

Effect of Silanated and Non-Silanated Glass Fiber on the Impact and Flexural Strength of Acrylic Denture Base

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Abstract

Aim of the Study: The aim of this study was to evaluate the effect of silanated and non-silanated glass fiber on impact and flexural strength of acrylic denture base.

Materials and Methods: A total number of 140 specimens were used in this study. The specimens were divided into three groups, heat cured acrylic resin {HCAR. (20 specimen), HCAR reinforced with glass fiber (60 specimens) and HCAR reinforced with silanated glass fiber (60 specimens)}. Each group (HCAR reinforced with glass fiber and HCAR. reinforced with silanated glass fiber) was divided into three sub-groups according to the percentage of glass fiber incorporation {(5% by weight, 10% by weight and 15% by weight. 60 all)}. Each sub group consists of 10 specimens for each test.

The specimens of wax patterns with different dimensions for every test were prepared as described in the A.D.A. specification No 12 for denture base polymers.

A Charpy's impact testing machine (a pendulum type) (Beijing Jinshengxin Testing Machine Co, Ltd, China) was used in this study for testing the impact strength, Flexural Strength Test: was performed using NEXYGEN from Lloyd Instruments.

Results: Regardless of fiber concentration or silane application, it was found that fiber addition decreased impact and flexural strength mean values significantly. Also, in regardless of fiber concentration, it was found that silane application decreased the flexural and impact strength significantly.

Conclusion: Since glass fiber addition with and without silane coupling agent decreased impact, and flexural strength mean values of the experimental heat-cured acrylic resin significantly, modification of heat-cured acrylic resin with certain amounts of glass fibers, may be time consuming and less value in improving mechanical properties of the heat-cured acrylic denture base.

Keywords: Silanated; Non-Silanated Glass Fiber; Acrylic Denture Base

Introduction

For many years, conventional heat cured acrylic resin was widely used as denture base owing to its easy manipulation, repair and low cost. But it has some disadvantages such as sudden fracture, water sorption and easily stained.

Fracture of conventional heat cured acrylic resin denture base in clinical use may result from a large transitory force caused by an accident or a small force during repeated chewing [1].

Many efforts were done to improve the mechanical properties of heat cured acrylic denture base to improve its resistance to fractures and make it more durable. Among these efforts were by incorporation of different additives to the polymer like glass fibers, metal wires, long carbon fibers, metal powder fillers, and Carbon nanotubes [2].

Reinforcing plastics by glass fiber was found to increase mechanical and physical properties such as high specific strength and stiffness. So that it was used for manufacturing aircraft and spacecraft parts because of their particular mechanical and physical properties. In addition, for fiber reinforced-polymeric composite in the electronic industry, they were employed for producing printed wiring board [3,4].

Silane is a chemical compound with chemical formula SiH_4 . Silanes are used as coupling agents to let glass fibers adhere to a polymer matrix and stabilizing the composite material. Silane coupling agents may reduce the number of cellulose hydroxyl groups in the fiber matrix interface [5].

Silane coupling agents were also found to be effective in modifying natural fiber-polymer matrix interface and increasing the interfacial strength [6].

This *in vitro* study was done to evaluate the effect on impact and flexural strength of heat cured acrylic resin after reinforcing with silanated and non silanated glass fibers with percentages 5%, 10% and 15% by volume.

Aim of the Study

The aim of this study was to evaluate the effect of silanated and non-silanated glass fiber on impact and flexural strength of acrylic denture base.

Materials and Methods

A controlled experimental study was carried out in the laboratory of the Prosthodontics Department Faculty of Dental Medicine Al Azhar University, Cairo, Egypt. A total number of 140 specimens were used in this study. The specimens were divided into three groups, heat cured acrylic resin {HCAR (20 specimen), HCAR reinforced with glass fiber (60 specimens) and HCAR reinforced with silanated glass fiber (60 specimens)}. Each group (HCAR reinforced with glass fiber and HCAR reinforced with silanated glass fiber) was divided into three sub-groups according to the percentage of glass fiber incorporation {(5% by weight, 10% by weight and 15% by weight. 60 all)}. Each sub group consists of 10 specimens for each test.

Group I: (Control group) 20 specimens conventional heat cured acrylic resin, 10 specimens was used for flexural strength test and 10 specimens for the impact strength test.

Group II: Conventional heat cured acrylic resin with non-silanated glass fibers. It consisted of 60 specimens and divided into three sub groups:

- **Sub group A:** 5% glass fibers. 10 specimens for flexural strength test and 10 specimens for the impact strength test.
- **Sub group B:** 10% glass fibers. 10 specimens for flexural strength test and 10 specimens for the impact strength test.
- **Sub group C:** 15% glass fibers. 10 specimens for flexural strength test and 10 specimens for the impact strength test.

Group III: Conventional heat cured acrylic resin with silanated glass fibers. It consisted of 60 specimens and divided into three sub-groups:

- **Sub group A:** 5% glass fibers with silane coupling agent: 10 specimens for flexural strength test and 10 specimens for the impact strength test.
- **Sub group B:** 10% glass fibers with silane coupling agent: 10 specimens for flexural strength test and 10 specimens for the impact strength test.
- **Sub group C:** 15% glass fibers with silane coupling agent: 10 specimens for flexural strength test and 10 specimens for the impact strength test.

Preparation of glass fibers

The glass fiber was supplied in long strands (50 mm length) made of strong and flexible thread fibers which had a nominal diameter of 10 μm . Glass fiber was cut into a short 6 mm length by using microtome (Rotary microtome) also called Minot microtome. Melter electric balance was used to weight the glass fiber in relation to the acrylic powder [7].

Glass fiber was added to acrylic powder by three percentage 5%, 10%, and 15% ratio of the powder weight. The desired weight of fibers was first mixed with a predetermined volume of methyl methacrylate liquid, and then the required weight of powder was added to the mix of liquid with glass fiber and stirred until the fibers were randomly oriented to give isotropic properties with the polymer.

The groups to which silanated glass fibers were added; silane coupling agent was added to the methyl methacrylate liquid and mixed with each other.

Preparation of the specimens**Group I (Control group)**

Wax patterns with different dimensions for every test were prepared as described in the A.D.A. specification No 12 for denture base polymers [8].

According to ISO 1567: 1999 (E), specimen with dimensions 80 mm length, 10 mm width and 4 mm thickness with a notch in the middle of the specimen with 2 mm width were used for testing impact strength. Specimens with dimensions of 65 mm length, 10 mm width and 2.5 mm thickness were used for testing flexural strength.

According to the manufacturer's instructions wax specimens were flaked; heat cured acrylic resin packed, deflaked, finished and polished. All specimens were stored in distilled water at 37°C for 24 hrs before testing.

Group II (Conventional heat cured acrylic resin with glass fibers only)

Glass fibers were added to acrylic powder by three percentage 5%, 10%, and 15% ratio of the powder weight. The desired weight of fibers was first mixed with a predetermined volume of methyl methacrylate liquid, and then the required weight of powder was added to the mix of liquid with glass fiber and stirred until the fibers were randomly oriented to give isotropic properties with the polymer then packed into the mold then deflaked, finished and polished.

Group III (Conventional heat cured acrylic resin with glass fibers and silane coupling agent)

Specimens were prepared like that for group II in addition that silane coupling agent was added to the methyl methacrylate liquid. Triethoxy vinyl silane (5 wt %) was dissolved in a 95:5 (wt) ethanol: water mixture.

Impact strength test

A Charpy's impact testing machine (a pendulum type) (Beijing Jinshengxin Testing Machine Co, Ltd, China) was used in this study for testing the impact strength, and joules were used for recording the amount of energy absorbed up to the fracture. The specimen was supported horizontally, and the pendulum was adjusted to zero line, and the specimen was then struck by the hammer at the mid span on the opposite side to the groove, and the value for impact strength by joules was directly recorded from the scale. Impact strength = energy absorbed/(width x thickness).

Flexural strength test

This test was performed using NEXYGEN from Lloyd Instruments. Specimens were free of porosity, used for the 3-point bending tests. The specimen strips were removed from water storage, and the flat surface immediately laid on the supports of the flexural testing (50 mm span) device and loaded using the universal testing machine. (Model LRX plus, Lloyd, Ametec instruments. Fareham, England), at a crosshead speed of 5 mm/min. The recording of the measuring results ended when the samples fractured.

Flexural strength (σ) was calculated from

$$\sigma = \frac{3 F l}{2 b h^2}$$

Where F is the load (force) at the fracture point (N), L is the length, (b) is width and (h) is the thickness of the specimen [9].

Data analysis was performed in several steps. Initially, descriptive statistics for each group results. One way ANOVA followed by pair-wise Tukey’s post-hoc tests were performed to detect significance between subgroups. Three-factor analysis of variance ANOVA test of significance was performed to detect significance between variables affecting mean values (fiber, concentration, and silane). Statistical analysis was performed using Asistat 7.6 statistics software for Windows (Campina Grande, Paraiba state, Brazil). P values ≤ 0.05 are considered to be statistically significant in all tests.

Results

Impact strength

Descriptive statistics showing mean values, standard deviations (SD) for impact strength measured in (J) recorded for fiber reinforced groups and control groups are summarized in table 1.

Variables			Mean \pm SD	ANOVA	
F			P value		
Fiber reinforced experimental groups	5%	Non- Silanated	139.58 \pm 0.938	13.93	< .0001*
		Silanated	138.67 \pm 3.19		
	10%	Non- Silanated	137.84 \pm 1.60		
		Silanated	136.15 \pm 2.56		
	15%	Non- Silanated	135.86 \pm 1.93		
		Silanated	135.42 \pm 1.67		
Control group			139.98 \pm 0.69		

Table 1: Comparison of impact strength results (Mean values \pm SD) between fiber reinforced experimental and control groups* significant ($p < 0.05$).

From the data shown in the table 1: we noted that the highest impact strength was recorded for the control group (139.98 \pm 0.69), followed by non-silanated 5% fiber reinforced group (139.58 \pm 0.938), followed by silanated 5% fiber reinforced group (138.67 \pm 3.19). For non-silanated 10%, fiber reinforced group (137.84 \pm 1.60), followed by silanated 10% fiber reinforced group (136.15 \pm 2.56). For non-silanated 15%, fiber reinforced group (135.86 \pm 1.93), while the lowest impact strength mean value was recorded for silanated 15% fiber reinforced group (135.42 \pm 1.67).

The difference between fiber reinforced groups and control groups was statistically significant as indicated by the one-way ANOVA test (F = 13.93, p value = < 0.0001 < 0.05).

Pair-wise Tukey’s post-hoc tests showed non-significant difference between 5% fiber reinforced subgroup (non-silanated and silanated), (control and 5% fiber reinforced subgroups), (control and silanated 10% fiber reinforced subgroup), (15% fiber reinforced subgroup (non-silanated and silanated), (control and 15% fiber reinforced subgroups). The difference between silanated 10% fiber reinforced

subgroup and other fiber reinforced subgroups or control group was statistically significant. The difference between silanated 15% fiber reinforced subgroup and other fiber reinforced subgroups or control group was statistically significant.

Flexural strength

Descriptive statistics showing mean values, standard deviations (SD) for flexure strength measured in (MPa) recorded for fiber reinforced groups and control groups are summarized in table 2.

Variables			Mean \pm SD	ANOVA	
F			P value		
Fiber reinforced experimental groups	5%	Non-Silanated	46.62 \pm 10.9	51.3	0.001*
		Silanated	57.08 \pm 15.2		
	10%	Non-Silanated	57.49 \pm 14.0		
		Silanated	58.05 \pm 11.5		
	15%	Non-Silanated	58.06 \pm 28.7		
		Silanated	59.07 \pm 24.2		
Control group			68.0 \pm 15.8		

Table 2: Comparison of flexural strength results (Mean values \pm SD) between fiber reinforced experimental and control groups* significant ($p < 0.05$).

From the data shown in the table 2, we noted that the highest flexural strength mean value was recorded for the control group (68.0 \pm 15.8), then silanated 15% fiber reinforced group (59.07 \pm 24.2) followed by non-silanated 15% fiber reinforced group (58.06 \pm 28.7). Then for silanated 10% fiber reinforced group (58.05 \pm 11.5) then non-silanated 10% fiber reinforced group (57.49 \pm 14.0). Then for silanated 5% fiber reinforced group (57.08 \pm 15.2). While the lowest flexural strength mean value was recorded for non-silanated 5% fiber reinforced group mean value (46.62 \pm 10.9).

The difference between fiber reinforced experimental and control groups were statistically significant as indicated by the one-way ANOVA test ($F = 51.3$, $p \text{ value} = < 0.0001 < 0.05$). Pair-wise Tukey's post-hoc tests showed non-significant ($p > 0.05$) difference between 15% fiber reinforced subgroup (non-silanated and silanated), 10% fiber reinforced subgroup (non-silanated and silanated), (5% fiber reinforced silanated and 10% fiber reinforced subgroups) while the difference between non-silanated 5% fiber reinforced subgroup and other fiber reinforced subgroups or control group was statistically significant.

Discussion

Improvement of mechanical properties of heat cured acrylic denture base was studied by reinforcing it with glass fibers [3,4].

The incorporation of glass fibers to heat cured acrylic denture base was limited to 20% due to the deleterious effects on the dough properties above this percentage, in this study three percentages 5%, 10% and 15% were used [10].

Adequate adhesion of the glass fibers to the polymer is the most important variable for the strength of the composite so that stresses can be transferred from the matrix to the fibers. The silane coupling agent can be used to improve the adhesion. Effective impregnation allows the resin matrix to come into contact with the surface of every fiber and thus bonding is improved [11].

Regardless of fiber concentration or silane application, it was found that fiber addition decreased impact and flexural strength mean values significantly. These findings could be explained as the high fiber content might affect the bond strength between the reinforcing material and the denture base [12].

These results come in agree with Valittu [13] who found that unsilanized glass fiber has decreased the flexural strength of acrylic denture base and explained this result by the poor adhesion between the glass fibers and acrylic resin matrix.

Irrespective of silane application, the addition of 15% fiber recorded significantly lower impact strength mean values than 5% and 10% fiber addition. Addition of 5% glass fiber decreased impact strength mean values non-significantly, while the reduction by 10% fiber addition is significant. Also, it was noted that 5% fiber addition recorded significantly higher impact strength mean values than 10% and 15% glass fiber additions.

Regardless of fiber concentration, it was found that silane application decreased the impact strength significantly. Also, it was noted that silanated fiber recorded non-significantly lower impact strength mean values than non-silanated one. These findings could be explained as the microscope image analysis showed the existence of voids between glass fibers and polymer matrix and partial bonding between glass fibers and polymer material [14].

Irrespective of silane application, it was found that 5% fiber addition decreased flexural strength mean values significantly; it was noted that 10% fiber addition recorded significantly higher flexural strength mean values than 5% fiber addition. Also, it was noted that 15% fiber addition recorded higher flexural strength mean values than 10% fiber addition. These findings could be explained as shown by Kaine [15], who noted that in early stages of flexural test, the lower surface of the test specimen lengthens slightly but the inner glass fiber does not change. Therefore, the flexural modulus measured at this point is not influenced by the quality of glass fiber.

Regardless of fiber concentration, it was found that silane application decreased the flexural strength significantly. Also, it was noted that silanated fiber recorded significantly higher flexural strength mean values than non-silanated one. The results of this study come in agree with the study done by Anasane N, Ahirrao Y, Chitnis D, Meshram S. They studied the effect of joint surface contours and glass fiber reinforcement on the transverse strength of repaired acrylic resin they reported that the addition of glass fibers showed a decrease in the transverse strength of repaired acrylic resin [16].

On the other hand, the results of this study disagree with the findings reported by Smith. Agha H, Flinton R, Vaidyanathan T and Valittu., *et al.* who shown improvement in mechanical properties after reinforcement by discrete glass fibers in the resin [17,18].

Conclusion

Since glass fiber addition with and without silane coupling agent decreased impact, and flexural strength mean values of the experimental heat-cured acrylic resin significantly, modification of heat-cured acrylic resin with certain amounts of glass fibers, may be time consuming and less value in improving mechanical properties of the heat-cured acrylic denture base.

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