806.0			

DF: Degree of freedom, SS: Sum of square, MS: Mean square

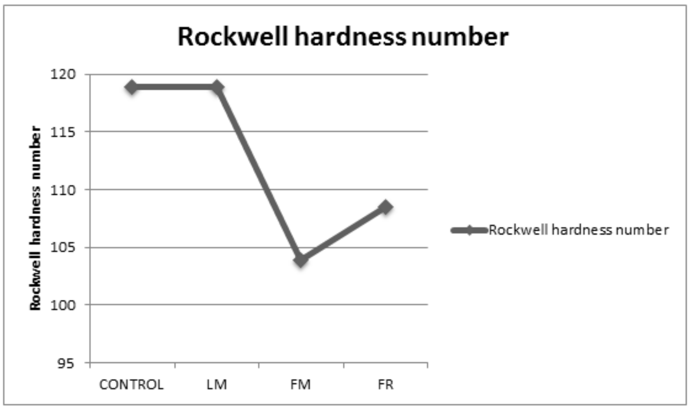

Figure (3): Duncan's Multiple Range Test of the hardness of the experimental groups.

Showed that incorporation of fibers resulted in decrease in hardness (at p=0.05). The decreased surface hardness of the bulk reinforced acrylic resin may be caused by both the effect of incorporated fibers and the reduced proportion of the resin matrix. The randomly oriented and woven glass fibers prduced lower indentation resistance, this could be attributed to the higher percentage of residual monomer content, Figure(4), and Table (4), because surface hardness is affected by high levels of residual monomer, which has a plasticizing effect that reduces inter chain forces so that deformation could occur more easily under load.[6,36]

Table (4): One – Way analysis of variance (ANOVA) of the percent of residual monomer of the experimental groups.

Source	DF	SS	MS	F-value	P-value
Factor	3	0.006146	0.002049	15.08	0.000
Error	20	0.002717	0.000136		
Total	23	0.008862			

DF: Degree of freedom, SS: Sum of square, MS: Mean square

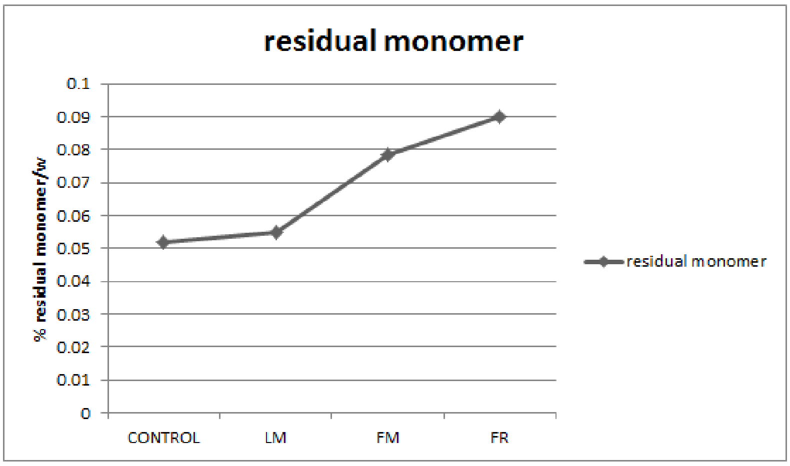

Figure (4): Duncan's Multiple Range Test of the percent of residual monomer of the experimental groups.

In this study the reinforcement with light cure frame work system did not affect the surface hardness(at p=0.05), figure 3,of the acrylic resin because there is no change in the monomer polymer ratio and the net cured with light before use so no impregnation in the monomer. Decrease of residual monomer volume, enhancing mechanical properties of the material and increasing the flexural strength values. [17,18]

The high levels of residual monomer, figure and Table 4, adversely affect acrylic resin properties [36-40] that has a plasticizing effect that reduces inter chain forces, consequently absorption of water into the acrylic resin that replaces residual monomer particles, and because water molecules are smaller than inter chain distance in the resins they can be absorbed into the material and decrease the secondary chemical bonding forces between these chains, thus decreasing the mechanical properties of the resin because of the plasticizing effect of water molecules.[40]

CONCLUSIONS

Visible light cure fiber frame work system increase acrylic resin denture base resistance to fracture without affecting the surface hardness and residual monomer content.

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