International Journal of Mechanical and Thermal Engineering

E-ISSN: 2707-8051
P-ISSN: 2707-8043
IJMTE 2023; 4(1): 23-27
Received: 09-12-2022
Accepted: 30-01-2023

Pritosh Tomar
Ph.D. Student, Department of Mechanical Engineering, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

PC Gope
Professor, Department of Mechanical Engineering, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Sonika Chauhan
Assistant Professor, Department of Mechanical Engineering, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Corresponding Author:
PC Gope
Professor, Department of Mechanical Engineering, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Influence of fiber Reinforcement on properties of PMMA

Pritosh Tomar, PC Gope and Sonika Chauhan

Abstract
In this study, a composite material with PMMA and MMA as the matrix components was created and reinforced with Chopped glass fibers at various weight percentages (5, 10%). Because it has a number of advantageous qualities, such as being simple to make, lightweight, affordable, and others, poly methyl methacrylate, or PMMA, polymer, has been widely employed in dental applications throughout the years. But when put under a lot of strain, it has poor mechanical qualities. By combining two different types of fibres, the goal of this research was to create composite materials with improved mechanical qualities. The composite specimens were prepared using the BIS standard processing method for full dentures. To ascertain whether or not reinforcing materials and the saline coupling agent have a chemical relationship, SEM tests were performed on Chopped nylon fiber before and after salinization. All specimens underwent physical testing including heat conductivity, water sorption, and solubility. All specimens underwent physical testing for heat conductivity, water sorption, and solubility. According to the findings, reinforced specimens had much lower heat conductivity, water absorption, and solubility than pure specimens. Sisal fibres reinforced PMMA specimens exhibited a modest drop in thermal conductivity with increasing fibre concentration, while composite specimens showed increases in water sorption and solubility. The silane treatment produced a new absorption band, according to FTIR measurements.

Keywords: PMMA, denture material, fiber reinforced

Introduction
A dentistry speciality called prosthodontics helps restore missing teeth and improves their aesthetics and functional qualities using artificial, biocompatible replacements. Replaced by artificial teeth or detachable or fixed dentures. a lack of teeth. The standard of care for edentulous individuals is a full removable denture. The edentulous patients' mastication, appearance, comfort, and health are all restored by the dentures [1]. The denture base and teeth make up the dentures. The denture bases are an important part because they help to keep the prosthesis in place and provide stability and support. Methyl methacrylate is polymerized to create the polymer PMMA (Polymethyl-methacrylate). Its unique features, such as improved mechanical strength, reduced absorption, and good transmission in the UV-Visible range, make it a popular choice as a basis material in composite thin films. Polymers and polymer Nano composites are currently employed extensively in a variety of technical applications, including waveguide materials, contact lenses, optoelectronic devices, electrical and optical devices, optical coatings, biomaterials, and microelectronic devices.

A thermoplastic substance with an amorphous structure is PMMA. Due of their special characteristics, notably their light weight, flexibility, minimal thermal expansion, excellent transparency, and relative affordability, they are more easily produced at lower temperatures. PMMA is highly sought after for optical applications since it is optically transparent. Due to its exceptional insulating qualities, low dielectric constant, and low dielectric loss across a wide frequency range, it is a good option for organic field effect transistors (OFETs), organic based thin film transistors (OTFTs), and organic solar cells [3]. The top surface morphology of dielectric materials has an impact on the device's performance in addition to this.

PMMA resin, a substance frequently used in denture bases. It offers a lot of benefits, including affordability, patient acceptability, affordability, stability of the oral cavity, and cosmetic qualities, but it also has a lot of disadvantages.

Its mechanical and physical qualities have been improved using a variety of means, including The chemistry of PMMA may be altered, filler materials can be added, and novel denture base materials can be developed to strengthen denture materials. The best choice seems to be a resin reinforced with fibers [2, 3]. To the family of denture base materials, reinforcing fibres were introduced. Due to their biocompatibility, plant fibres are one of the better biomaterials compared to natural fibers [4]. To the family of denture base materials, reinforcing fibres were introduced. Due to their biocompatibility, plant fibres are one of the better biomaterials compared to natural fibers [4]. Natural fibres offer several benefits over artificial fibres, including being a renewable resource, being less damaging to processing equipment, being light, affordable, having good relative mechanical qualities, and being ecologically friendly [5, 6].

Ihsan *et al*. investigated the effects of incorporating several fillers, such as Ag, TiO_2, ZrO_2, Al_2O_3, SiC, SiC-nano, Si_3N_4, and HA-nano, in a ratio of 10% wt on PMMA's thermal conductivity and flexural strength. According to the findings of the research, adding filler materials increased the thermal conductivity of PMMA. The flexural strength measurements did not significantly alter.

The main cause of clinical failure is fracturing of the denture material. Poor flexural strength was related to cyclic loading and the brittle nature at glass transition temperature [4, 5]. The mechanical qualities of denture acrylic have been continuously improved since PMMA was first used as the basis material for dentures [6, 7]. The flexural strength and fundamental mechanical characteristics of PMMA have been improved by a number of tests [8–10]. Improved material qualities were seen in PMMA supplemented with zirconia, metal wires, nanoparticles, sapphire whiskers, and fibres made of glass, aramid, carbon, polyurethane, and nylon. Despite the fact that a few mechanical property metrics were improved as a result of these research, clinical settings call for a more thorough improvement in material characteristics to deal with challenging intraoral conditions. Translational research benefits from the examination of fatigue life, fatigue fracture, propagation resistance, surface roughness, surface hardness, long-term wear, and biological reactions [3]. For the creation of innovative denture composite materials that may be used in clinical settings, further testing is necessary. Furthermore, it is challenging for a researcher to thoroughly examine and create the optimal denture base material due to the larger material selection available for the three denture material composites.

New materials, procedures, and clinical research have been produced as a result of advances in prosthodontic science, improving the function and aesthetics of prosthesis materials. Polyamide, metal, fibre, and flexible denture base materials were developed as a result of the advancements. When making dentures, these materials were tried and tested alongside more traditional ones, although the results in terms of clinical effectiveness and success rates differed.

Materials and Methods

PMMA mould preparation to produce the acrylic specimen: sample design (62*10*2.5 mm) is made using modelling wax and invested in the dental flask using dental stone and model plaster in the traditional method. After 45 minutes, the flask is maintained for dewaxing. Any waxy residue is then removed by rinsing the mould with hot water, followed by cleaning with soap solution. After allowing the mould to dry, a thin coating of separating media is applied and left to dry. The acrylic specimen preparation process might then begin using the mould. Making a PMMA resin specimen as follows-

Control group test specimen made with conventional heat polymerized PMMA resin (DPI heat cure) polymer and monomer (2.4 gm: 1 ml) are 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.

Fig 1: Cutting of samples according to standards

Fig 2: Denture samples of different fiber loading

Silane-treated E-glass fibres of varied lengths and concentrations are collected, impregnated in the determined monomer for 5 minutes, and then the polymer powder is weighed, combined with the monomer and glass fibre, and allowed to attain dough consistency. Once packed, it is subjected to a pressure of 1400 psi and bench-cured for 30 minutes in a hydraulic press machine.

Fig 3: Bending test of sample

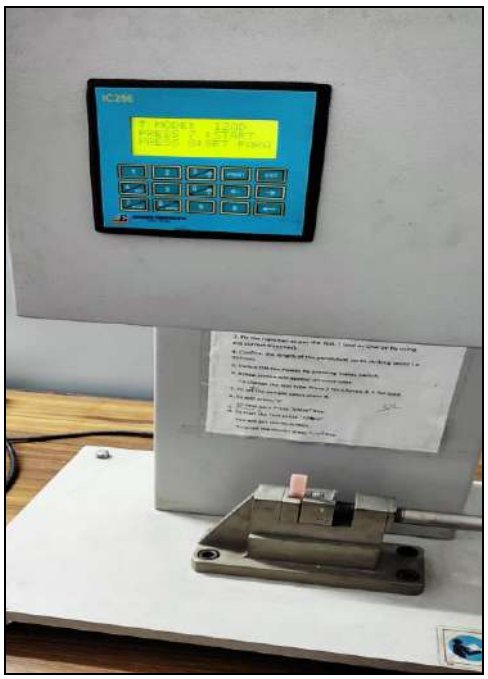

Fig 4: Impact Test for PMMA samples

Once in the water bath, the flask is transferred with a clamp. The water bath gradually increased in temperature to 72 °C and then held that temperature for 90 minutes. After 60 minutes, the water bath's temperature was maintained at 100 °C. Once the polymerization cycle is complete.

Results and Discussion

Impact Test

Since its introduction in 1936, acrylic resin has been the chosen material for denture foundations due to its aesthetic characteristics and ease of manufacture. However, it would be wonderful to have a material that is also indestructible in a therapeutic situation. Many different compounds have been suggested for use as denture base materials. Impact resistance has been tested for a linear poly (methyl methacrylate), four rubber-methacrylate denture base polymers, and a polysulphone denture base polymer. Oral tests showed that the polysulphone material had an impact resistance that was nearly four times higher than standard poly (methyl methacrylate) and almost twice as high as the best rubber-methacrylate.

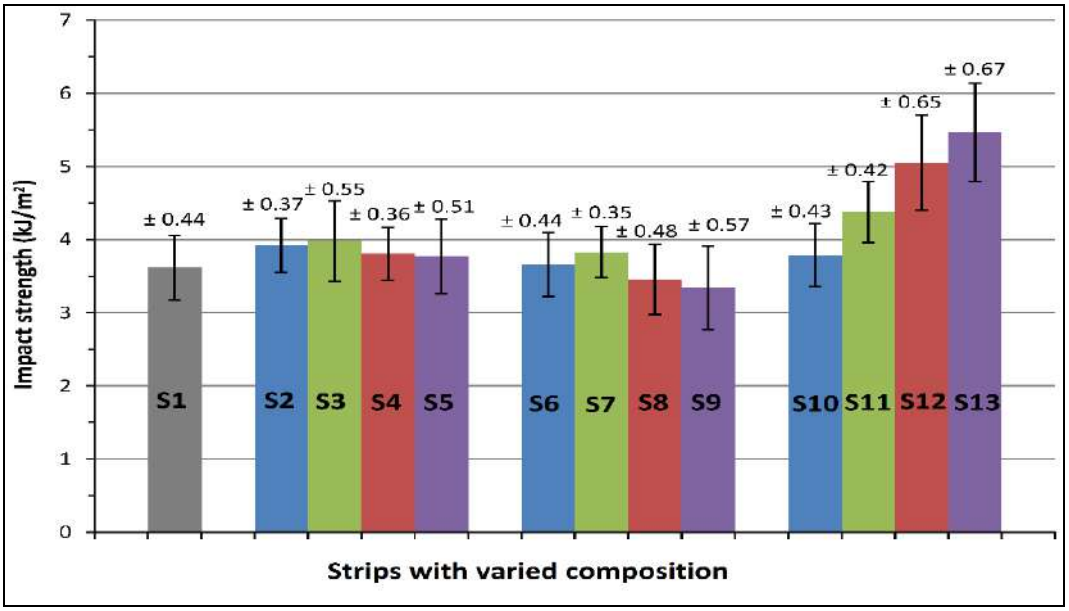

Fig 4: Impact Test result of varied composition samples

Infrared spectroscopy using Fourier transforms (FTIR)

To ascertain if there is a chemical link between reinforcement materials and the saline coupling agent, the (FTIR) test was applied to reinforcement material (sisal fibres) both before and after salinization. KBR is combined with a small quantity of ingredients before being put inside the apparatus. Absorption-collected infrared spectrums were put to work in the (400–4000 cm–1) region.

Test for Thermal Conductivity

Using an equipment available at plant of Pyrax Polymer, Roorkee. the heat conductivity of several materials was calculated using Lee's Disc technique. It consists of three copper discs, A, B, and C. The heater is put between discs B and C, and the sample (S) is inserted between discs A and B.

- In comparison to the control group without fibres, all changed groups demonstrated a considerable improvement in flexural strength.
- The 20 mm diameter, 6 mm length chopped glass fibre in 2.5 wt% group of fibre reinforced materials had the best flexural strength
- There was a noticeable shift in the flexural strength value when comparing different fibre weights with the same fibre length.
- The flexural strength value decreased as the proportion of fibre weight increased, with the exception of fibres longer than 3 mm.

Conclusion

The fact that all groups with fibre reinforcement had better flexural strength values than the control group without any fibres suggests that glass fibre adhered to the PMMA matrix satisfactorily. For a 6 mm long fibre reinforced in 2.5 wt%, a superior flexural strength value was attained. According to the current study, fibre that is 6 mm long and added in 2.5 wt% can perform better when subjected to flexural loading. However, additional research is needed since the flexural strength is also influenced by the orientation of the fibres, the quality of the matrix, surface scratches, and other similar parameters in addition to the bonding of the fibres to the matrix, the concentration of the fibres, and the aspect ratio.

References

1. Kiran A, Amin F, Mahmood SJ, Ali A. Flexural strength of modified and unmodified acrylic denture base material after different processing techniques. J Ayub Med. Coll. Abbottabad. 2020;32(Suppl. 1):S672-S677.
2. Cheng L, Zhou X, Zhong H. NaFloaded core-shell PAN-PMMA nanofibers as reinforcements for Bis-GMA/TEGDMA restorative resins. Mater Sci Eng C Mater Biol Appl. 2013;34:262-269.
3. Vidotti HA, Manso AP, Leung V, do Valle AL, Ko F, Carvalho RM. Flexural properties of experimental nanofiber reinforced composite are affected by resin composition and nanofiber/resin ratio. Dental Materials. 2015 Sep 1;31(9):1132-1141.
4. Nandal S, Ghalaut P, Shekhawat H, Gulati M. New Era in Denture Base Resins: A Review. Dent J Adv Stud. 2013;01(03):136-143.
5. Naji SA, Behroozibakhsh M, Kashi TSJ, Eslami H, Masaeli R, Mahgoli H, Tahriri M, Lahiji MG, Rakhshan V. Effects of incorporation of 2.5 and 5 wt% TiO2 Nanotubes on fracture toughness, flexural strength, and microhardness of denture base poly methyl methacrylate (PMMA). J Adv. Prosthodont. 2018;10(2):113-121.
6. Yang A, Zhao D, Wu Y, Xu C. Effect of polyimide addition on mechanical properties of PMMA-based denture material. Dental Materials Journal. 2017 Sep 25;36(5):560-565.
7. Kul E, Aladag LI, Yildal R. Evaluation of thermal conductivity and flexural strength properties of poly (methyl methacrylate) denture base material reinforced with different fillers, The Journal of Prosthetic,

Dentistry. 2016 Nov 1;116(5):803-810.
8. Oleiwi JK, Salih SI, Fadhil HS. Water Absorption and Thermal properties of PMMA Reinforced by Natural Fibers for Denture Applications. International Journal of Mechanical and Production Engineering Research and Development. 2018 Jun;8(3):1105-1116.
9. Asopa V, Suresh S, Khandelwal M, Sharma V, Asopa SS, Kaira LS, *et al*. A comparative evaluation of properties of zirconia reinforced high impact acrylic resin with that of high impact acrylic resin, The Saudi Journal for Dental Research. 2015 Jul 1;6(2):146-151.
10. Salih SI, Oleiwi JK, Fadhil HS. Study Compression and Impact Properties of PMMA Reinforced by Natural Fibers Used in Denture, Engineering and Technology Journal. 2018 Jun 1;36(6 Part A):652-655.
11. Hamad QA. Study the Effect of Nano Ceramic Particles on Some Physical Properties of Acrylic Resins. Engineering and Technology Journal. 2017 Apr 28;35(2 Part A).
12. Sharhan HA, Rasheed ZN, Oleiwi JK. Synthesis and Physical Characterization of PMMA/PP and PMMA/PAN Composites for Denture Applications. Journal of Applied Sciences and Nanotechnology. 2021 Sep 1;1(3):13-23.
13. Hameed AM, Ali HA. Using Wheat and Barely Legs for Manufacturing Multi-Applications Composite Material. InJournal of Physics: Conference Series 2021 Mar 1 (Vol. 1795, No. 1, p. 012044). IOP Publishing.
14. Jawad KH, Hasson B. Developing strategy for a successful antioxidant, anticancer activity via an improved method prepared to porous silicon nanoparticles. Journal of Applied Sciences and Nanotechnology. 2021 Dec 1;1(4):1-1.
15. Fan M, Dai D, Huang B. Fourier transform infrared spectroscopy for natural fibres. Fourier transform-materials analysis. 2012 May 23;3:45-68.
16. Guerrero BM, Maqueda P, Artiaga R, Jiménez PS, Cosp JP. Structural and Chemical Characteristics of Sisal Fiber and Its Components: Effect of Washing and Grinding, Journal of Natural Fibers. 2016;14:1-14.
17. Rüttermann S, Krüger S, Raab WH, Janda R. Polymerization shrinkage and hygroscopic expansion of contemporary posterior resin-based filling materials—a comparative study. journal of dentistry. 2007 Oct 1;35(10):806-813.
18. Vallittu PK. Effect of 180-week water storage on the flexural properties of E-glass and silica fiber acrylic resin composite. Int. J Prosthodont. 2001;13(13).
19. Miettinen VM, Narva KK, Vallittu PK. Water sorption, solubility and effect of post-curing of glass fibre reinforced polymers. Biomaterials. 1999 Jul 1;20(13):1187-1194.
20. Jagger RG. Effect of the curing cycle on some properties of a polymethylmethacrylate denture base material. Journal of oral rehabilitation. 1978 Apr;5(2):151-157.
21. Hamanaka I, Iwamoto M, Lassila L, Vallittu P, Shimizu H, Takahashi Y. Influence of water sorption on mechanical properties of injection-molded thermoplastic denture base resins. Acta Odontologica Scandinavica. 2014 Nov 1;72(8):859-865.
22. Da Silva EM, Almeida GS, Poskus LT, Guimaraes JGA. Relationship between the degree of conversion, solubility and salivary sorption of a hybrid and a nanofilled resin composite. J Appl. Oral Sci. 2008;16:161-166.
23. ISO. ISO: 20795-1 Dentistry—Denture Base Polymers; ISO: Geneva, Switzerland; c2008. [Google Scholar]
24. Yang A, Zhao D, Wu Y, Xu C. Effect of polyimide addition on mechanical properties of PMMA-based denture material. Dental Materials Journal. 2017 Sep 25;36(5):560-565.
25. Gad MM, Al-Thobity AM, Rahoma A, Abualsaud R, Al-Harbi FA, Akhtar S. Reinforcement of PMMA denture base material with a mixture of ZrO2 nanoparticles and glass fibers. International journal of dentistry. 2019 Jan 28. 2489393.
26. Reinforced PMMA Targeted for Denture Base Application. Materials (Basel). 2021 May 19;14(10):2659. Doi: 10.3390/ma14102659.
27. Pritosh Tomar. Heat transfer augmentation techniques used in circular tube heat exchanger using inserts: a review, Int J Technol Manag (ijrtm) ISSN 2454-6240. April 2017;3(2):14-23.