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Reinforcement of Heat Cured Denture Base Material with Combination of Silanized Polyamide and Polyester Fibers and its Effect on Some Mechanical Properties

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ABSTRACT

Introduction: *Poly (methyl methacrylate) has several disadvantages (poor mechanical properties) like impact and transverse strength. In order to overcome these disadvantages, several methods were used to strengthen the acrylic resin by using different fibers or fillers. This study was conducted to evaluate the effect of treatment fiber on the mechanical properties of poly (methyl methacrylate) denture base material.* ***Materials and methods:*** *Specimens were prepared from polymethyl metha acrylic (PMMA), which was divided into 4 groups based on the presence of fiber (first group without fiber as control group, second group with salinized polyester fibers, third group with salinized polyamide fibers and fourth group combination of salinized polyester and salinized polyamide fibers).* ***Results:*** *The results show that the highest mean values for all tests included in the study appeared in Group IV (combination of salinized polyester and salinized polyamide fibers) except for the surface roughness test the highest mean values were found in Group III (salinized treated polyamide fibers), and only polyamide fiber slight improved roughness and other groups have no effect on surface roughness.* ***Conclusion:*** *The addition of salinized treated fiber (polyester, polyamide, and combination of both fiber) improve transverse, impact strength and hardness properties of denture base material and has no effect on the surface roughness.*

Keywords: Polyester, Polyamide, Methyl methacrylate, Impact strength

INTRODUCTION

Heat cured acrylic resin is the material of choice in the construction of dental prosthesis (complete and partial denture) because of its biocompatibility and natural appearance [1]. According to its weakness in some mechanical properties like transverse, impact or tensile strength [2], researchers attempt to overcome this weakness by adding several materials like powders or fibers [3]. The selection of fibers used must be not interfering with esthetic and appearance [4]. Several studies used polyester fibers alone or in combination with other fibers like polypropylene fibers due to its good esthetics [5]. The salinization procedure used in order to make the fibers in good attachment with acrylic matrix [6]. The use of polyamide fibers will increase the strength of heat cured acrylic resin (transverse strength), especially when used with another fiber like aramid or glass fibers [7]. The addition of polyamide or polyester fibers without chemical treatment revealed a poor adhesion between the acrylic matrix and the fibers [8]. In this study, we used 3 groups of heat cured acrylic resin (first group without fibers, a second group with salinated polyester fibers and a third group with a combination of salinated polyester and polyamide fibers).

PATIENTS AND METHODS

Surface modification was done by adding trimethoxysilyl propyl methacrylate (TMSPM) to two types of fiber (polyamide, polyester) and following the procedure by use of probesonicated apparatus, 30 g of fiber was added to 200 ml of pure ethanol in bucker for 20 minutes than by using a sterile syringe, silane was added dropwise (TMSPM) (1.5 g 5% wl to nanofiller) under rapid stirrer. After removal from the stirrer, buker was covered with parafilm and was left for 2 days.

After 2 days the parafilm and ethanol (solvent) were removed by the use of a rotary evaporator for 30 min, 600°C at 150 rpm. Then it was dried for 20 hours at 60°C in a vacuum oven for each test, and by using laser cutting machine

plastic patterns were constructed with shape and dimension according to ISO. By weighting 0.5%, 1% and 1.5%, both polyester and polyamide fiber was added to acrylic cure.

After mixing monomer with a mixture of powder and fiber, put in a mold which was previously prepared for each test, after lubricating the mold with separated media press it under pressure for 5 min by the use of hydrolytic press.

Transverse Strength Testing

Specimen design: The specimens were prepared with dimensions (65 mm × 10 mm × 2.5 mm) according to ADA specification, No.12, 1999. All specimens were immersed in distilled water for 48 hours before testing (ADA specification, No.12, 1999).

Testing procedure: Test was performed using a universal Instron testing machine, each specimen was positioned on the testing fixture which consisted of two parallel supports 50 mm apart, the load was applied with a crosshead speed of 1 mm/min by a rod placed centrally between the supports making deflection until a fracture occurs.

Impact Strength Testing

Specimen design: The specimens were prepared with dimensions of 80 mm × 10 mm × 2.5 mm according to ISO, 179-1. All specimens were immersed in distilled water for 48 hours before testing (ADA specification, No.12, 1999). The type of the test is unnotched Charpy for impact strength test.

Testing procedure: Test was performed using an impact testing machine following the procedure is given by ISO, 179, where specimen was supported horizontally at the ends and was struck by a free-swinging pendulum (two joules capacity), a scale was used to register the impact energy absorbed by the specimen when fracture occurs.

Surface Hardness Testing

Specimen design: The specimens were prepared with dimensions of 65 mm × 10 mm × 2.5 mm according to ADA specification, No.12, 1999. All specimens were immersed in distilled water for 48 hours before testing (ADA specification, No.12, 1999).

Testing procedure: Test was performed using durometer hardness tester (shore D hardness) according to ANSI/ADA specification, 1999, which consisted of a bluntly pointed indenter; measurements were recorded from a digital scale for the shore D hardness.

Surface roughness tests

Test specimens: Specimens with a dimension of 65 mm × 10 mm × 2.5 mm were prepared to be used for surface roughness test. All specimens were immersed in distilled water at 37°C for 48 hours before being tested (ADA specification No.12, 1999).

Test equipment and procedure: The Profilometer device (surface roughness tester) was used to study the effect of fibers reinforcement on the micro-geometry of the test surface and this device has surface analyze (sharp stylus made from diamond) to trace the profile of the surface irregularities. Maximum distance can be move to 11 mm.

RESULTS

The descriptive statistics shown in Table 1 revealed that the highest mean values for all tests included in the study assigned to Group III (combination of silanated polyester and silanated polyamide fibers) except for the surface roughness test the highest mean values found in Group I (silanated polyamide fibers) (Figure 1).

Table 1 Descriptive statistical analysis for all tests and groups

Variable		N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Surface Roughness	Control	10	3.3704	0.80747	2.7928	3.948	2.39	4.66
	Group I	10	3.5611	0.8421	2.9587	4.1635	2.68	5.84
	Group II	10	3.0833	0.72714	2.5631	3.6035	2.35	4.28
	Group III	10	2.6553	0.32211	2.4249	2.8857	2.2	3

Surface Hardness	Control	10	81.35	1.49015	80.284	82.416	79.3	83.6
	Group I	10	78.13	1.09347	77.3478	78.9122	76.3	79.8
	Group II	10	77.41	0.71095	76.9014	77.9186	76.3	78.4
	Group III	10	82.14	1.84704	80.8187	83.4613	79.6	84.7
Transverse strength (N/mm^2)	Control	10	93.302	2.22781	91.7083	94.8957	90.1	98.02
	Group I	10	91.823	2.53268	90.0112	93.6348	87.17	95.4
	Group II	10	91.744	2.43954	89.9989	93.4891	87.48	95.78
	Group III	10	93.429	1.30332	92.4967	94.3613	92.1	95.8
Impact Strength (Kj/m^2)	Control	10	8.241	0.61472	7.8013	8.6807	7.26	9.3
	Group I	10	8.749	0.84032	8.1479	9.3501	7.7	10.57
	Group II	10	8.282	1.11212	7.4864	9.0776	6.31	9.96
	Group III	10	10.653	0.64629	10.1907	11.1153	9.78	11.7

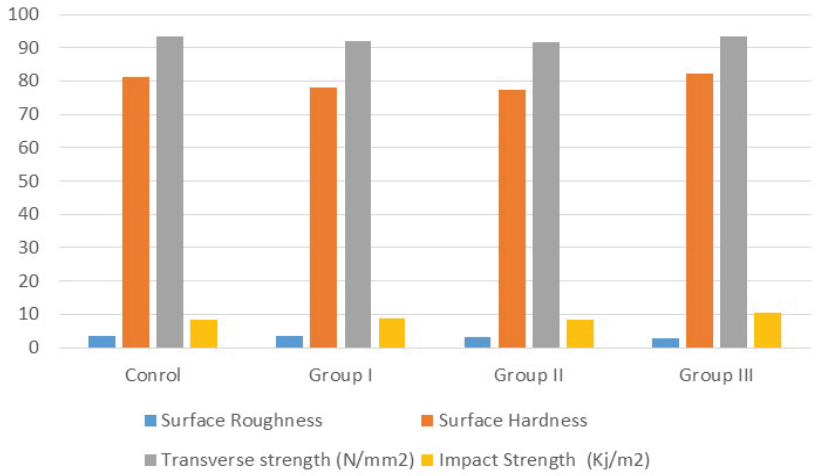

Figure 1 Bar chart plot for mean values for all groups in each test

When applying ANOVA table with multiple comparison least significant difference test (LSD) to compare the mean values for each test, there was highly significant difference between and within the groups for surface hardness and impact strength test ($p<0.01$), while significant differences were found between and among groups compared to surface roughness test and no significant difference was obtained for transverse strength ($p=0.172$) (Tables 2 and 3).

Table 2 ANOVA table for all tests

Variable		Sum of Squares	df	Mean Square	F	Sig.
Surface Roughness	Between Groups	4.655	3	1.552	3.113	Sig.
	Within Groups	17.943	36	0.498	-	-
	Total	22.598	39	-	-	-
Surface Hardness	Between Groups	163.719	3	54.573	29.767	H.S
	Within Groups	65.999	36	1.833	-	-
	Total	229.718	39	-	-	-
Transverse strength (N/ mm2)	Between Groups	25.139	3	8.38	1.762	0.172
	Within Groups	171.249	36	4.757	-	-
	Total	196.388	39	-	-	-
Impact Strength (Kj/m2)	Between Groups	38.856	3	12.952	18.918	H.S
	Within Groups	24.647	36	0.685	-	-
	Total	63.503	39	-	-	-

Table 3 LSD multiple comparisons among all groups for each test

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Surface Roughness	Control	Group I	-0.1907	0.31572	0.55	-0.831	0.4496
		Group II	0.2871	0.31572	0.369	-0.3532	0.9274
		Group III	.71510*	0.31572	Sig.	0.0748	1.3554
	Group I	Group II	0.4778	0.31572	0.139	-0.1625	1.1181
		Group III	.90580*	0.31572	Sig.	0.2655	1.5461
	Group II	Group III	0.428	0.31572	0.184	-0.2123	1.0683
Surface Hardness	Control	Group I	3.22000*	0.60553	H.S	1.9919	4.4481
		Group II	3.94000*	0.60553	H.S	2.7119	5.1681
		Group III	-0.79	0.60553	0.2	-2.0181	0.4381
	Group I	Group II	0.72	0.60553	0.242	-0.5081	1.9481
		Group III	-4.01000*	0.60553	H.S	-5.2381	-2.7819
	Group II	Group III	-4.73000*	0.60553	H.S	-5.9581	-3.5019
Transverse strength (N/mm^2)	Control	Group I	1.479	0.97539	0.138	-0.4992	3.4572
		Group II	1.558	0.97539	0.119	-0.4202	3.5362
		Group III	-0.127	0.97539	0.897	-2.1052	1.8512
	Group I	Group II	0.079	0.97539	0.936	-1.8992	2.0572
		Group III	-1.606	0.97539	0.108	-3.5842	0.3722
	Group II	Group III	-1.685	0.97539	0.093	-3.6632	0.2932
Impact Strength (Kj/m^2)	Control	Group I	-0.508	0.37004	0.178	-1.2585	0.2425
		Group II	-0.041	0.37004	0.912	-0.7915	0.7095
		Group III	-2.41200*	0.37004	H.S	-3.1625	-1.6615
	Group I	Group II	0.467	0.37004	0.215	-0.2835	1.2175
		Group III	-1.90400*	0.37004	H.S	-2.6545	-1.1535
	Group II	Group III	-2.37100*	0.37004	H.S	-3.1215	-1.6205

DISCUSSION

On using a heat cured acrylic resin as a denture base material, it is important to improve its mechanical properties (impact and transverse strength) to withstand the functional and masticatory forces [9]. The addition of fibers either polyester or polyamide after the chemical treatment (salinization) leads to improve the mechanical properties which are important to avoid breakage of the denture extra orally and avoiding fatigue phenomena intraorally [10].

In surface roughness test, the results showed a significant increase in surface roughness mean value (3.56) in Group I (silanated polyamide fibers group) in comparison to other groups, this can be explained by accumulation of a large number of polyamide fibers near the surface of the samples due to its low weight [11,12]. According to the results, the Group III (combination of salinated polyamide and polyester fibers) showed us a least mean value (2.65) which represents a significant decrease in the surface roughness; this can be explained due to well distribution of the 2 mixed fibers between the polymer matrixes [13].

For hardness test the higher value (82.14) for the Group III represents a highly significant difference due to the location of these fibers near the surface, also the treatment (silanization) will increase the interfacial bonding between fibers and acrylic matrix, this comes in agreement with Ahmed and Wel [14-16]. On the other hand, the hardness values between the control group and Group (I and II) (81.3 for control, 78.1 for Group I and 77.4 for Group II) showed a significant decrease of the values, this may be related to the less effect of the single type of the fibers either polyester or polyamide fibers as compared to third group effect on hardness statistically significant but clinically non-significant.

For transverse strength test which showed a non-significant difference between groups (p=0.172) this may be related to non-organized distribution of the fibers incorporated (either polyester or polyamide) due to the technical difficulties in ensuring parallel alignment of the fibers to the surface of the samples leading to produce effective result [17]. These results disagree with Unalan, et al., who studied the reinforcing effect of different types and concentrations of E-glass fibres on the transverse strength of denture base material and found that addition of chopped strand mat glass fibre was the most effective method to improve the transverse strength of PMMA denture base resin [18].

In the impact strength test, the results showed a highly significant increase (mean value=10.653) in the third group, this can be explained by a good adhesion between these fibers and the resin matrix due to the surface fiber treatment leading to good interfacial bonding between resin matrix and fibers, so lead to prevent the propagation of cracks and the stress is transferring from the matrix to fibers [19]. On the other hand, the results showed us non-significant differences in impact strength mean values between control group, the first and second group may be related to the poor interfacial adhesion between these single fibers and the resin matrix, these results disagreed with Fatihallah, et al., [20].

CONCLUSION

The addition of salinized treated fiber (polyester, polyamide, and combination of both fiber) improve transverse, impact strength and hardness properties of denture base material and has no effect on surface roughness.

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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