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Reinforce Acrylic Resin with Different Kinds of Fibers After Breaking

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ABSTRACT

Introduction: Every year, thousands of acrylic dentures break, which creates additional costs for patients. One of the treatment options may be denture repair along with the use of a thread as reinforcement. Purpose of the study was to assess the effect of a different fiber's reinforcement on the flexural strength and Isolde impact resistance of conventional heat-polymerized poly (methyl methacrylate) [PMMA] resin repair with self- curing material.

Materials and methods: Totally 192 specimens of standard dimensions were prepared for each of the eight experimental groups; unreinforced conventional acrylic resin, material breaking and glue with self-curing resins and the same resin reinforced with unidirectional glass, carbon, polyethylene fibers. Each group was further subdivided into two groups of 12 specimens, based on storage conditions (dry and wet). Samples were then subjected to a 3-point bending test and flexural strength (FS) was calculated. Second group was tested for Isolde impact resistance (IS).

Results and discussion: Samples repair with self-curing resins have lower mechanical properties more than 30% compare to hot curing resin. Reinforcing of repairing samples with different kinds of fibers can improve flexural strength and impact resistance. The best results were observed for plasma treated PE fibers and carbon fibers. Storage long time in water can reduce FS about 20% and improve IS more than 5% for samples with fibers and 20% for samples without reinforcement due to water plasticizing effect.

Conclusion: Acrylic prosthesis after breaking can be reinforced with different kinds of fibers to prevent further fractures.

Key words: Acrylic resins, Polyethylene, Carbon, Glass fibers, Mechanical properties

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INTRODUCTION

Fracture of denture base resins is of great concern, and many approaches have been used to strengthen acrylic resins. Breaking is often related to the poor fit of denture base, poorly balanced occlusion, problems in the design and manufacturing of the denture, low strength of the repair material, as well as the inherent stress on the denture base, which happens over time [1,2]. Preparation of a new denture is time-consuming and generate additional cost for patients, and denture repair is considered an alternative [3].

Many authors reported that joint between acrylic denture after reparation with self-curing reins, is lower compare to not destroy material. One of attempt commonly known in literature, for increasing mechanical resistance of acrylic resins is incorporation of different kinds of fibers or steel wire [1-8]. Other attempt is using nano- materials (halloysite tubes, silica, titanium dioxide, ceramic) for improvement of mechanical properties [9].

The same approach- reinforcing can be made after breaking the material during normal clinical treatment, when space for glass fiber is created and all denture is repair with self- curing resin [10,11].

Purpose of this study was measuring the effect of 3 fiber strengtheners on the fracture resistance of denture base acrylic resin, after repairing with self- curing material. Impact resistance,

transverse strength, of a heat-polymerized denture base resin, reinforced with single or double bundles of glass, carbon, and polyethylene fibers were studied. Tests were performed in dry and wet conditions. The hypothesis put forward for this study is that the material, after being broken and reinforced with various fibers, will be more resistant than the unreinforced material.

MATERIALS AND METHODS

For the tests following materials were used: Spofacryl (SpofaDental Jicin, Czech Republic, color Z, batch 6473409). This material is denture base materials based on PMMA; liquid contains MMA. After breaking samples were repaired with self- curing resin -Duracyl Plus (SpofaDental Jicin, Czech Republic, color Z, batch 5790419]. Glass fiber ribbons width 2 mm was bought from Krossglas SA (Krosno, Poland). Caron fiber width 2 mm was bough like a commercially product from Dexcraft (Warsaw, Poland). Glass and carbon fiber before using were washed twice with distillate boiling water to remove rests from spinning process. After drying glass fibers were silanized with2% alcoholic solution of trimethoxysil propyl methacrylate (Sigma Aldrich, Katowice- Poland) and dry at 110oC for 12 hours. Polyethylene fiber Construct (Kerr Orange US, lot 5926502) width 2 mmm was used like an example of polyethylene fibers.

Samples preparation

Acrylic resin Spofacryl was mixed according the manufacture instruction (2g powder with 1 ml of liquid). After dough time material was placed in metal forms (65 X 2.5 X 10 mm) pressed between two metal slabs and polymerized in water 30 minutes at 60oC and 1 hour at 100oC. After curing samples were removed from the form and stored in laboratory conditions. Next day they were broken in compressive strength instrument SHIMADZU AGS-G 5kN (Shimadzu, Duisburg, Germany). Two pieces of breaking samples were collected together, and breaking edges were grind with carbide cutter to form 3 mm space for self-curing resin, like a normal laboratory procedure during denture reparation. Round joints were created according Anasane N [11]. For the samples reinforced with fiber, slot for fibers was formed (2.5 X 40 mm) in braking acrylic samples with the same cutter. All cutting surfaced of acrylic resins were wetted with monomer Duracryl for wettability improvement and partially dissolving of repairing parts. Fibers were storage in the glass with monomer during 5 minutes for good soaking. Breaking parts of acrylic resins after grinding and washing with monomer were fixed to metal form (which previously were used for polymerization). Duracryl resins was mixed 2g powder with 1 g of liquid and 3 mm space between two part of sample was filled with this material. Samples of fibers were immersed into the resins in position shown in Figure 1. After 4 minutes when surface of self- curing resins stayed mat metal form was covered with metal slabs and gently pressed by finger to avoid flow out the fibers from the forms. Material was polymerized in hot water 50oC under pressure 0.2 bars during 15 minutes in pressure unite (Zhermapol, Warsaw, Poland). Then the specimens were removed from the forms and the surfaces were finished using 800-, 400- and 200-grit sandpapers.

For testing 8 groups of samples were prepared with 24 pieces for one combination for flexural strength test and for Isolde impact resistance. Totally 192 samples were tested. Following groups of acrylic blocks were created:

A: Heat curing denture base,

B: Heat curing after breaking repair with self-curing resin,

C: Repair and reinforced with 1 glass fiber,

D: With 2 glass fibers (in position like in Figure 1),

E: One polyethylene fiber,

F: Two polyethylene fibers positioned like glass fibers,

G: One carbon fiber,

H: Two carbon fibers.

Each group was divided by two, first part was tested after 24 hours' storage at room temperature. Second group was placed in to distillate water at 37°C during 3 months. One is a week water was changed.

Flexural strength

Three-point flexural test, adopted by international standards for polymer materials, including ISO 1567:1999 Dentistry-Denture base polymers, is the most common technique of measuring flexural properties of denture bases. Strength of acrylic resin, processed and cured

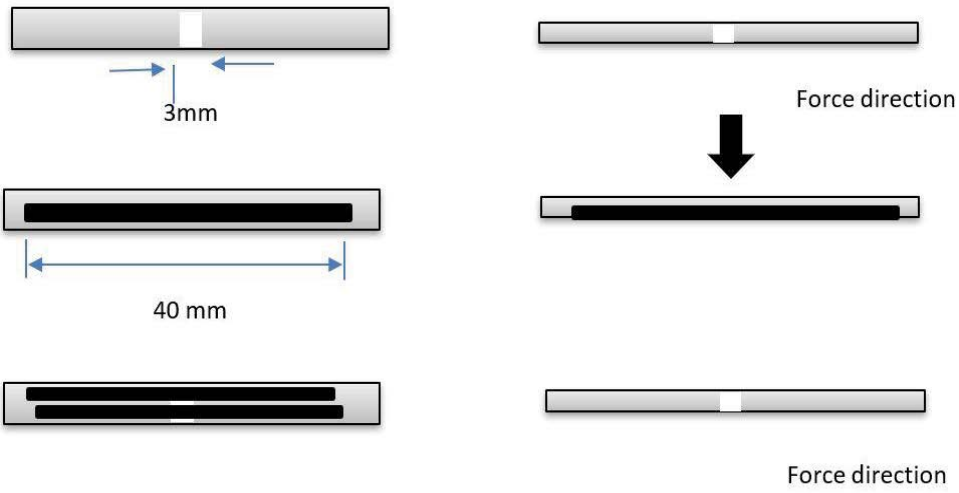

Figure 1: Samples for flexural test. In white place repair with self- curing resin, in black position of fibers.

with any method, should be no less than 65 MPa [12].

Six samples from one group (A-H) were tested on a Shimadzu (AGS 10 kNG) flexural strength instrument. First group of tests were carried out 24 hours after the samples, stored in room temperature before the test, were prepared. Second was repeated after 3 months' storage in distillate water. The rate of the head breaking in the three-point bending test was 5 mm/min. The end of the test was established as the moment when the sample was destroyed.

The flexural strength was determined using following formula:

$$S = \frac{3PI}{2bd^2}$$

Where S is the FS- flexural strength (MPa), P is the load at fracture (N), I- is the distance between the supporting wedges (50 mm), b is the width of the specimen (mm), and d is the thickness of the specimen (mm).

Izold strength

Six samples of each of the compositions (a total of 84 samples) were tested according to Faot and others [13]. First group of tests were carried out 24 hours after the samples, stored in room temperature before the test, were prepared. Second was repeated after 3 months' storage in distillate water.

An impact strength test was performed using a pendulum Charpy-type impact test machine (VEB, Leipzig, Germany). Each specimen was horizontally positioned with 40 mm between the two fixed supports. At room temperature, a drop weight of 0.5 J was applied at the mid-span of the specimen, and the value of the impact strength (kJ/m2) was digitally recorded.

Isolde Impact strength were calculated following formula

$$P = \frac{b * h}{W}$$

Where P is the Izold Impact resistance (kJ/mm2), W is the work at fracture (J), b is the width of the specimen (mm), and h is the thickness of the specimen (mm).

Statistical analyzing

All experiments were performed in triplicate for each parameter, which gives 9 repetitions for each parameter. Data were represented as mean ± standard error of the mean. Data were analyzed by two-way ANOVA (in GraphPad Software Inc., San Diego, CA, USA), with p-value<0.05 as a statistically significant.

RESULTS

Table 1 Izold impact resistance of acrylic samples storage 24 hours at room temperature and 3 months in water at 37oC. Value in kJ/ m^2. Material reinforced with carbon fiber3.97 ± 0.11 in kJ/m^2 is most resistance compare to other fibers (p value<0.1). Samples after breaking and glue with self- curing resins have the impact resistance 50% lower compare to original ones (0.654±0.039 versus 1.232 ± 0.152 kJ/m^2 (p value <0.1)) after 3 months storage in distillate water. This property can be improved by adding different kind of fibers too (glass or polyethylene).

Table 1: Izold impact resistance of acrylic samples storage 24 hours at room temperature and 3 months in water at 37°C. Value in kJ/m².

	After polymerization	After 3 months at 37oC	Confidential level
	Mean ± SD	Mean ± SD	
Superacryl	0.853 ± 0.097	1.232 ± 0.152	p=0.941
Superacryl repair with Duracryl	0.601 ± 0.13	0.654 ± 0.039	p=0.936
Superacryl repair with Duracryl+1 ribbon glass fibers	1.274 ± 0.081	1.184 ± 0.084	p=0.936
Superacryl repair with Duracryl+2 ribbon glass fibers	2.071 ± 0.081	2.194 ± 0.121	p=0.91
Superacryl repair with Duracryl+1 ribbon carbon fibers	3.785 ± 0.083	3.97 ± 0.11	p=0.910
Superacryl repair with Duracryl+2 ribbon carbon fibers	3.97 ± 0.128	4.04 ± 0.104	p=0.910
Superacryl repair with Duracryl+1 ribbon PE fibers	1.41 ± 0.106	1.55 ± 0.059	p=0.910
Superacryl repair with Duracryl+2 ribbon PE fibers	2.142 ± 0.222	2.216 ± 0.184	p=0.910

Table 2: Flexural resistance of acrylic samples storage 24 hours at room temperature and 3 months in water at 37oC. Value in MPa.

	After polymerization	After 3 months at 37oC	Confidential level
	Mean ± SD	mean ± SD	
Superacryl	98.71 ± 2.85	80.64 ± 6.98	p=0.97
Superacryl repair with Duracryl	65.85 ± 3.41	62.7 ± 1.94	p=0.99
Superacryl repair with Duracryl+1 ribbon glass fiber	126.58 ± 6.43	106.1 ± 3.41	p=0.98
Superacryl repair with Duracryl+2 ribbon glass fibers	196.44 ± 6.15	182.43 ± 7.54	p=0.98
Superacryl repair with Duracryl+1 ribbon carbon fibers	106.37 ± 4.04	97.11 ± 5.86	p=0.99
Superacryl repair with Duracryl+2 ribbon carbon fibers	224.25 ± 7.03	206.35 ± 10.64	p=0.99
Superacryl repair with Duracryl+1 ribbon PE fibers	111.18 ± 5.84	108.97 ± 5.08	p=0.979
Superacryl repair with Duracryl+2 ribbon PE fibers	196.3 ± 8.88	181.19 ± 7.4	p=0.99

Table 2 flexural resistance of acrylic samples storage 24 hours at room temperature and 3 months in water at 37oC. Value in MPa. Acrylic resin reinforced with fiber has higher breaking resistance compare to not reinforced material (p value <0.05). Results obtained from polyethylene or carbon fibers are remarkably similar. For example, repair material has flexural strength 62.7 ± 1.94 MPa versus 206.35 ± 10.64 MPa with carbon fibers.

DISCUSSION

The hypothesis put at the beginning was confirmed in the research, because the samples of broken acrylic reinforced with various fibers turned out to be more resistant to breaking from the reference sample. Wolfaardt et al. reported that many different factors affected physical properties of acrylic resin dentures. This can be size and shape denture thickness, different types of denture base materials, and presence of teeth which can influence on the physical and mechanical characteristics of bases during denture processing [14]. Damage in the acrylic resin denture base of removable dentures is one of the most common (64%) causes of repair of dentures [15].

One way to improve mechanical properties of acrylic reins is putting into the material different kinds of fibers: glass, nylon, polyamide, polyethylene (PE), carbon. Results from other investigation shown that not all kinds of fibers have positive effect on the mechanical properties of acrylic resin. One of the biggest factors is possibility of the resins to penetrated inside the fibers and form sufficient chemical bonding between them [1-4].

According to Uzun et al. the highest impact test values were produced by polyethylene-reinforced group, and the lowest values were obtained from specimens containing no fibers. The same author observed that the lowest transverse strength values were obtained for specimens strengthened with polyethylene fibers. Explanation of this result may be a fact that surface of polyethylene fibers used in this work were not subjected to any modification [16].

Plasma treated PE fibers inside poly methyl methacrylate were tested by Ramon and other. They observed increase in fracture strength, and such treated bars also demonstrated resistance to crack propagation. The bars remained in one piece, held together throughout the compression loading by the polyethylene fiber. Results from current study also demonstrate that samples after incorporation of polyethylene fiber have higher flexural strength [7,17].

Special modification of surface, for example silanization for glass fibers for improving

mechanical properties was investigated by Kanie et al. [18]. Flexural strength and deflection in specimens reinforced with silanized glass fiber of 1 mm thickness were significantly higher than those of unreinforced specimens [4,6,]. Similar observations were undertaken for the impact strength in specimens reinforced with silanized glass fiber of 2 mm thickness was significantly higher, than that of unreinforced specimens [7,8]. Ladha et al. reported that specimens reinforced with Stick glass fibers exhibited highest flexural strength followed by those reinforced with Stick Net glass fibers. Nylon fiber reinforcement decreased the flexural strength of acrylic resin. Results from current investigation clearly shown that glass fibers can improve mechano-chemical properties of breaking and glue acrylic resin. This value can be twice bigger comparing to reference samples [2].

All fibers placed parallel to the direction of applied force produced the most favorable combination of increased resistance to bending and to flexural fatigue. But placement of properly oriented fibers that are well centered within the resin samples is technically difficult and yields less predictable property improvements than result from randomly dispersed fibers [2,3]. This phenomenon can explain higher standard deviation between one group of samples with fiber inside, during current investigation.

All the specimens in the eight groups stored under wet conditions showed decrease in flexural strength in comparison to those stored in dry conditions. This is according with other authors observation [1-7]. But samples tested for Isolde impact resistance after 3 months' storage at water obtain better results. This can be easily explained by water plasticizing effect. This improvement is better visible for non-reinforced samples compare to fibers groups. The main limitation of the study is the composition of individual acrylic resins, which may differ from each other. Therefore, it is necessary to optimize the curing cycle and fibers concentration and position inside the denture to obtain material with higher breaking resistance.

CONCLUSION

The reinforcement of breaking denture base resin with pre-impregnated glass fibers or plasma treatment of polyethylene ribbons may be a useful means of strengthening denture bases and protect from future fracture. Carbon fibers also have good strengthening properties, but their use due to black color is clinically limited.

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