IMPACT STRENGTH OF E-GLASS REINFORCED PMMA

Merin Mathew[1], Kamalakanth Shenoy[2], Ravishankar K.S[3]

HOW TO CITE THIS ARTICLE:
Merin Mathew, Kamalakanth Shenoy, Ravishankar KS. "Impact strength of e-glass reinforced PMMA". Journal of Evolution of Medical and Dental Sciences 2013; Vol2, Issue 32, August 12; Page: 5971-5979.

ABSTRACT: BACKGROUND: Poly methyl methacrylate is one of the most widely accepted biomaterial in prosthetic dentistry due to its biocompatibility, insoluble and non corrosive characteristics, good transparency, good color stability over the years, easy to process and repair, dimensionally stable, comparatively low density (1.19g/cm^3), and low heat distortion temperature. However these materials are far from being ideal because of their inferior mechanical and thermal properties. So the present study is to achieve the desirable impact strength of poly methyl methacrylate material, by reinforcing it with E glass fibers. **AIM:** Determination of impact strength of PMMA denture base by varying the weight percentage of glass fiber, by varying the aspect ratio of glass fiber. Determination of the optimum property of the PMMA denture base using the correct weight percentage and aspect ratio. **MATERIALS AND METHODS:** Specimens prepared using a standard cylindrical mold of 8mm diameter and 45mm length. A total of 100 samples prepared (10 samples in each group) Polymer –monomer ratio 2.4:1 by Weight used to prepare samples. Impact strength is tested using balanced impact testing apparatus. The micro structural analysis using SEM performed for the specimen which showed the highest impact strength value. Detailed statistical analysis done by one way ANOVA. **RESULTS:** Highest impact strength is obtained with 12mm long fiber reinforced in 10weight percentage concentration.
KEYWORDS: PMMA, Impact strength, Silane treated E glass fiber.

INTRODUCTION: Skull bone corrections and prosthetic facial bone corrections is the most emerging and advanced field in craniofacial reconstruction and dentistry. One of the most widely used materials in prosthetic dentistry is poly methyl methacrylate. These are biocompatible, non toxic, non irritant, insoluble and non corrosive in oral fluids. These materials are transparent, so can easily be pigmented, good color stability over the years, easy to process and repair. Dimensionally stable, comparatively low density (1.19 g/cm^3). Its heat distortion temperature is above 75°c, which is higher than the temperature of the hot foods, we take as food into the mouth. These materials can take good polish; all these make PMMA as an excellent denture base material and maxillofacial prosthetic material. However these materials are far from being ideal because of their poor mechanical and thermal properties.[1, 2, 3] In order to achieve the desirable impact strength characteristic of poly methyl methacrylate, a study can be conducted by reinforcing it with E glass fibers since it is a most commonly used fiber for acrylic reinforcement due to its higher mechanical properties, low susceptibility to moisture absorption, resistance to chemicals, thermal stability and high melting point.

AIM:

- To determine impact strength of PMMA material by varying the weight percentage of glass fiber**.** (2.5wt%, 5 wt%, 10 wt %)

- To determine impact strength of PMMA material by varying the length/ thickness ratio of glass fiber.(3mm/ 20µm, 6mm/ 20µm, 12mm/ 20µm)
- Comparison of the above and determine the optimum property of the PMMA material using the correct weight percentage and aspect ratio.

MATERIALS AND METHODS:

MATERIALS: Cylindrical metallic die having 8mm diameter and 45mm length for the preparation of wax pattern, modeling wax, elastomeric impression material(addition silicone putty consistency), dental stone type III gypsum product, type II gypsum product, silane treated E glass fibers

METHODS:

- Preparation of gypsum moulds to obtain the acrylic specimen: Die of 8mm diameter and 45mm length fabricated in stainless steel. Using elastomeric impression material, the impression of the die is taken, the modelling wax poured into the impression and the wax pattern obtained is invested in the dental flask in the conventional manner using dental stone and model plaster. After 1 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[6]. Preparation of PMMA resin specimen:

a. Control group: Control group test specimen made with conventional heat polymerized PMMA resin (DPI heat cure) polymer and monomer (2.4gm: 1ml) 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 is given and bench cured for 30 minutes in 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[6].

b. Reinforced group: Silane treated E glass fibers of varying length and concentration is taken and impregnated in the measured monomer for 5 minutes, then the polymer powder is weighed and mixed with monomer and glass 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 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[6].

TESTING:

Impact strength testing: Impact strength measured using balanced impact testing apparatus fig.1. The specimen placed in the groove provided in the right hand side of the testing apparatus. Once

after placing the specimen firmly in position, the oscillation is given to both the arms provided in the test apparatus. The energy absorbed by the material is taken as the impact strength and it is directly observed from the scale attached to the apparatus. Fig2. The values obtained were multiplied using a conversion factor to match it with Izod value. Table-1.

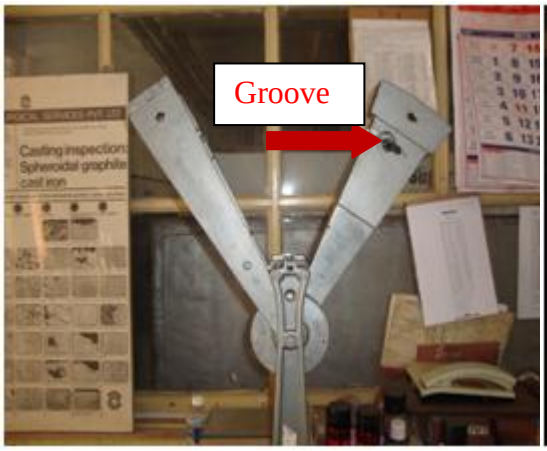


Figure 1

Figure 2

Figure 3

RESULTS:

- When we compare same fibre weight with different fibre length it shown significant change in strength. Table-2
- In the same way when we compare different fibre weight with the same fibre length it also shown significant change in strength except 3mm fibre length. Table-2.

Table 1:

Serial no.	Control specimen	3mm long fiber			6mm long fiber			12mm long fiber		
		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	0.25	0.5	0.75	0.88	0.63	1.13	1.25	0.75	1.13	4.38
2	0.25	0.5	0.63	0.88	0.63	0.88	1.25	0.88	1.13	4.38
3	0.25	0.5	0.75	0.75	0.63	1	1.88	0.88	1.88	4.38
4	0.25	0.5	0.63	0.88	0.5	0.88	1.88	0.88	1.25	4.38
5	0.25	0.5	0.63	0.88	0.5	1	1.88	0.88	1.88	4.38
6	0.25	0.50	0.75	0.88	0.63	1	1.88	0.75	1.25	3.75
7	0.25	0.63	0.75	0.88	0.63	1	1.88	0.88	1.25	4.38
8	0.25	0.63	0.75	0.88	0.63	1	1.88	0.75	1.25	3.75
9	0.25	0.5	0.63	0.88	0.5	1	1.88	0.75	1.25	4.38
10	0.25	0.63	0.5	0.75	0.5	1	1.88	0.75	1.13	4.38
Mean	0.25	0.54	0.68	0.85	0.57	0.99	1.75	0.81	1.34	4.25

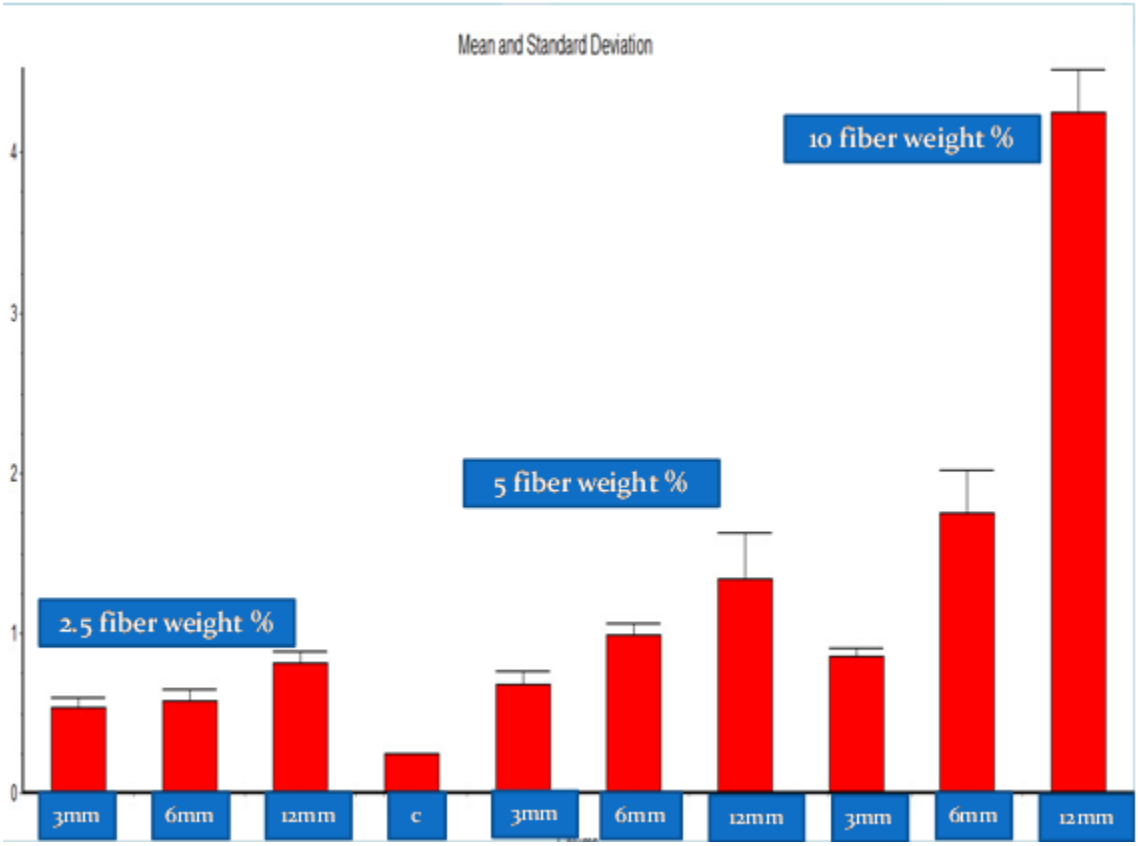


Table 2:

Fiber weight %	2.5 wt%	5 wt%	10wt%	
Fiber length	3mm	3mm	3mm	P< 0.001
	6mm	6mm	6mm	P< 0.001
	12mm	12mm	12mm	P< 0.001
	P< 0.001	P< 0.001	P< 0.001	

DISCUSSION: Poly methyl methacrylate is a widely accepted biomaterial in both medicine and dentistry due to its acceptable advantages. However these materials are far from being ideal mainly due to its inferior mechanical properties.[1, 2, 3]

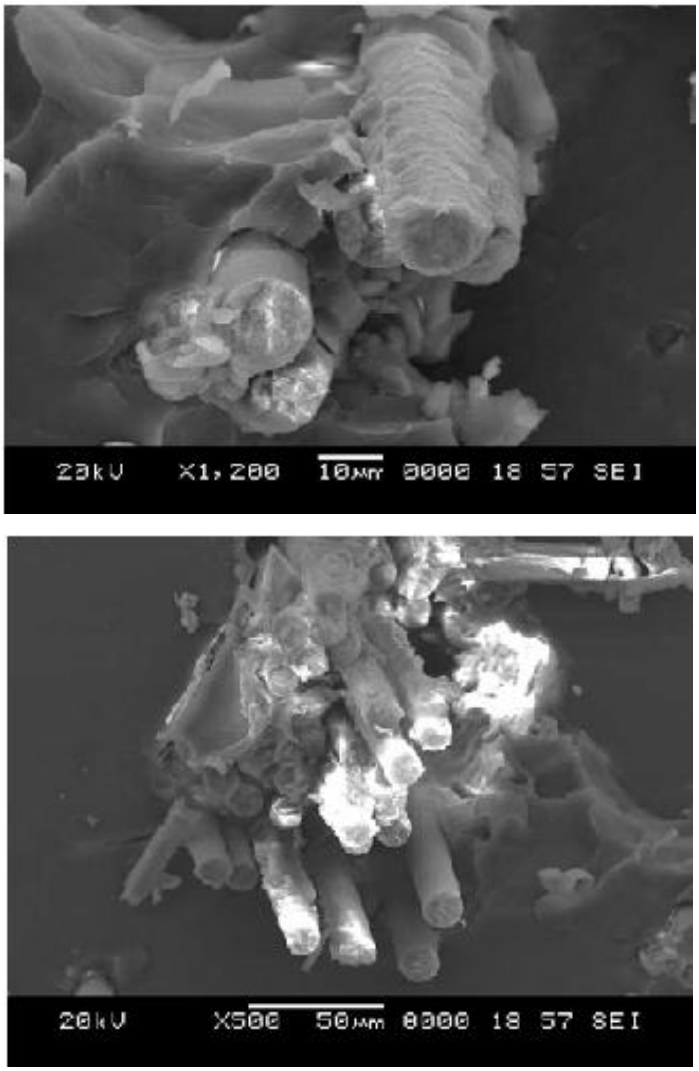
Strengthening of PMMA resin can be done using metal plates and wires [4, 9], but they are unaesthetic and prone to corrosion. Fibers like nylon, glass fibers[5, 8], aramid[5, 6], carbon[7], Kevlar[10], polyethylene [11], etc have also been used to reinforce PMMA. Among these E glass fibers are most commonly used reinforcing fiber for acrylic because it provide good electrical, thermal insulation and strongly resist attack by water in addition to the superior mechanical properties and easy manipulation [5].

Impact strength is carried out on unnotched test specimens using balanced impact testing apparatus. Polymeric materials that are sensitive to the stress concentrations at the notch ('notch-sensitive') will perform poorly in the notched impact test. To avoid such stress concentrations at sharp corners or cutouts, unnotched specimens are also frequently tested to give a more complete understanding of impact resistance. Rigid brittle polymers are often very notch sensitive and they show much low impact strength.[12] Liviu et al conducted a study to find out the effect of notch on the impact strength and they suggest that unity value is obtained for the ratio of impact strength of notched specimen and unnotched specimen indicates notch has no effect on the impact strength.[13]

The present study used silane treated E glass fiber to reinforce PMMA resin matrix as the matrix- fiber interface could be strong due to chemical bonding. All reinforced groups' exhibit increase in the impact strength than control. This is due to the presence of fillers. Fillers intersect micro cracks and bridge the gap between two surfaces of the crack. Under loading condition, when a crack starts to propagate, the fibers apply force opposing the crack propagation, so the strength increases[14]. Fiber –matrix interface force is directly proportional to the surface area between the fiber and the matrix so the concentration of fibers also plays a major role in enhancing the strength characteristics. Fiber- matrix debonding can cause a reduction in the undamaged structural strength and stiffness of the fiber reinforced polymers.[15]

Ductile material deform plastically results in blunting the tip of the crack and absorbs more energy at fracture, where as the brittle materials will not show much plastic deformation and crack propagate through the stressed region and absorbs little energy at fracture. Polymer composite material often shows a mixture of ductile and brittle failure process. There are several failure mode in polymer composite material such as delamination or interlaminar fracture, matrix cracking or intralaminar fracture, matrix- fiber debonding, fiber breaking, fiber pull out etc [16]. SEM analysis performed to study the fracture mechanism and fiber matrix interface. It is observed that the fiber bonded well with the matrix and little plastic deformation occurred before failure (Figure 4). The present study shown increase in the concentration and aspect ratio of E glass fiber (12mm long fiber 10 wt %) shown superior impact strength which is the main property for artificial prosthesis.

Figure 4:



CONCLUSION: Results suggest that 10 fibre weight % with 12mm fibre length shown superior impact strength. Addition of silane treated E glass fiber showed improved impact strength which would be the important factor for artificial prosthesis. But increase in fibre concentration may compromise the flexibility. Still more studies should put forward for obtaining optimum fibre weight percentage, aspect ratio and exact orientation of fibres to attain good flexibility with better strength.

REFERENCES:

1. Kenneth J. Anusavice, Phillips' Science of Dental Materials, Eleventh Edition, Elsevier (pages: 92,165-166, 722-750).
2. R. Rodford, The development of high impact strength denture-base materials, Journal of dentistry, October 1986, volume 14, issue.5 pages 214-217.

3. S.K Khindria, Sanjeev Mittal, Urvashi Sukhija, Evolution of denture base materials, Review article. The Journal Of Indian Prosthodontic Society, April 2009,Vol 9,Issue 2,
4. Mona K. Marei, Ahmed El-Sabrooty, Ahmed Y. Ragab, Mohamed A. El-Osairy. A study of some physical and mechanical properties of metal filled acrylic resin, Saudi dental journal, 1994, 6-2-pages: 69-77.
5. Jacob John, Shivaputrappa A. Gangadhar and Ila Shah, Flexural strength of heat-polymerized polymethyl methacrylate denture resin reinforced with glass, aramid, or nylon fibers, J Prosthetic Dent, 2001 86:424-7.
6. Sanjiv Rajender Dagar, Ashok J Pakhan, RU Thombare, Bhagwandas K Motwani (Evaluation of flexural strength and impact strength of heat polymerized PMMA denture base resin reinforced with glass and nylon fibers. Journal of Indian Prosthodontic Society 2008, pages: 98-104.
7. Segerström Susanna; Ruyter I Eystein Effect of thermal cycling on flexural properties of carbon-graphite fiber-reinforced polymers, Dental materials: official publication of the Academy of Dental Materials2009, 25(7): pages 845-51.
8. Kim SH, Watts DC (The effect of reinforcement with woven E-glass fibers on the impact strength of complete dentures fabricated with high impact acrylic resin. 2004 march.
9. Vallittu PK. Effect of some properties of metal strengtheners on the fracture resistance of acrylic denture base material construction. J Oral Rehabil 1993; 20:241-8.
10. Berrong JM, Weed RM, Young JM. Fracture resistance of Kevlar-reinforced poly (methyl methacrylate) resin: a preliminary study. Int J Prosthodont 1990, 3:391-5.
11. Gutteridge DL. The effect of including ultrahigh-modulus polyethylene fibre on the impact strength of acrylic resin. Br Dent J 1988; 164:177-80.
12. Polymer blends: a comprehensive review by Lloyd M. Robeson. Page 341.
13. Liviu Marsavina, Anghel Cernescu, Emanoil Linul, Dan Scurtu, Constantin Chirita, Experimental Determination and comparison of some mechanical properties of commercial polymers, Materiale Plastice. 2010, 47. Nr.1.
14. Yong – Hoon cha, Kyoung- Suck kim, Duck – Joong kim . Evaluation on the fracture toughness and strength of fiber reinforced brittle matrix composites. KSME international Journal, 1998, Vol 12. No.3 PP 370-379.
15. K Sanda. N Itaya, Y.shindo. Self healing of interfacial debonding in fiber reinforced polymers and effect of microstructure on strength recovery. The open mechanical engineering journal 2008, 2, 97-103.
16. M.S. Sham Prasad, C.S. Venkatesha, T. Jayaraju, Experimental Methods of Determining Fracture Toughness of Fiber Reinforced Polymer Composites under Various Loading Conditions. Journal of Minerals & Materials Characterization & Engineering, 2011, Vol. 10, No.13, pp.1263-1275.

E-Glass fiber

Hydraulic Apparatus

Polymethyl methacrylate powder, methyl methacrylate monomer liquid and separating medium

Unident acrylizer

AUTHORS:

1. Merin Mathew
2. Kamalakanth Shenoy
3. Ravishankar K.S.

PARTICULARS OF CONTRIBUTORS:

1. Lecturer, Department of Dental Materials (Prosthodontics), Yenepoya University.
2. Professor and Head of the Department, Department of Dental Materials (Prosthodontics), Yenepoya University.
3. Assistant Professor, Department of Dental Materials (Prosthodontics), Yenepoya University.

NAME ADRRESS EMAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Merin Mathew,
Lecturer, Dental Materials,
MAHE institute of Dental Sciences,
Mahe, U.T. of Puducherry.
Email – lecturermerin@gmail.com

Date of Submission: 21/07/2013.
Date of Peer Review: 22/07/2013.
Date of Acceptance: 03/08/2013.
Date of Publishing: 07/08/2013.