An Investigation of Physical and Mechanical Properties of Bioglass Loaded PMMA Bone Cements

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**ABSTRACT:**Bioglass-loaded PMMA (Polymethyl methacrylate) bone cements are composite materials used in orthopedic applications, particularly in bone reconstruction and fixation procedures. Bioglass is a type of bioactive glass that has the ability to bond with bone tissue, promoting bone regeneration and integration. PMMA is a commonly used bone cement that provides stability and mechanical strength.These composite materials combine the excellent mechanical properties of PMMA bone cement with the bioactive characteristics of bioglass, offering improved biocompatibility and enhanced bone regeneration potential. As a result, they have gained significant attention for various orthopedic applications, including joint replacements, bone augmentation, and fracture fixation.The aim of this research is to investigate the physical and mechanical properties of bioglass loaded PMMA bone cements.Cement PreparationSetting Time MeasurementBioactivity and Biocompatibility AssessmentPorosity and Density AnalysisThe morphology of the Bioglass show’s crystalline appears in the SEM image, the elemental composition of it is confirmed by EDXA which shows Ca,Si,P,Mg . The polymer PMMA has a plane morphology and the SEM image of Bioglass with PMMA shows that Bioglass is bonded to the surface and has higher surface roughness than the pristine (Saadh et al., 2024) The PMMA/Bioglass composite exhibits promising properties, making it a potential for a range of biomedical applications, including bone substitutes, tissue engineering scaffolds, and other load-bearing implants (Almatrafi et al., 2024)

**KEYWORDS:**PMMA, Bioglass, scaffold, biocompatible, fracture

# INTRODUCTION

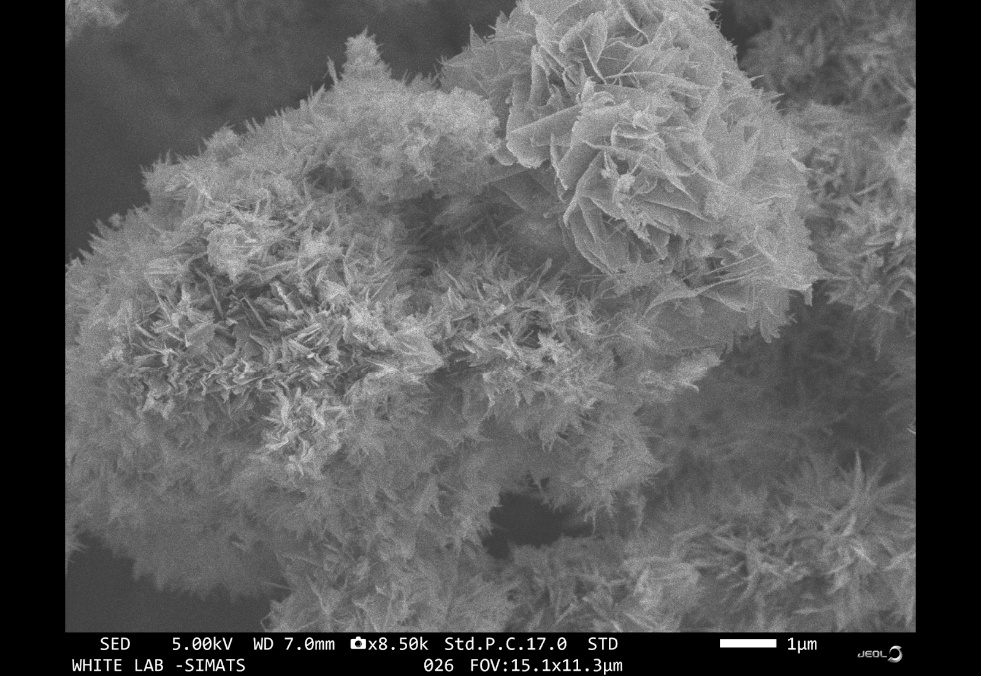
Bioglass, also known as bioactive glass, is a type of glass that has been specially formulated to interact with biological tissues when implanted in the body mainly in bone regeneration [(Zheng et al., 2021)](https://paperpile.com/c/LD13fa/gd5D9).The remarkable biocompatibility of bioglass is one of its most important characteristics [(Matsumoto & Sato, 2015)](https://paperpile.com/c/LD13fa/BMl9h). It solidifies a link with bone when in touch with live tissues.Promotes the development of bone tissue [(Liu et al., 2016; Shanmugam et al., 2013)](https://paperpile.com/c/LD13fa/HJaUf+Kmn1). It facilitates the attachment and proliferation of bone cells, assisting in the regeneration of broken or missing bone.Drug distribution can be carried out using it. Its porous design makes it excellent for localized drug administration at specific locations within the body because it enables the regulated release of medications [(Skwira et al., 2023)](https://paperpile.com/c/LD13fa/sTZcf)[(Ajay et al., 2023; Chokkattu et al., 2023; Padarthi et al., 2023)](https://paperpile.com/c/LD13fa/Sjo2x+a6vkg+zuZoF)[(Dharman et al., 2023; S. Sindhu et al., 2023; Sreenivasagan et al., 2023)](https://paperpile.com/c/LD13fa/EJMVc+6ByOn+loRar)[(Ramakrishnan et al., 2023; Shenoy & Maiti, 2023; J. S. Sindhu et al., 2023)](https://paperpile.com/c/LD13fa/e6ZE2+PoCKD+Eympe)[(Kasabwala et al., 2021; Rajeshkumar & Lakshmi, 2021; Varghese et al., 2023)](https://paperpile.com/c/LD13fa/y8gle+Bftc1+QEdnt). A typical composition of bioglass constitutes of Silica (45%),Sodium Oxide (24.5%), Calcium Oxide (24.5%),Phosphorus Pentoxide (6%)[(Fiume et al., 2018; Viishaal Srikanth Srivatsa & Manogaran, 2024)](https://paperpile.com/c/LD13fa/qoyEi+pimo). However, 3D BG scaffolds in bone tissue engineering are often impeded by its brittleness, low fracture toughness and less osteoinductivity [(Yao et al., 2014)](https://paperpile.com/c/LD13fa/fcB8n), adding a nanoparticle like magnesium and PMMA is an effective way of increasing bone regeneration capacity [(Ben-Arfa et al., 2019)](https://paperpile.com/c/LD13fa/jDSwd)[(Keerthana & Ramesh, 2021; Murugesan, 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/LD13fa/BDEbd+cixFA+a8kxx)[(Keerthana & Ramesh, 2021; Murugesan, 2021; Subramanian et al., 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/LD13fa/BDEbd+cixFA+a8kxx+Tgq3y)[(Evaluation Composite Restoration Posterior Teeth Proanthocyanidin Pretreatment Liner Using Fédération Dentaire Internationale Criteria: Split-Mouth Randomized Controlled Trial, n.d.; Pranati et al., 2021; Sakthi 2021)(Evaluation Composite Restoration Posterior Teeth Proanthocyanidin Pretreatment Liner Using Fédération Dentaire Internationale Criteria: Split-Mouth Randomized Controlled Trial, n.d.; Pranati et al., 2021; Sakthi 2021)](https://paperpile.com/c/LD13fa/KUPp+f0xp+Q1TM)[(G. & Ganapathy, 2022; Kumar & Ramesh, 2021)](https://paperpile.com/c/LD13fa/7qnaA+ONkRj)). A synthetic polymer poly methyl methacrylate (PPMA)is created by polymerizing methyl methacrylate monomers.Medical equipment made of PMMA includes dental prostheses, and orthopedic implants[(Komatsu et al., 2022)](https://paperpile.com/c/LD13fa/xgjw1). Compared to glass, PMMA has a higher impact resistance. In some situations, it is a safer alternative because it is less prone to break on impact [(Hamajima et al., 2020; Sathya et al., 2024)](https://paperpile.com/c/LD13fa/8rslz+Ml6v).The ability of PMMA bone cement's bioactivity encourages better integration with the surrounding bone tissue by adding bioglass particles to it. Ions that are released by bioglass particles enhances the bone formation and lower the chance of implant loosening [(Tsukimura et al., 2009)](https://paperpile.com/c/LD13fa/yGKHk). Dentures, bridges, and dental crowns are all made of PMMA-based materials,these materials biocompatibility can be increased by adding bioglass particles, which could decrease the possibility of bacterial colonization [(Thiripelu et al., 2024; Zia et al., 2022)](https://paperpile.com/c/LD13fa/eU1sE+M9B8).It has been demonstrated that magnesium has a beneficial effect on bone regrowth. It can encourage the production of hydroxyapatite, a mineral that makes up natural bone, and enhance osteoblast activity[(Garcia et al., 2015)](https://paperpile.com/c/LD13fa/zMAb3). Inclusion of magnesium may increase the scaffold's bioactivity and promote better host tissue integration.Anti-inflammatory properties are seen in magnesium. Its inclusion can lessen implant-site inflammation, which is crucial for tissue repair and integration [(Kang et al., 2022)](https://paperpile.com/c/LD13fa/jHoK4).Mesoporous scaffolds can act as a support structure for the formation of bone tissue and blood vessels. They promote osteoconduction, allowing bone cells to move and develop new bone tissue inside the porous framework of the scaffold [(Kim et al., 2016; Paramasivam et al., 2023)](https://paperpile.com/c/LD13fa/Cp5yG+4Qm5).

The aim of the study is to analyze the mechanical biological properties of mesoporous Ca- Si-P-Mg incorporated with PMMA hybrid scaffolds.

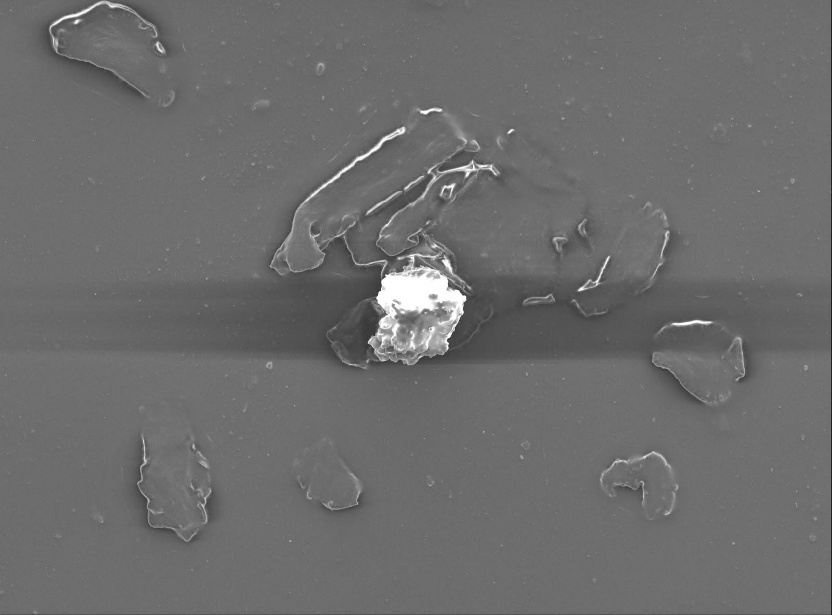
# Material and method

MATERIALS: PMMA bone cement powder Bioglass particlesMETHODS: Cement Preparation: PMMA bone cement powder and bioglass particles are mixed in the desired ratios. The mixing process is performed using a mechanical mixer or a mortar and pestle to ensure homogeneity.The PMMA bone cement liquid monomer is added to the powder mixture and mixed thoroughly according to the manufacturer's instructions. The ratio of powder to liquid is maintained as per the recommended formulation. Setting Time Measurement: The setting time of the bioglass loaded PMMA bone cement is measured using standardized testing methods such as the Gillmore needle test or the Vicat needle penetration test. Bioactivity and Biocompatibility Assessment Porosity and Density Analysis

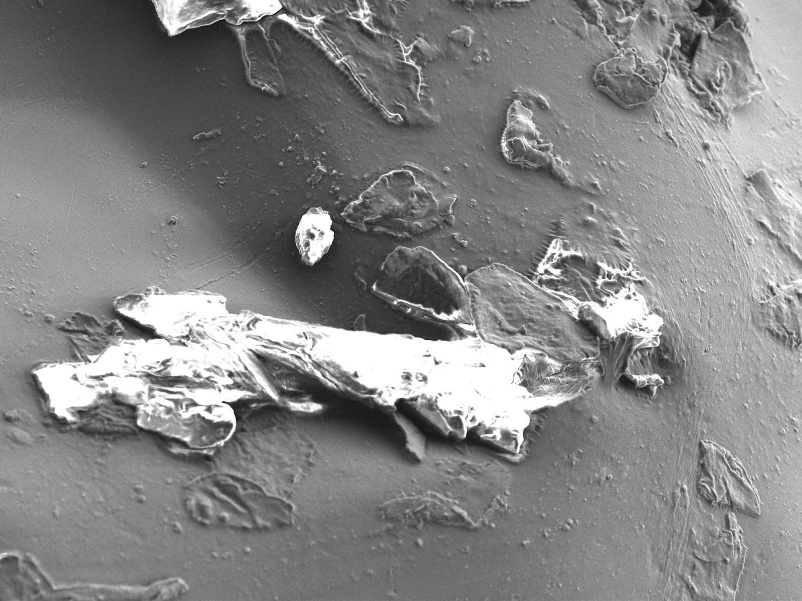
# Result



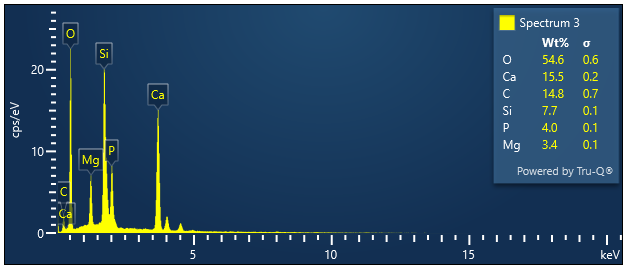
**Fig 1:** SEM image showing the morphology of bioglass



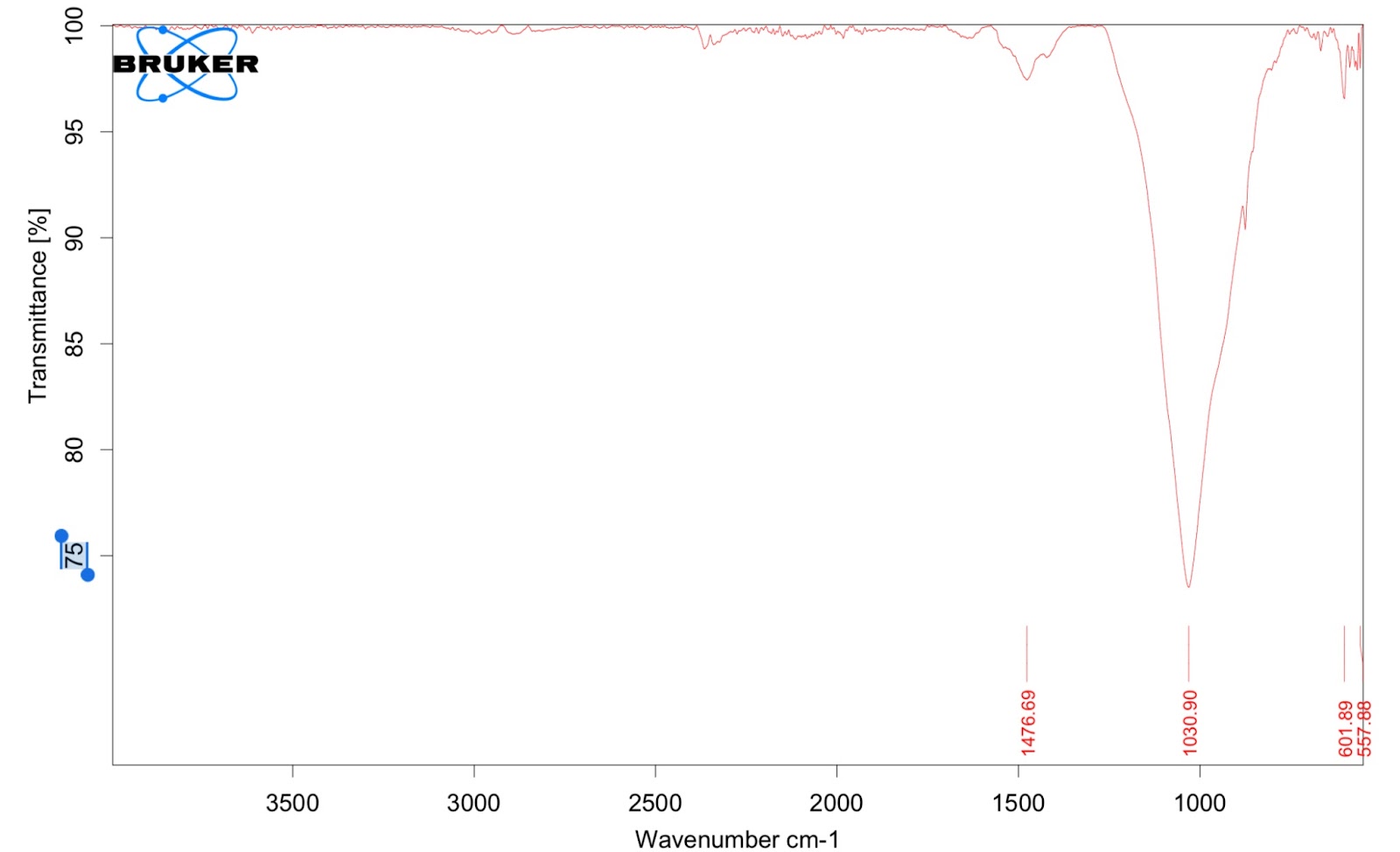
**Fig 2:** SEM image showing the morphology of Pristine PMMA



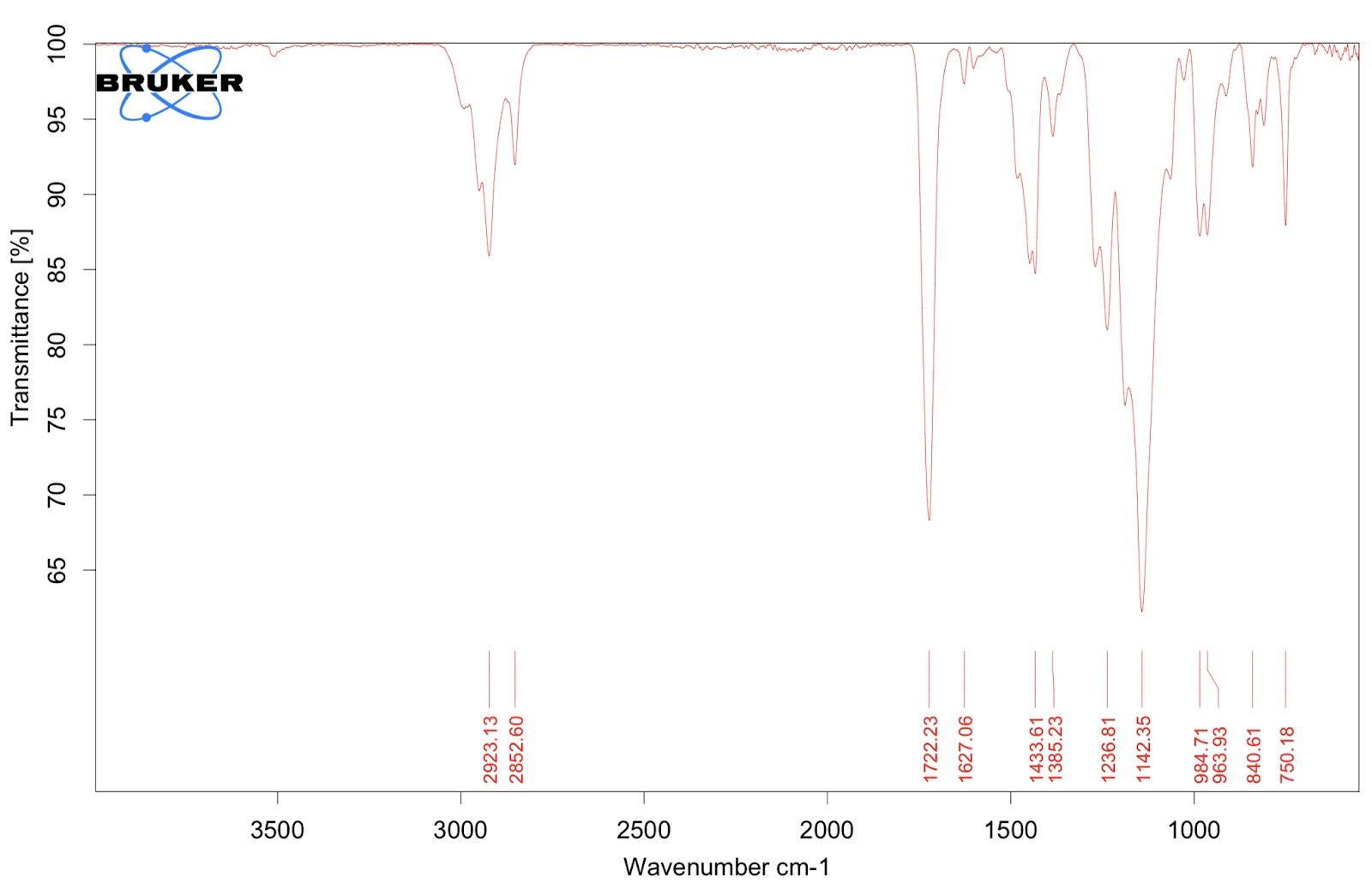
**Fig 3:** SEM image showing the morphology of PMMA Bioglass



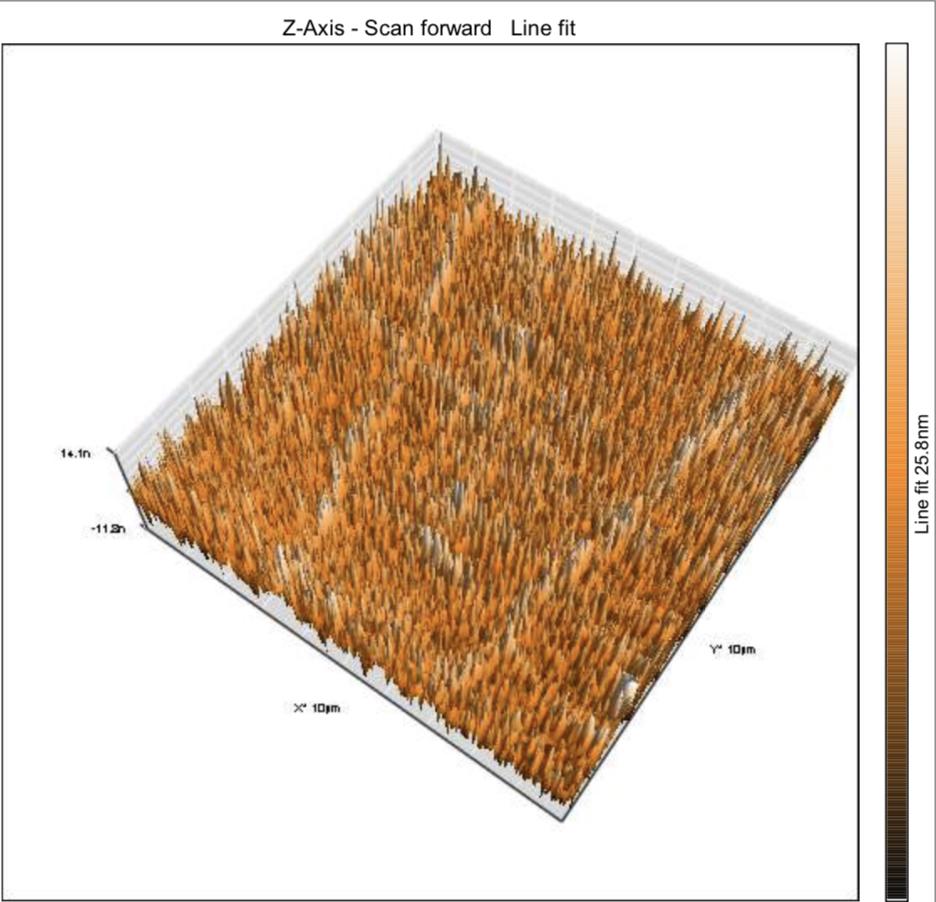
**Fig 4 :** EDXA showing the elemental composition of bioglass.



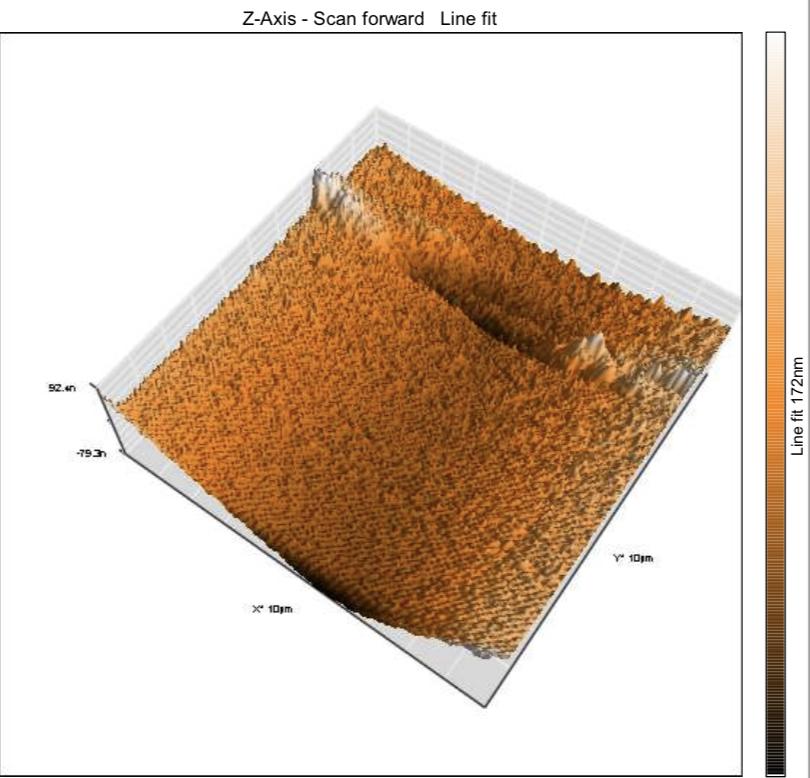
**Fig 5:** FTIR showing the peaks of the elements in the Bioglass



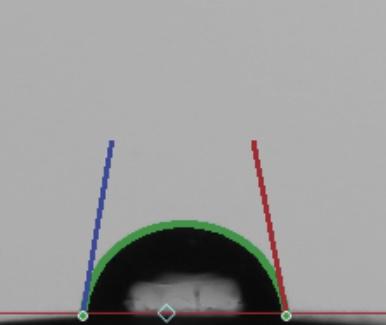
**Fig 6:** FTIR showing the peaks of the elements of PMMA Bioglass



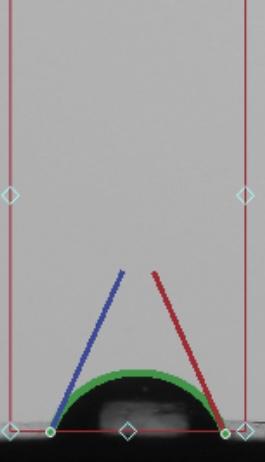
**Fig 7:** AFM shows the surface roughness of Pristin PMMA (S.A- 3.2172nm)



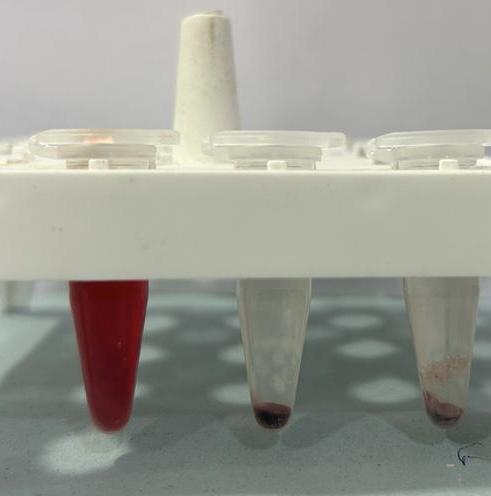
**Fig 5:** AFM shows surface roughness of PMMA Bioglass(S.A-17.582nm)



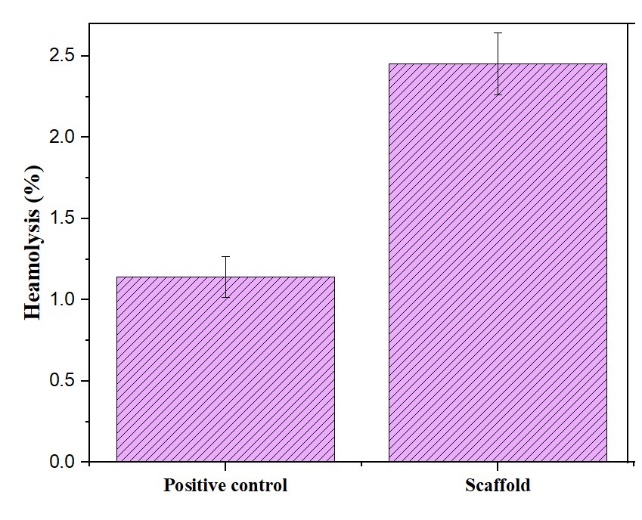
**Fig 8:** Contact angle of PMMA (79.8°)



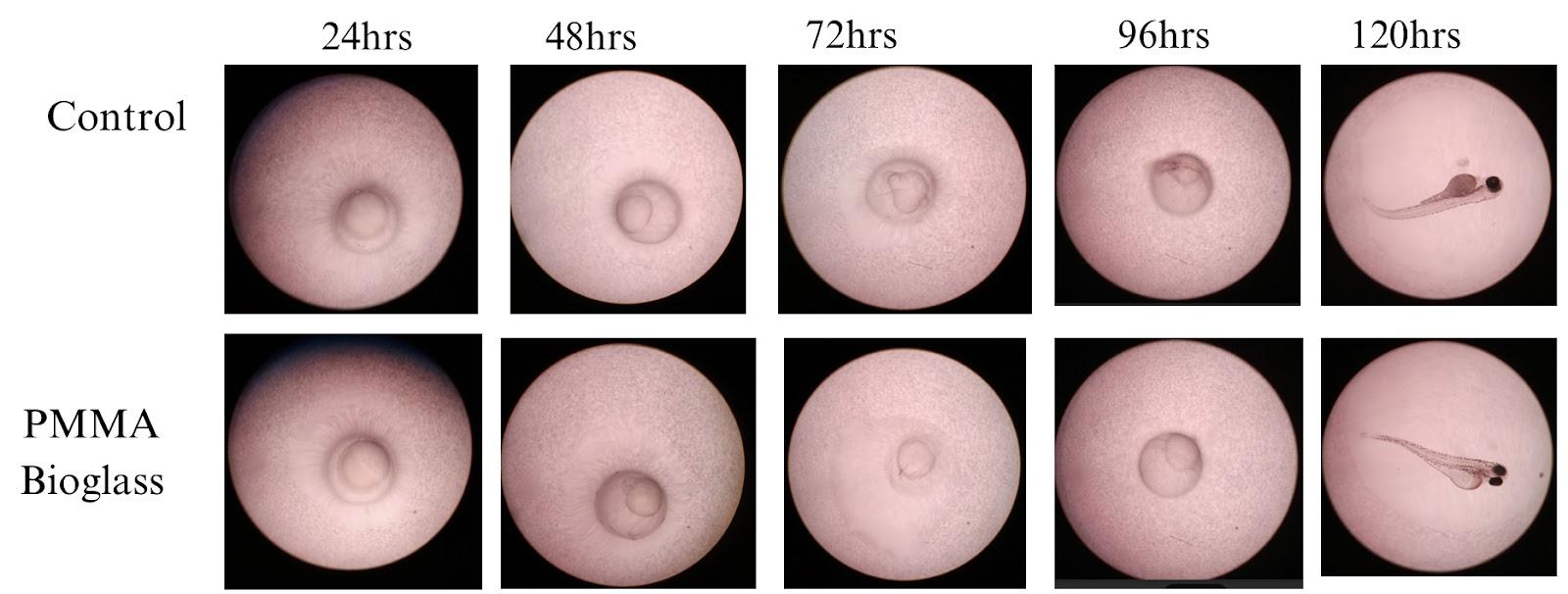
**Fig 9:** Contact angle of PMMA Bioglass (64°)



**Fig 10:** Hemocompatibility test of the scaffold

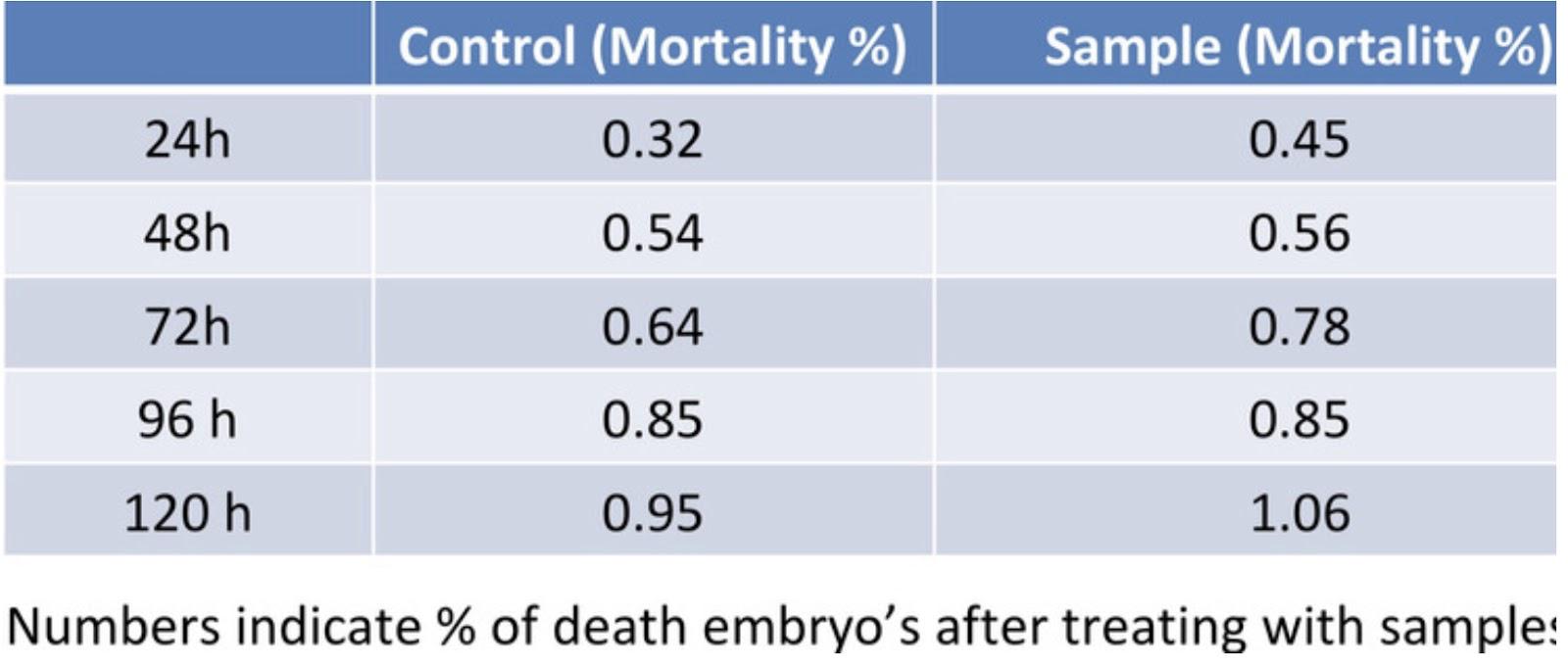


**Fig 11:** Hemocompatibiliy of the scaffold



**Fig 12:** Zebrafish toxicology analysis of PMMA bioglass

**Table 1:** Number of indicate % of death embryo’s after treating with sample



# Discussion

The morphology of the Bioglass show’s crystalline appears in the SEM image, the elemental composition of it is confirmed by EDXA which shows Ca,Si,P,Mg . The polymer PMMA has a plane morphology and the SEM image of Bioglass with PMMA shows that Bioglass is bonded to the surface and has higher surface roughness than the pristine PMMA which is given by AFM analysis. To test the biocompatibility of the scaffold we used hemocompatibility,zebrafish toxicology assay and contact angle.ZnO and MgO were doped into the 45S5 BG scaffolds by Cao et al. to demonstrate improved compressive strength and fracture toughness. The 2D Nano Silicate (Laponite®, XLS), a magnesium silicate (Na+0.7[(Si8Mg5.5Li0.3)O20(OH)4]−0.7), has been shown to greatly improve the mechanical characteristics of polymeric matrix because XLS nanosheet may function as the filler and physical crosslinker to the polymer [(Cidonio et al., 2019; Xavier et al., 2015)](https://paperpile.com/c/LD13fa/EzX01+jOJFb).Future studies can be carried out by optimisation of composite composition and also by assessing long term performance. The synergistic effects of bio active factors with Ca-Si-P-an composite can be investigated to develop scaffolds with additional functionality.Analysing the biodegradability of the scaffold whether it stays forever and help in remineralization of the bone or only till the bone gets healed by animal models. Future advancement in this area can significantly impact the field of dental tissue engineering and regenerative medicine

# Conclusion

The PMMA/Bioglass composite exhibits promising properties, making it a potential for a range of biomedical applications, including bone substitutes, tissue engineering scaffolds, and other load-bearing implants.

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