DEVELOPMENT OF THREE DIRECTIONAL THREE-DIMENSIONAL COMPOSITE DENTURES WITH SHORT GLASS FIBER REINFORCED METHYL METHACRYLATE USING FUSED FILAMENT FABRICATION PROCESS

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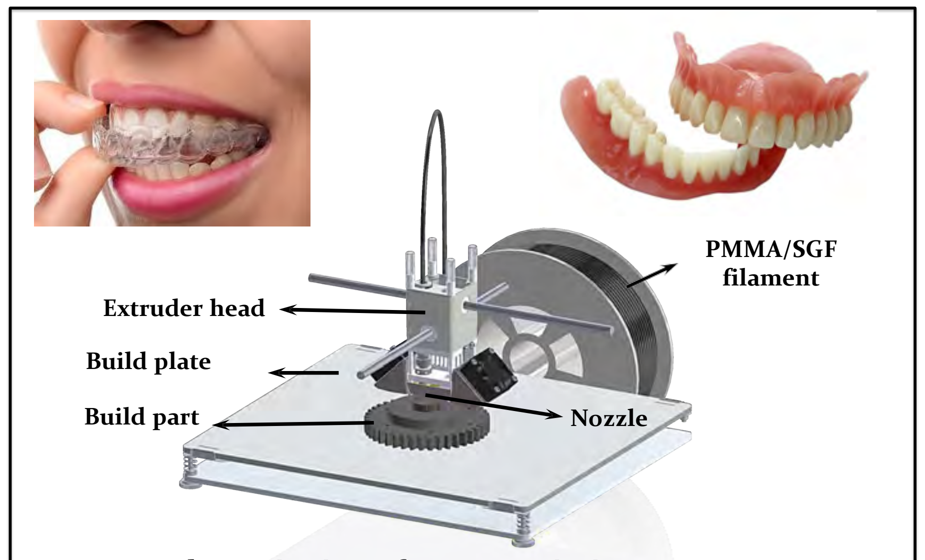
INTRODUCTION AND MOTIVATION

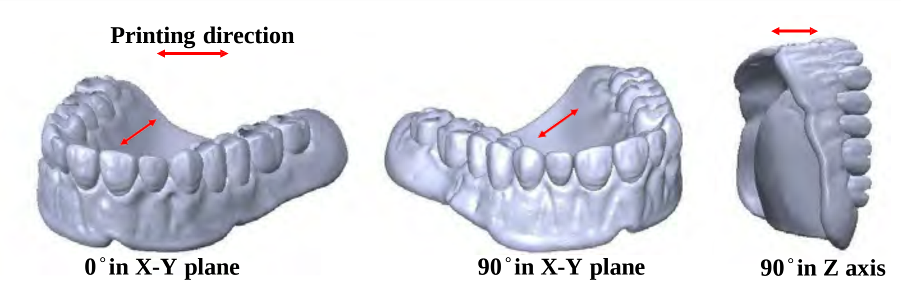
- 3D printing is becoming a subject of great interest in dentistry because if its ability to develop the parts in the layer-by-layer format.
- Use of 3D printing includes the production of drill guides for dental implants, production of physical models of prosthodontics, orthodontics and surgery, fabrication of frameworks for implant and dental restorations.
- Nowadays stereolithography & digital light processing processes are generally used in dentistry for prosthodontic and orthodontic treatments. In these processes, the parts are in constant exposure to chemical compounds which can create the long- and short-term health hazards on users
- So, in order to reduce or eliminate potential short-and-long-term health risks (e.g., allergenic reactions and inhalation toxicity) fused filament fabrication (FFF) or 3D printing process is addressed.



Schematic view of SF-PMC printing process

AIM OF THE PROJECT

- Evaluating the practicality of Fiber reinforced additive manufacturing for constructing patient specific and affordable composite denture bases with improved clinical properties: polymethylmethacrylate (PMMA) as matrix was reinforced with short glass fibers (SGFs) using the fused filament fabrication (FFF) process.
- Producing the dentures in three mutually perpendicular directions (0º in the X-Y plane, 90º in the X-Y plane, and 90º in Z-axis) and finding the optimum direction for highly accurate denture printing with minimum cost, less weight and more clinical properties.



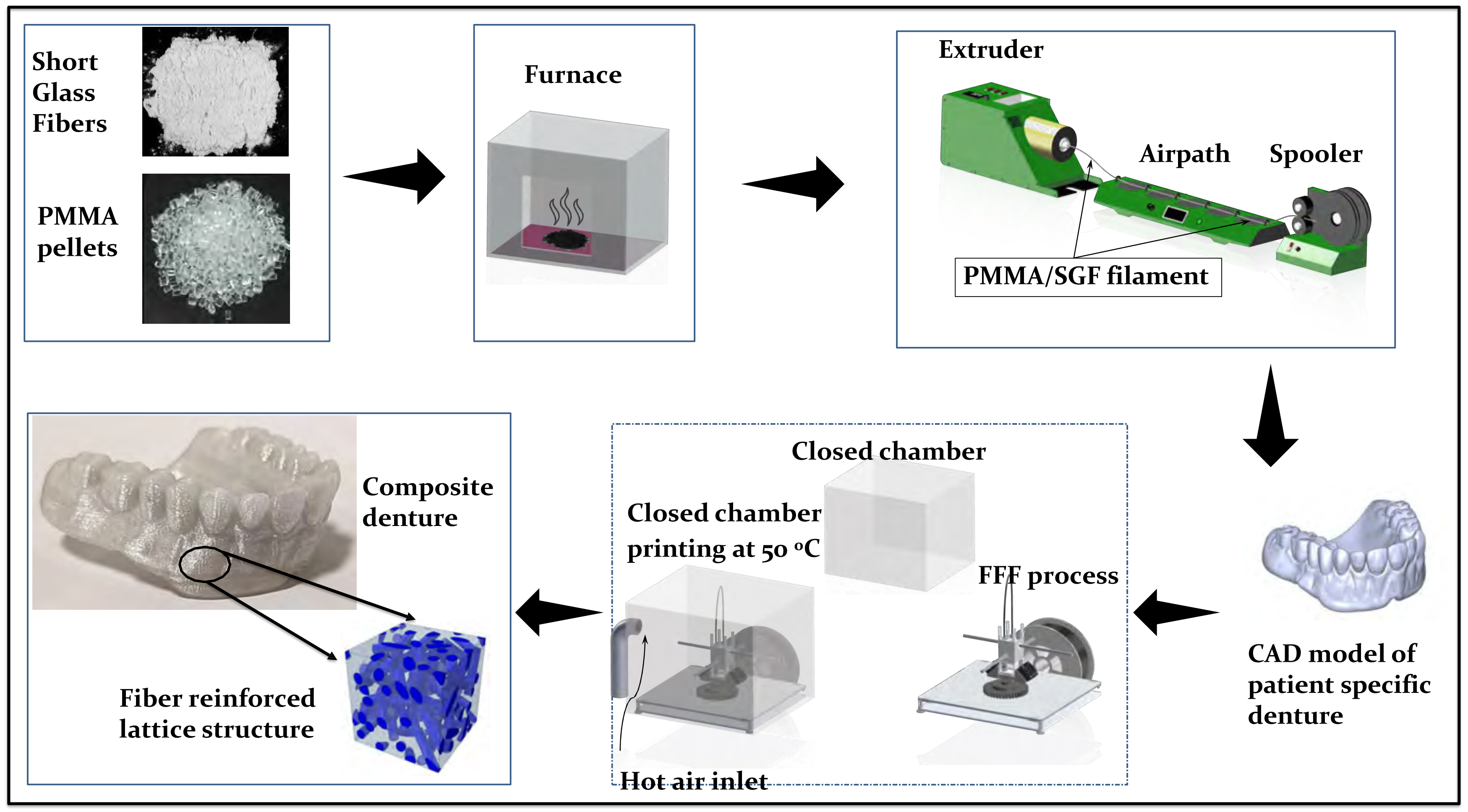
IMPACT OF RESEARCH ON MEDICAL INDUSTRY

This development of patient specific devices using FFF process, a well-known AM process will help in:

- Development of highly accurate, light and structurally durable medical devices that will enhance patient comfort in the long-term.
- low-cost manufacturing of devices without the need for high-priced accessories, tooling and equipment.
- reducing potential short-and-long-term health risks (e.g., allergenic reactions and inhalation toxicity) associated with some materials and techniques.

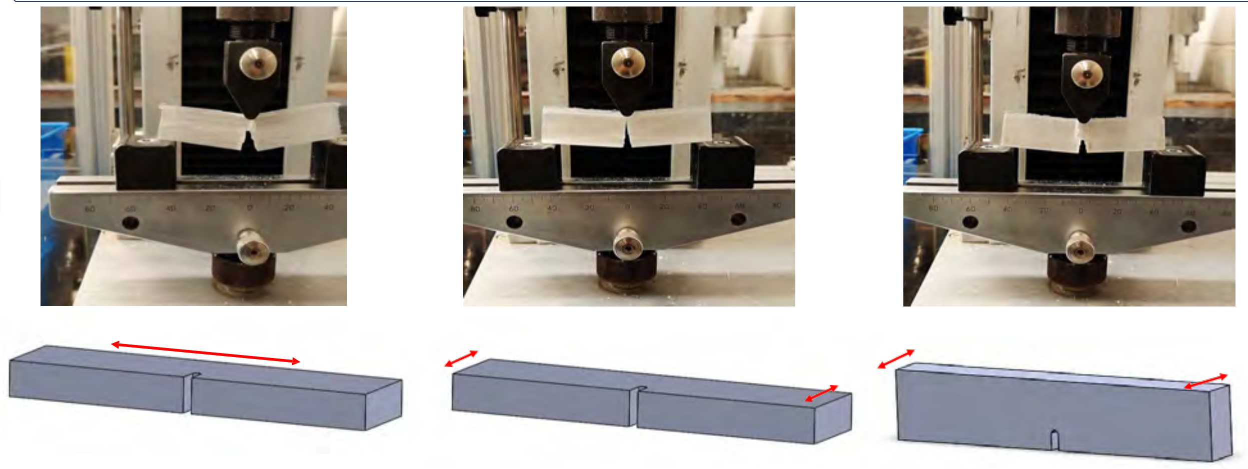
MATERIALS & METHODS

DETAILED DESCRIPTION OF THE PROCESS

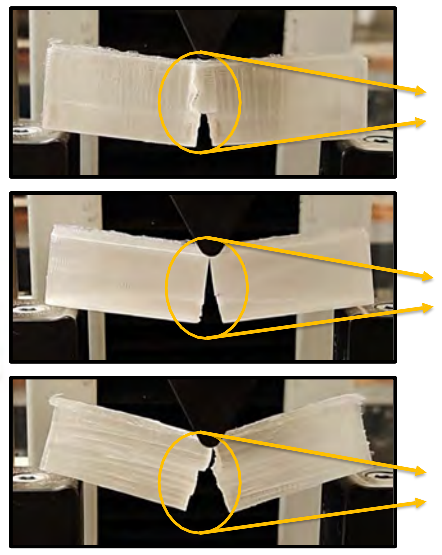


RESULTS AND DISCUSSIONS

Detailed description of fracture test specimens deformed under applied compressive loading are shown below:



0˚in X-Y plane | 90˚in X-Y plane | 90˚in Z axis



Crack propagation in samples printed in 0º in X-Y plane

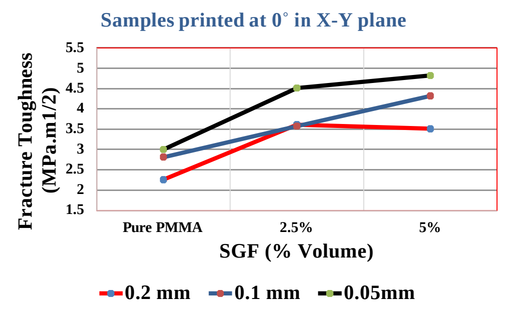
Crack propagation in samples printed in 90º in X-Y plane

Crack propagation in samples printed in 90º in Z-axis

Table 1. Different experimental parameters

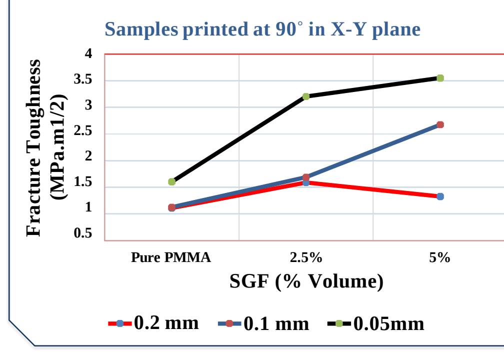
Parameters	Type	Values		
Printing orientation	(Fixed and categorical)	0	90	90T
SGF concentration (% by vol.)	(Random and continuous)	0	2.5	5
Layer height (mm)	(Random and continuous)	0.2	0.1	0.05

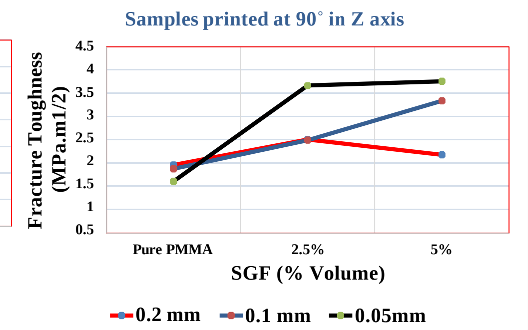
FRACTURE TOUGHNESS RESULTS



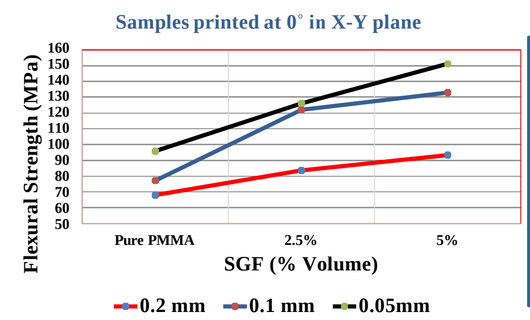
Analysis of fracture toughness

- Fracture toughness (FT) is more for samples printed in 0˚ in X-Y plane
- FT increases as the glass fiber percentage increases
- FT is more for samples with lower layer height



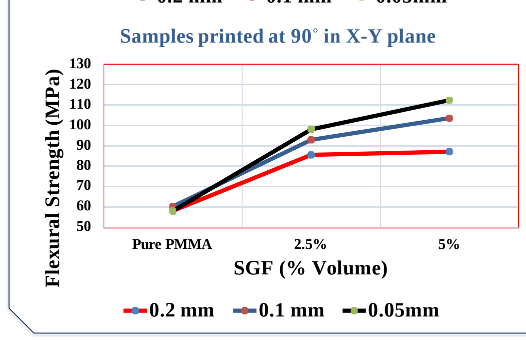


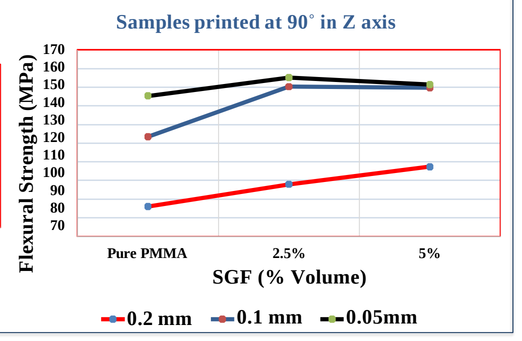
FLEXURAL TESTING RESULTS



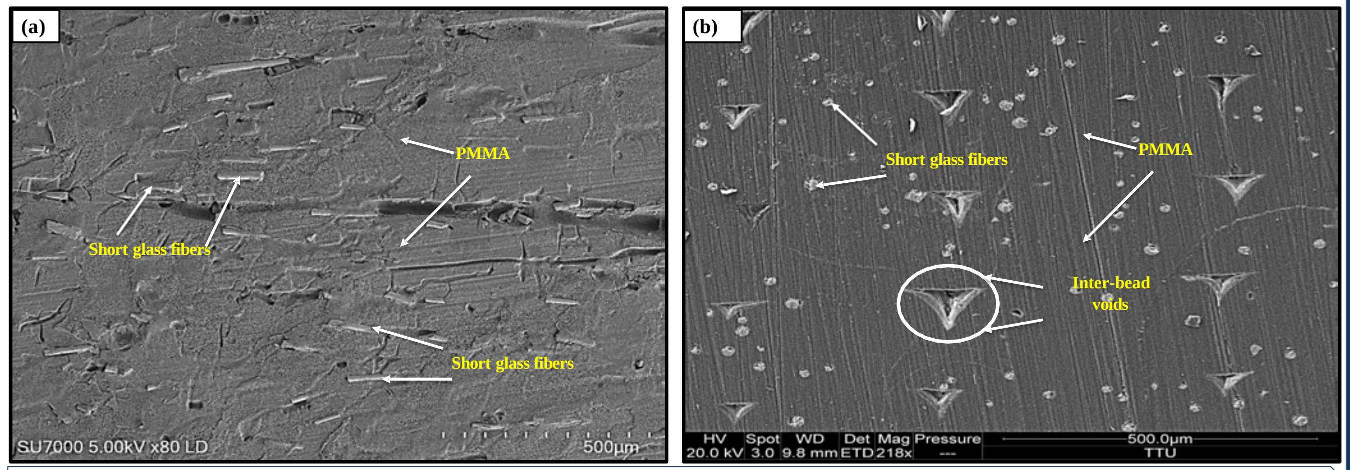
Analysis of flexural strength

- Flexural strength is more for samples printed in 0˚ in X-Y plane
- Strength increases as the glass fiber percentage increases
- Strength is more for samples with lower layer height





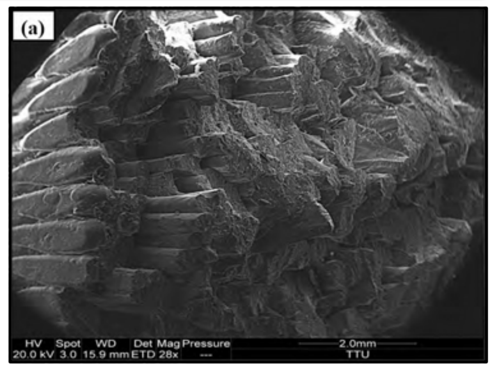
MICROSTRUCTURAL ANALYSIS GLASS FIBER REINFORCED PMMA

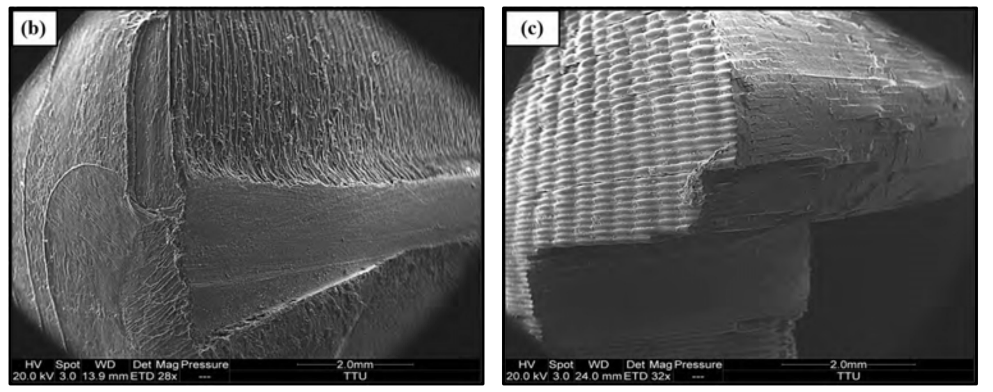


Surface analysis through scanning electron microscopy showed the good adhesion between the fibers and the matrix and also shows that the fibers are well oriented in the printing direction which is the source of providing maximum clinical properties in printing direction

FRACTOGRAPHY ANALYSIS OF GLASS FIBER REINFORCED PMMA

- Figure a, b, and c shows the fracture surfaces of samples developed in 0º in the X-Y plane, 90º in the X-Y plane, and 90º in Z-axis.
- We can easily observe from the fractography analysis that the samples break in different way even if the load application is same.
- This creates the possibility of getting different properties in all the three directions.





COST AND WEIGHT ANALYSIS

Product	Cost ($)
PMMA	39.95$/Kg
Short glass fibers	19.95$/Kg
Denture base (PMMA)	1.00$/25g
Denture base (PMMA/2.5%SGF)	0.972$/25g
Denture base (PMMA/5%SGF)	0.948$/25g

Sample	Layer height (mm)	Weight (g)	Time (hour)
Pure PMMA	0.2	20.72	5 h
Pure PMMA	0.1	21.28	10 h
Pure PMMA	0.05	21.09	15 h
PMMA/2.5%SGF	0.2	17.63	5 h
PMMA/5%SGF	0.2	19.66	5 h

CONCLUSIONS OR ACHIEVEMENTS

- SGF is distributed uniformly inside the PMMA matrix with fewer gaps at the interface indicating good adhesion between the polymers and fibers
- Patient specific composite dentures are successfully developed using 3D printing technique
- Fracture toughness and flexural properties show a significant increase in SGF concentration and decrease in layer height
- Dentures are successfully developed in three mutually perpendicular directions with more properties in 0˚ in X-Y plane

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