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Effects of Mica and Glass on Surface Hardness of Acrylic Tooth Material

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The purpose of this study was to evaluate the effects of four different ratios of silanized mica filler and milled glass fiber on the surface hardness of an acrylic denture tooth material. Acrylic resin disks made of polymethyl methacrylate (PMMA) used in fabrication of denture teeth were used as the control group. Eight test groups were prepared by adding a ratio of 5%, 10%, 15%, or 20% by weight of silane-treated mica filler or milled glass fibers to the PMMA resin of denture teeth. Surface hardness test was performed for each group. There were statistically significant differences in surface hardness between the control group and 5%, 10%, and 15% mica- and glass-containing test groups ($p<0.05$). It was determined that addition of 5%, 10%, and 15% of silane-treated mica filler or silane-treated milled glass fiber to the PMMA resin of denture teeth resulted in significantly improved surface hardness.

Keywords: Acrylic denture teeth, Surface hardness, Fillers

INTRODUCTION

Plastic teeth are prepared from acrylic and modified acrylic materials similar to denture plastics. However, the mechanical properties — such as compressive strength, abrasion resistance, elastic modulus, elastic limit, and hardness — of acrylics are low when compared with other restorative materials. On this account, the softness and low abrasion resistance of plastic teeth may be unfavorably cited as a disadvantage, because the teeth are more easily abraded and hence the occlusal vertical dimension of the denture may be altered[1].

For long-term use of prostheses, a key consideration is the adequate mechanical properties of artificial tooth materials. To date, many studies have reported on the influence of various reinforcement materials on different mechanical properties of acrylic resins[2-12]. Indeed, to improve the mechanical properties of acrylic resins, different types of materials have been added to the polymer materials — namely, carbon fibers[2,3], polyaramid fibers[3], glass fibers[3-7], polyethylene fibers[8-10], Kevlar fibers[7,11], and mica fillers[12]. Although many studies[13-17] have been carried out on fiber-reinforced plastic to improve the mechanical properties of acrylic resins, they have been hampered by difficulties in overcoming problems of esthetics and manipulation, and thus have not gained popularity. Polyethylene and Kevlar fibers have been used as strengtheners in roved or chopped strands, or in mat form, but none of these formats have found favor for clinical use[18,19]. As for carbon fibers, they are not popular for clinical use because the black color of the fibers poses many esthetic problems[7].

In terms of reinforcement fillers, the most common micas (one kind of silicate sheet) are biotite and muscovite (which are mainly aluminum silicate minerals) and they typically exhibit an intermediate Mohs hardness (2.5−3)[20]. Mica has been used as a filler for plastics due to its low cost, easy availability, and outstanding electrical, thermal, and chemical resistance characteristics. It is also transparent, flexible and elastic, and can be ground to very fine particles with a high aspect ratio[20]. Although mica has an intermediate Mohs hardness, its broad particle size distribution and surface treatment effect are believed to contribute substantially to abrasion resistance. In terms of handling and manipulation, extra benefits include easy achievement of mold details, easy removal of molding material, as well as high solvent resistance due to the platelet nature of mica — giving rise to lower viscosity and restricted diffusion of solvent molecules in layers[20]. To enhance the adhesion of inorganic filler particles to the matrix base of composite tooth materials, these particles are typically subjected to a silane-coupling treatment.

As for glass fibers in chopped form, they have received the attention of several researchers. This is largely due to their potentially simple incorporation technique into the resins, and in particular their adaptability to the polymethyl methacrylate (PMMA) resin[19].

In the present study, we sought to improve the surface hardness of the PMMA resin of denture teeth. To this end, the preferred additive choices of mica filler and glass fiber were added to this material. Four different ratios of silanized mica filler and milled glass fiber were employed, and the aim of this study was to evaluate their effects on the surface hardness of an acrylic denture tooth material.

MATERIALS AND METHODS

Test materials

Acrylic resin disks made of polymethyl methacrylate (PMMA) (Samet, Ruthinium Dental Manufacturing, Italy), which is used in the fabrication of denture teeth, were prepared according to manufacturer's instructions. These specimens were used as the control group. Test groups were modified from the control group's PMMA material by adding four different ratios (5%, 10%, 15%, 20%) of silane-treated mica filler and four different ratios (5%, 10%, 15%, 20%) of silane-treated milled glass fibers by weight. As a result, one control and eight experimental groups were obtained (Table 1). Each group consisted of seven samples. The dimensions of each sample were 16 mm in diameter and 7 mm in thickness.

For the silane-treated muscovite mica filler (DYO Boya Fabrikalari Sanayii ve Ticaret A.Ş., İzmir, Turkey) used in this study, its physical properties were as follows: *ca.* 32 μm in particle size, 2.7 g/cm^3 in density, and 2.5 in Mohs hardness. As for the silane-treated milled E-glass fibers (Cam Elyaf A.Ş., Çayırova, Turkey), the physical properties were as follows: 32 μm in particle size, 1.2 μm in diameter, 0.8 mm in length, 2.54 g/cm^3 in density, and 6.5 in Mohs hardness.

The silane coupling agent used in this study, A-174 (Union Carbide Corp., Danbury, UK), contained 3-methacryloxypropyl trimethoxysilane (3-MPS). It was added to a solution of distilled water and ethanol (20% of distilled water by weight) previously adjusted to pH 5.5. The mixture was stirred with a high shear mixer for one hour, and then filtered on a Buncher filter. Treated mica fillers and glass fibers were then dried at 120℃ for 24 hours[20].

Table 1 Contents of control group and test groups

Group	Content
Control group	PMMA
Test group 1	5% mica filler-added PMMA
Test group 2	10% mica filler-added PMMA
Test group 3	15% mica filler-added PMMA
Test group 4	20% mica filler-added PMMA
Test group 5	5% glass fiber-added PMMA
Test group 6	10% glass fiber-added PMMA
Test group 7	15% glass fiber-added PMMA
Test group 8	20% glass fiber-added PMMA

PMMA: Polymethyl methacrylate

Specimen preparation

Control group specimens were prepared in a powder/liquid (P/L) ratio of 20 g to 10 ml according to manufacturer's recommendations. To incorporate mica into PMMA material, the P/L ratio was decreased to 20 g/14 ml. This modified P/L ratio was employed to ensure better impregnation of the mica filler. For the impregnation of glass fibers, it was not necessary to change the control group's P/L ratio.

To modify PMMA, the total weight of powder and liquid (wt powder + wt liquid) was first calculated, and then 5%, 10%, 15%, and 20% of this value was determined. Accordingly then, the four different ratios of additives were added to the predetermined weight of PMMA powder and mixed thoroughly. Hence, eight groups of test samples were obtained containing 5%, 10%, 15%, and 20% of mica and glass.

Glass fibers and mica fillers were incorporated with no spatial orientation into the acrylic resin powder at concentrations of 5, 10, 15, and 20% (w/w), stirring by hand in the same direction for one minute. Methyl methacrylate (MMA) liquid was added to the mixture and stirred so that the additives were randomly oriented to give isotropic properties to the composites. Flasked acrylic resin dough was polymerized at 175℃ under a pressure of 160 bar for three minutes (Elimko 2200 Hydrocontrol Machine, Ankara, Turkey), and then cooled with water under a pressure of 160 bar for three minutes according to manufacturer's instructions. The specimens were carefully removed, and the surfaces of the specimens were finished with up to 1200-grit silicon carbide paper with running water as the coolant.

Surface hardness test

Surface hardness was tested using Shore D hardness test. All specimens were stored in distilled water in a thermostatically controlled water bath (M96K Water Bath, Elektromag, Turkey) at 37℃ for a week and then tested. Surface hardness measurements were obtained for all specimens with a Shore D hardness tester (Harteprüfer, Schleicher, Germany). A 5-kg load was applied for 15 seconds by a cone-shaped indenter. Three indentations were made and measured at different points on each specimen, and the average value determined.

Statistical analysis

Statistical calculations were performed with GraphPad Prisma V.3 program for Windows. In the

comparison of glass-containing groups of different ratios *versus* the control group, and likewise for mica-containing groups *versus* the control group, Kruskal—Wallis test followed by Dunn's multiple comparison test were used. Besides, Mann—Whitney U test was used to compare glass and mica of the same percentage between the two additive test groups. Statistical significance level was set at $p<0.05$.

RESULTS

Table 2 shows the average hardness values and standard deviations of the control group and glass- and mica-added test groups.

Table 2 Surface hardness values of mica- and glass-added PMMA

	Hardness value (mean±SD)		MWp-value
	Mica	Glass	
Control	68.6 ± 1.9	68.6 ± 1.9	—
5%	75.7 ± 1.2	77.3 ± 1.7	0.072
10%	77.3 ± 2.0	77.1 ± 2.8	0.535
15%	74.7 ± 2.5	75.8 ± 1.4	0.455
20%	74.2 ± 2.5	74.6 ± 2.0	0.901
KWp-value	0.0004	0.0003	—

MW : Mann—Whitney U test
KW : Kruskal—Wallis test

Table 3 Results of Dunn's multiple comparison test

Comparison group	Mica	Glass
Control - 5%	P < 0.05	P < 0.001
Control - 10%	P < 0.001	P < 0.001
Control - 15%	P < 0.05	P < 0.05
Control - 20%	P > 0.05	P > 0.05
5% - 10%	P > 0.05	P > 0.05
5% - 15%	P > 0.05	P > 0.05
5% - 20%	P > 0.05	P > 0.05
10% - 15%	P > 0.05	P > 0.05
10% - 20%	P > 0.05	P > 0.05
15% - 20%	P > 0.05	P > 0.05

When the surface hardness values of the different mica-containing groups were compared with the control group, the differences were statistically significant except for the 20% mica group. Interestingly, same results were obtained with the glass-containing groups (Tables 2 and 3, Kruskal—Wallis test and *post hoc* Dunn's multiple comparison test).

As for the differences in surface hardness value between the same percentage of mica- and glass-containing groups, they were not statistically significant ($p>0.05$) (Table 2, Mann—Whitney U test).

DISCUSSION

With a view to improving the mechanical and physical properties of PMMA, many studies[3-5,7,11] have investigated the effects of several reinforcement materials on PMMA. These studies were mainly performed on denture base acrylics. It has been reported that glass fibers enhanced the mechanical properties of denture base resin, such as transverse strength[5], impact strength[7], and fracture resistance[3]. Nonetheless, a few researches[6,12] have been undertaken to improve the mechanical properties of the PMMA resin of denture teeth. In the same vein, the purpose of the present study was to investigate the effects of mica or glass incorporation on the surface hardness of PMMA tooth material.

For hardness testing of plastics, it is most commonly measured by the Shore (Durometer) test. Shore D hardness test, one of the Shore tests, is then usually used to determine the relative hardness of the harder plastic materials[21,22]. For this reason, Shore D test was used in this study.

In this study, it was concluded that 10% mica- and 10% glass-containing groups exhibited the best surface hardness values. As for the addition of 20% mica or 20% glass to the PMMA resin of denture teeth, increases in surface hardness value were not statistically significant. This was most likely because a specific percentage of fillers would enhance the mechanical properties at an optimal level. Beyond this limit, deviation from ideal mechanical properties may occur. Thus, it was the key purpose of the present study to determine this critical value. Results of this study showed that 10% was the ideal percentage for both glass and mica.

Unalan *et al.*[12] found that addition of silanized mica in the ratios of 5% to 20% significantly decreased the wear rate of PMMA. Likewise, Gurbuz *et al.*[6] observed that addition of similar ratios of glass fibers caused the wear rate of PMMA to decrease significantly. The findings of these studies were thus consistent with those of these previous studies[6,12] that examined the surface hardness of PMMA. In summary, results of the present study

revealed that both mica filler and glass fibers had a positive effect on the surface hardness of PMMA as an artificial tooth material.

However, to ascertain the clinical relevance of the incorporation of these additives into PMMA, other testing methods — such as impact testing, fatigue testing, and fracture testing — should be performed.

CONCLUSIONS

Within the limitations of this *in vitro* study, the following conclusions were drawn:

1. Both mica and glass added in the ratios of 5%, 10%, and 15% increased the surface hardness values of PMMA significantly.
2. For the same percentage of additive incorporation to improve the surface hardness of PMMA, glass fibers exhibited a slightly superior performance than mica fillers — thereby offering a better reinforcement to the acrylic resin denture teeth.

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