Original Article

Vickers Hardness and Specific Wear Rate of Poly Propylene Reinforced PMMA

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Abstract

Background: Poly (methyl methacrylate) is one of the most widely accepted biomaterial in prosthetic dentistry due to its acceptable advantages. However the conventional PMMA used are far from being ideal because of their inferior mechanical properties. So the present study is to determine the Vickers Hardness and specific wear rate of the polypropylene reinforced PMMA.

Aim: Determination of Vickers Hardness number and specific wear rate of PMMA denture base by varying the weight percentage of polypropylene fiber and by varying the aspect ratio of polypropylene fiber.

Materials and Methods: To measure the Vickers hardness, specimens prepared, using a standard rectangular mold of 62 mm length, 10 mm breadth and 2.5 mm thickness. Vickers Hardness number measured using Vickers hardness test apparatus having square based diamond pyramid as indenter. For wear analysis, specimens prepared, using a standard cylindrical mold of 8 mm diameter and 25 mm length. Specific wear rate measured after measuring the weight loss in the pin on disc method by Wear and Friction Monitor TR-20ICL. Microstructure of the abraded surface observed through Trinocular inverted metallurgical microscope model Metji M1004. Detailed statistical analysis performed using One-way Analysis of Variance (ANOVA), Turkey-Kramer Multiple Comparisons Test.

Results: Polypropylene reinforced PMMA shown superior Vickers hardness number compare to control and the specific wear rate for the reinforced groups were less compare to control.

Keywords: Polypropylene fiber, PMMA, Specific wear, Vickers hardness

INTRODUCTION

Poly (methyl methacrylate) continued to be a preferred biomaterial of choice in prosthetic and craniofacial reconstructive dentistry due to its acceptable advantages. But the mechanical performance of these materials is inferior. Fiber reinforcement is a good method to improve mechanical characteristics and to prolong the service life of the PMMA based materials.[1] Poly propylene is a synthetic polymer and the fiber made out of it possesses superior mechanical properties, corrosion resistance, biocompatibility, etc.[2] So the current study utilized polypropylene fiber as a reinforcing agent. Polymer composites are made of matrix and dispersed phase. Poly (methyl methacrylate) is the primary matrix phase which is continuous and poly propylene fibers are the secondary dispersed phase which is discontinuous.[3] Measurement of Hardness and abrasion resistance is an effective tool in understanding the overall mechanical behavior of any material including the polymer composites.[4]

Aim

- To determine hardness and specific wear resistance of PMMA material by varying the weight percentage of polypropylene fiber (2.5 wt%, 5 wt%, 10 wt %).
- To determine hardness and specific wear resistance of PMMA material by varying the length/thickness ratio of polypropylene fiber (3 mm/220 μm, 6 mm/220 μm, 12 mm/220 μm).
- Comparison of the above and understand the optimum property of the PMMA material using the correct weight percentage and aspect ratio.

MATERIALS AND METHODS

Materials

Modeling wax, dental stone type III gypsum product, model plaster type II gypsum product, poly propylene fibers, heat polymerizing PMMA powder and monomer liquid, separating medium.

Methods

Preparation of Gypsum Moulds to Obtain The Acrylic Specimen for Hardness Test

Wax pattern (62 mm X 10 mm X 2.5 mm) is prepared, using modeling wax and invested in the dental flask in the conventional manner using dental stone and model plaster. After one hour, the invested flask kept for dewaxing, then any waxy residue removed by washing the mould by hot water and then cleaned using soap solution, allowed to dry, thin layer of separating medium is applied in the mould space, allowed to dry. The mould was then ready to be used for the preparation of acrylic specimen.

Preparation of Gypsum Moulds to Obtain the Acrylic Specimen for Wear Analysis

Wax pattern (8 mm diameter, 25 mm length) is prepared using modeling wax and invested in the dental flask in the conventional manner using dental stone and model plaster. After one hour the invested flask kept for dewaxing, then any waxy residue removed by washing the mould by hot water and then cleaned using soap solution, allowed to dry, thin layer of separating medium is applied in the mould space, allowed to dry. The mould was then ready to be used for the preparation of acrylic specimen.

Preparation of PMMA Resin Specimen

Control Group

Control group test specimen made with conventional heat polymerized PMMA resin (DPI heat cure) polymer and monomer (2.4 gm:1 ml) mixed and allowed to reach dough consistency. Dough is kneaded and then packed into the mould, flask is closed and a pressure of 1400 psi was given and bench cured for 30 minutes in a hydraulic press apparatus. Then the flask is clamped and transferred it into the water bath. Temperature of the water bath elevated slowly to 72°C, and maintained for 90 minutes. Then the temperature of the water bath elevated to 100°C and maintained for 60 minutes. After completion of polymerization cycle, the flask is allowed to cool in same water bath to room temperature, and the acrylic resin specimens are retrieved after deflasking. The specimen obtained were finished and polished in the conventional manner.[5]

Reinforced Groups

Poly propylene fibers of varying length and concentration is taken and impregnated in the measured monomer for 5 minutes, and then the polymer powder is weighed and mixed with monomer and polypropylene fiber and allowed to reach dough consistency. Then it is packed and a pressure of 1400 PSI is given and bench cured for 30 minutes in a hydraulic press apparatus. Then the flask is clamped and transferred it into the water bath. Temperature of the water bath elevated slowly to 72°C, and maintained for 90 minutes. Then the temperature of the water bath elevated to 100°C and maintained for 60 minutes. After completion of polymerization cycle, the flask is allowed to cool in the same water bath to room temperature, and the acrylic resin specimens are retrieved after deflasking. Specimens obtained were finished and polished in the conventional manner.

Hardness Testing

Hardness was measured using Vickers hardness test apparatus. It has a square based diamond pyramid as indenter. The value of the load (50 gm) and the time duration (10 seconds) that is to be applied was set. The test specimen was held firmly in position and lens were arranged to get the image clearly at its focal length, then the indentation made using set parameters. Indentations focused and the measuring lines were made to interact at two diagonally opposite corner. Readings were taken by pressing the read button. Similarly the lens was rotated and the measurement of diagonally opposite corner was measured.

Wear Analysis

Specific wear rate was measured using pin on disc method by Wear and Friction Monitor TR-20ICL. Weight of the specimen was measured and considered as initial weight W1. Specimen was inserted into the holder and made sure that the end surface of the specimen and disc surface was parallel to each other. Holder was adjusted to get the desirable wear track radius (D=60 mm). Load was given on the hang attached to the apparatus (300 gm). Specimen securely tightened to the holder. By using the controller attached to the device the speed of rotation (200 rpm) and the time duration for the rotation (10 minutes) were selected. Then the data recorded controller device was switched on. Once the rotation completed after set duration 10 minutes, the weight of the specimen measured W2. The procedure was repeated and the weight measured as W3. Weight loss W1-W2 and W2-W3 measured and average weight loss measured as ΔW. The experiment was repeated for 500 gm, 1000 gm load. The load was varied in order to understand the effect of load on the specific wear. Specific wear rate was obtained from the formula:

Specific Wear rate = ΔW/(load in Newton * sliding distance) gm/Nm

Where ΔW = average weight loss

Sliding distance S = *velocity m/sec * time sec*

Sliding velocity (V)= $\frac{¶DN}{60\times1000}$ m / sec

D= wear track diameter selected (60 mm)

¶ = 3.14

N = speed of the rotating disc (rpm) (200)

The surface after wear was observed through Trinocular inverted metallurgical microscope model Metji M1004.

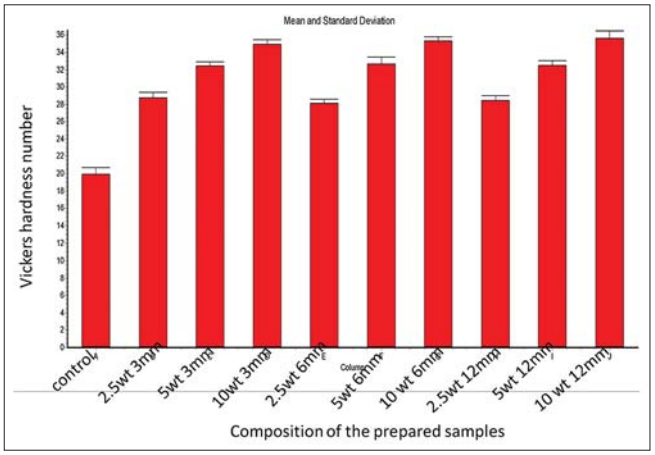
RESULTS

- All fiber reinforced groups shown higher Vickers hardness number compared to control group having no fiber.
- Comparing different fiber weight with same fiber length there was significant increase in the Vickers hardness number (Table 1 & Graph 1).
- Comparing different fiber length with same fiber weight percentage there was no significance in the Vickers Hardness number.
- Under all given loads, specific wear rate was more for the control group when compare with other polypropylene reinforced group (Table 2 & Graph 2).
- As the load increases from 300 gm to 1000 gm there was significant increase in the wear rate of the control group.
- As the fiber concentration increases, specific wear rate observed was less (Figures 1, 2 and Graph 2).

DISCUSSION

Polypropylene fiber has got superior mechanical property and chemical stability moreover poly propylene is used in variety forms in medicine as it is highly biocompatible.[6]

Hardness and wear resistance are related property and commonly examined mechanical properties in



Graph 1: Vickers hardness number of poly propylene fiber reinforced PMMA

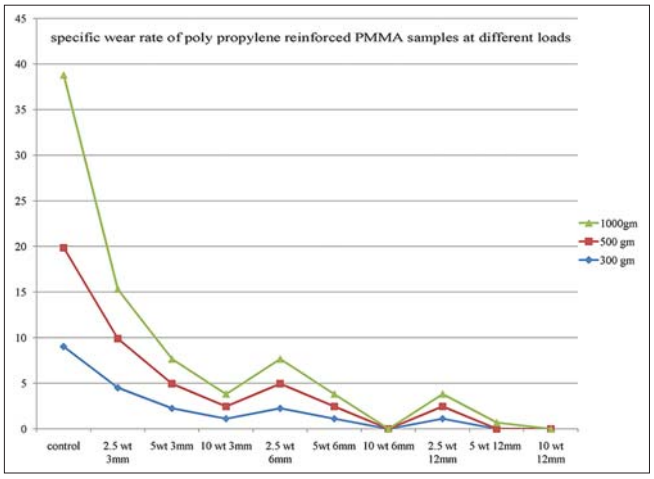
Table 1: Vickers hardness number of polypropylene reinforced PMMA

Serial no.	Control specimen	3 mm long ppf non treated			6 mm long ppf non treated			12 mm long ppf non treated		
		2.5 fiber wt%	5 fiber wt%	10 fiber wt%	2.5 fiber wt%	5 fiber wt%	10 fiber wt%	2.5 fiber wt%	5 fiber wt%	10 fiber wt%
1	20.4	29	32.6	34	27.8	33	36.1	29.2	33	36.1
2	19.4	29.6	33	35.1	28	33.4	35.7	28.6	33.1	36.7
3	19.4	28.9	31.8	35.5	29	32.9	35	27.8	32.6	36
4	21.2	27.8	32.4	34.8	27.9	32.7	34.9	29	31.8	35.8
5	20.1	28.3	32.8	35.3	28.2	31.2	35.2	27.9	32	35
6	18.9	29.1	32	34.9	28.1	32.9	35	28.1	32.5	34.4
Mean	19.9	28.783	32.433	34.933	28.166	32.683	35.316	28.433	32.5	35.66667
stdev	0.8342	0.6369	0.4633	0.5240	0.4320	0.7626	0.4792	0.5887	0.5215	0.828654

Table 2: Specific wear rate of the tested samples at different loads

	Control	2.5 wt 3 mm	5 wt 3 mm	10 wt 3 mm	2.5 wt 6 mm	5 wt 6 mm	10 wt 6 mm	2.5 wt 12 mm	5 wt 12 mm	10 wt 12 mm
Δw load 300 gm	0.001	0.0005	0.00025	0.000125	0.00025	0.000125	0	0.000125	0	0
Specific wear rate	9.02×10^{-7} g/NM	4.51×10^{-7} g/NM	2.26×10^{-7} g/NM	1.12×10^{-7} g/NM	2.26×10^{-7} g/NM	1.12×10^{-7} g/NM	0	1.12×10^{-7} g/NM	0	0
Δw load 500 gm	0.002	0.001	0.0005	0.00025	0.0005	0.00025	0	0.00025	0	0
Specific wear rate	10.83×10^{-7} g/NM	5.4×10^{-7} g/NM	2.7×10^{-7} g/NM	1.35×10^{-7} g/NM	2.7×10^{-7} g/NM	1.35×10^{-7} g/NM	0	1.35×10^{-7} g/NM	0	0
Δw load 1000 gm	0.007	0.002	0.001	0.0005	0.001	0.0005	0	0.0005	0.00025	0
Specific wear rate	18.93×10^{-7} g/NM	5.41×10^{-7} g/NM	2.7×10^{-7} g/NM	1.35×10^{-7} g/NM	2.7×10^{-7} g/NM	1.35×10^{-7} g/NM	0	1.35×10^{-7} g/NM	0.676×10^{-7} g/NM	0

Where Δw = average weight loss of specimen after wear test (w1-w2, w2-w3)



Graph 2: Specific wear rate of poly propylene reinforced PMMA samples at different loads

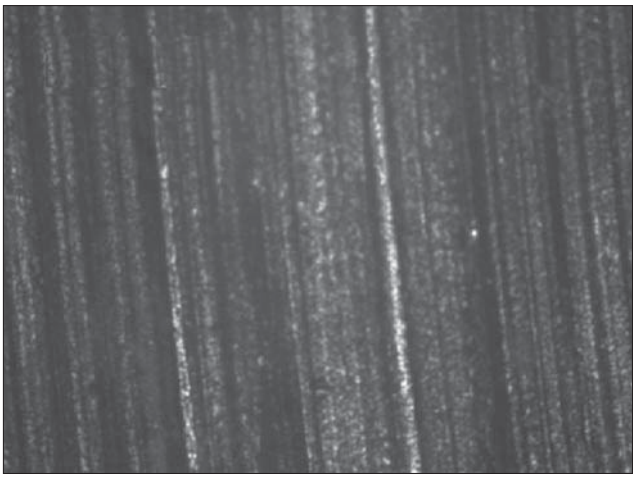


Figure 1: Abraded surface of the control specimen observed at 50× magnification

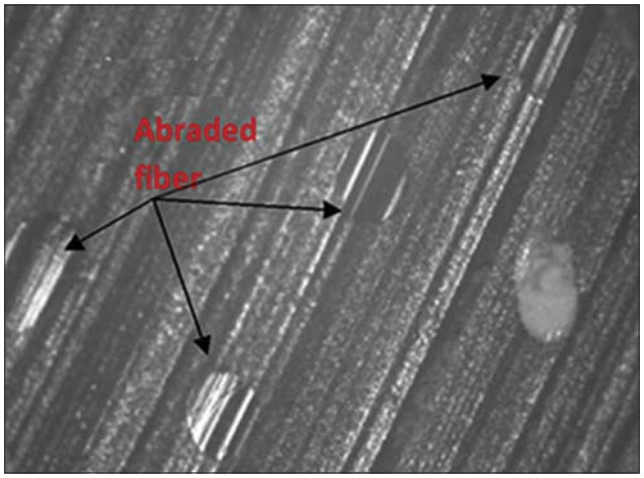


Figure 2: Abraded surface of the reinforced specimen observed at 50× maginfication

determining the longevity of the biomaterials inside the oral cavity.[7] In the oral cavity these materials are exposed to endogenous substances like proteins, enzymes, polysaccharides, bacteria etc and exogenous substances that coming through the food intake. These components establish a complex interaction, mechanical action on the artificial prosthesis and compromise its service life.[8] Presence of saliva can decrease the wear rate because in wet condition the abraded particles are removed from the surface otherwise these can act as additional abrasive and causes more wear.[9]

Vickers hardness test method is an accurate micro hardness test to measure the resistance offered by the polymer composite material when the load applied over the surface area of indentation. Vickers Pyramid number (HV) or Diamond Pyramid hardness (DPH) is the unit for measuring the Vickers hardness number.[10] In the present study, readings were taken on well polished samples immediately after the indentation made as it highly depends on the elastic recovery of the material and surface homogeneity.[11]

There are two different wear mechanisms such as cohesive and interfacial type of wear. Generally cohesive type of wear depends on the mechanical properties of the interacting material where as the interfacial wear depends on the chemistry of the surface involved in wearing. In polymer composite the cohesive two- body and three -body abrasions wear normally encountered and this is highly depend on the hardness of the materials in contact, applied load, sliding distance and geometry of the abrasive particle.[12] In the present study, the wear rate of the prepared polymer composite samples calculated under different loads and the results showed that the reinforced samples have better wear resistance than the control with no fiber and increase in the load applied increases wear, indicates that more energy required to cause the wear of fiber reinforced polymer. Hence hardness increased on increasing the fiber concentration as the wear and hardness are inversely related.[4]

CONCLUSION

- Poly propylene fiber is a good reinforcing material to poly methyl methacrylate as it enhances the hardness of the PMMA
- Fiber concentration affects the Vickers hardness number but aspect ratio did not play a significant role in the hardness number
- There is a significant change in the Specific wear rate of fiber reinforced specimens when compare to control specimen
- Load applied is one of the main factors which control the specific wear rate.

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