Fabrication and In Vitro Characterisation of Ca-Si-P-Mg- Mesoporous Composite Incorporated PMMA Scaffolds

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**Abstract:** The blend of calcium (Ca), silicon (Si), phosphate (P), and Magnesium (Mg) offers the potential for enhanced mechanical performance and improved biological response. PMMA is used as a base polymer is added to increase the strength of the scaffold and has well-established biocompatibility, ease of fabrication, and desirable mechanical properties.Blending PMMA with the Ca-Si-P-Mg components, gives synergistic effects of these elements, which are known for their osteogenic and angiogenic potential.The mesoporous nature of the scaffold provides a favorable environment for cell adhesion, proliferation, and differentiation, promoting tissue regeneration processes. Transparent bio glass solution was prepared by SOL GEL METHOD. Dissolve Ca-Si-P-Mg powder in acetone & 15% PMMA was dissolved in acetone ,Equal volumes of the transparent bio glass solution and the polymer mixture were added to obtain the scaffold material.The heat treatment was essential since the dissolubility of PMMA in these solvent mixture at room temperature is very low. The aim of this study is to analyse the mechanical biological properties of mesoporous Ca- Si-P-Mg incorporated with PMMA hybrid scaffolds.

**Keywords:** Bioglass, PMMA, Ca-Si-P-Mg, mesoporous composite, scaffold, bone regeneration, Solgel method.

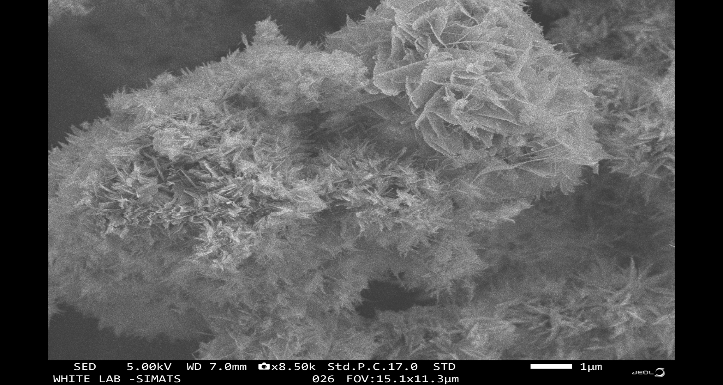
# Introduction

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/EZYPll/6XvP). The remarkable biocompatibility of bioglass is one of its(Chehelgerdi et al., 2023) most important characteristics [(Matsumoto & Sato, 2015)](https://paperpile.com/c/EZYPll/VcLN). 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/EZYPll/BC0V+Mgki). It facilitates the attachment and proliferation of bone cells, assisting in the regeneration of broken or missing bone(Nikalje et al., 2024).Drug distribution can be carried out using it. [(G. & Ganapathy, 2022; Kumar & Ramesh, 2021)](https://paperpile.com/c/EZYPll/2LfcO+0fvl3)) 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; Viishaal Srikanth Srivatsa & Manogaran, 2024)](https://paperpile.com/c/EZYPll/CcOm+s1yq). A typical composition of bioglass consists of Silica (45%),Sodium Oxide (24.5%), Calcium Oxide (24.5%),Phosphorus Pentoxide (6%) [(Fiume et al., 2018)](https://paperpile.com/c/EZYPll/i2cG). 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/EZYPll/gP9I), 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/EZYPll/c4C1).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/EZYPll/qsuC). 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/EZYPll/MFnG+x1vf). The ability of PMMA bone cement's bioactivity encourages better integration with the surrounding bone tissue by adding bioglass particles to it. [(Keerthana & Ramesh, 2021; Murugesan, 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/EZYPll/93DVX+QiNEH+UGXbu)[(Keerthana & Ramesh, 2021; Murugesan, 2021; Subramanian et al., 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/EZYPll/93DVX+QiNEH+UGXbu+vgXeM) Ions that are released by bioglass particles enhance bone formation and lower the chance of implant loosening [(Tsukimura et al., 2009)](https://paperpile.com/c/EZYPll/Ri2O). 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/EZYPll/xENy+Glf3).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/EZYPll/Mz8L). 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; Paramasivam et al., 2023)](https://paperpile.com/c/EZYPll/OlZk+nLJK).Mesoporous scaffolds can act as a support structure for the formation of bone tissue and blood vessels. [(*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/EZYPll/a6qMP+iJPDo+gkTz6) They promote osteoconduction, allowing bone cells to move and develop new bone tissue inside the porous framework of the scaffold [(Kim et al., 2016)](https://paperpile.com/c/EZYPll/Ruea). The aim of the study is to analyze the mechanical biological properties of mesoporous Ca- Si-P-Mg incorporated with PMMA hybrid scaffolds.

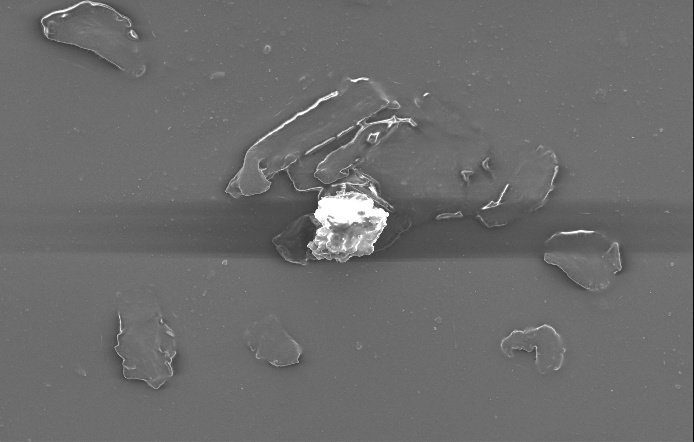
# Material and method

Transparent bio glass solution was prepared by SOL GEL METHOD. Dissolve Ca-Si-P-Mg powder in acetone & 15% PMMA was dissolved in acetone ,Equal volumes of the transparent bio glass solution and the polymer mixture were added to obtain the scaffold material.The heat treatment was essential since the dissolubility of PMMA in these solvent mixture at room temperature is very low.

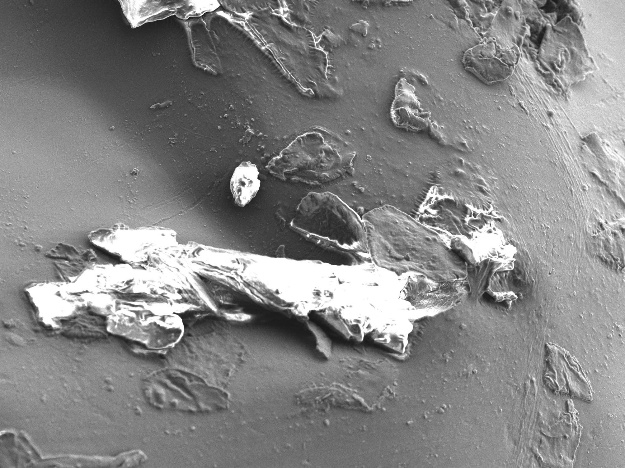
# Results



**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

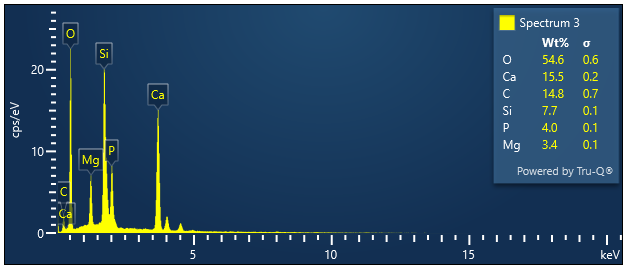
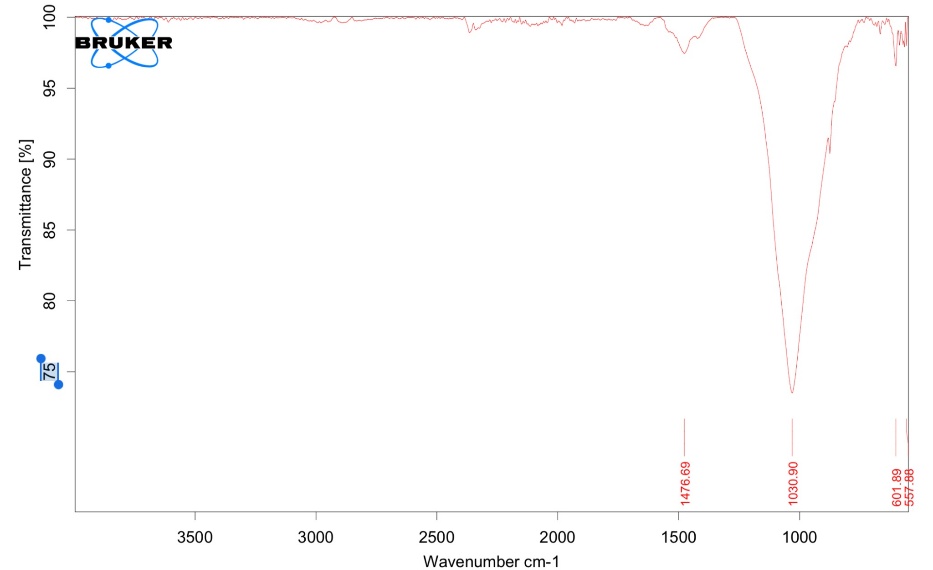
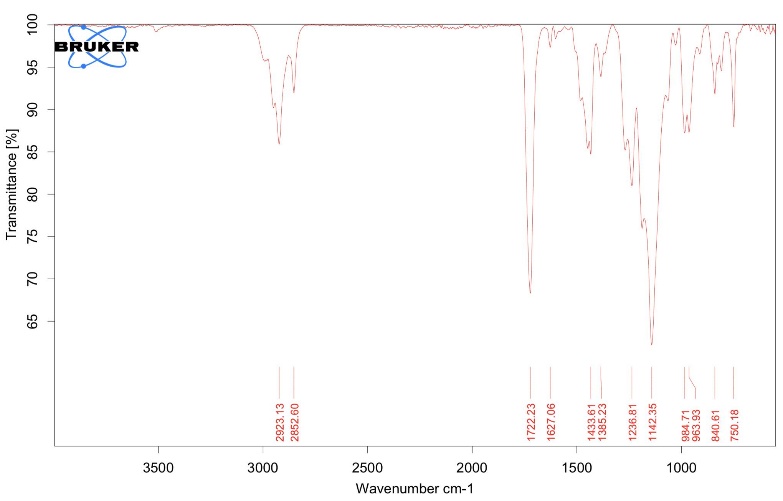


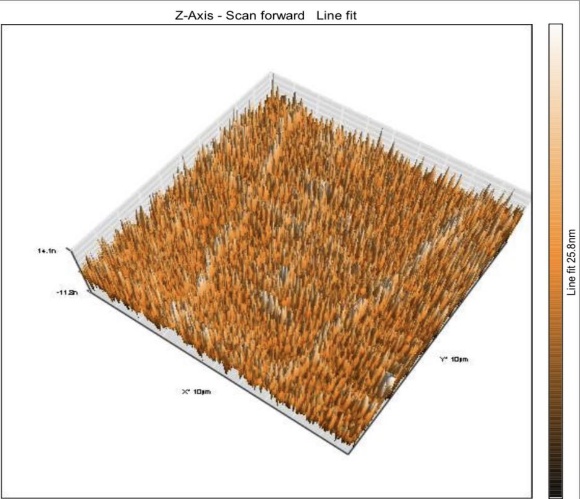
Fig 4: EDXA showing the elemental composition of bioglass.



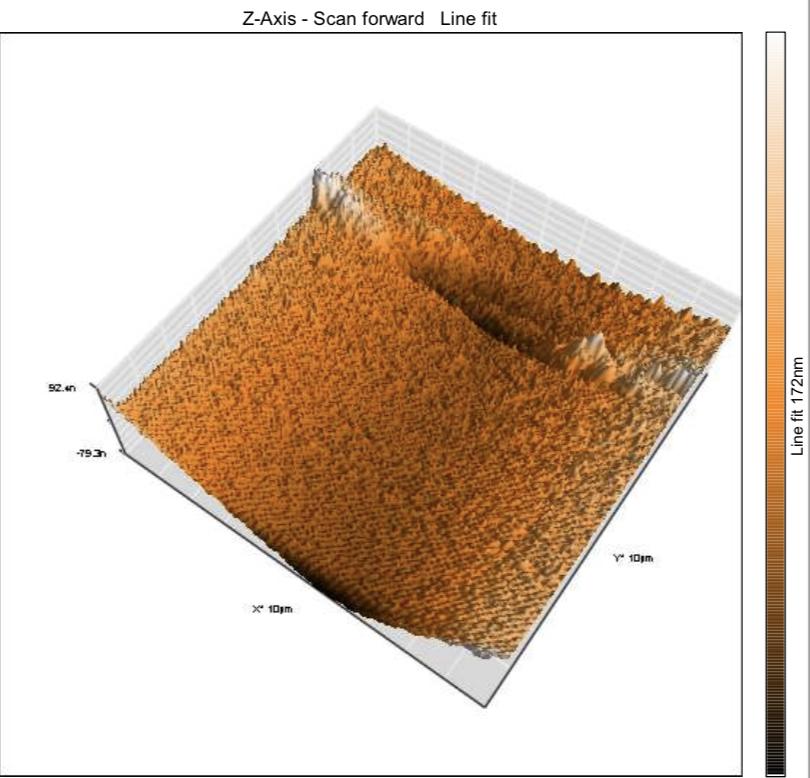
**Fig 5:** FTIR showing the peaks of the elements in the Bioglass



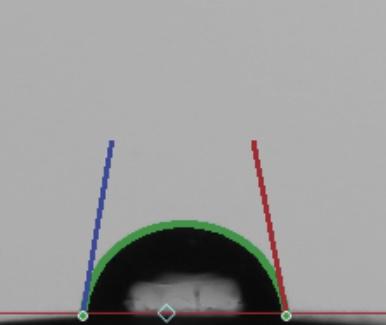
**Fig 6:** FTIR showing the peaks of the elements of PMMA Bioglass



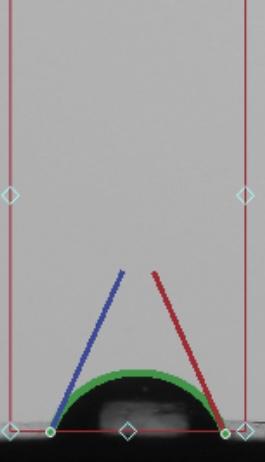
**Fig 7:** AFM shows the surface roughness of Pristin PMMA (S.A- 3.2172nm)



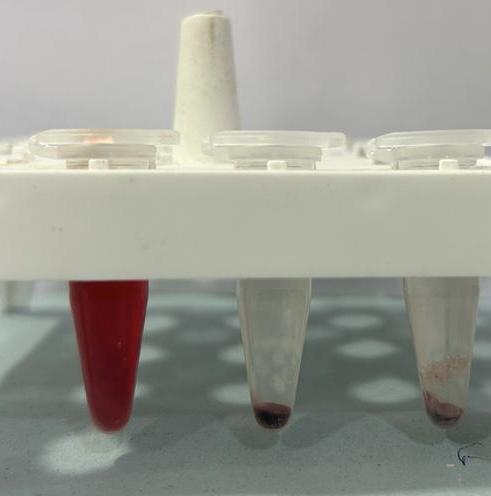
**Fig 8:** AFM shows surface roughness of PMMA Bioglass(S.A-17.582nm)



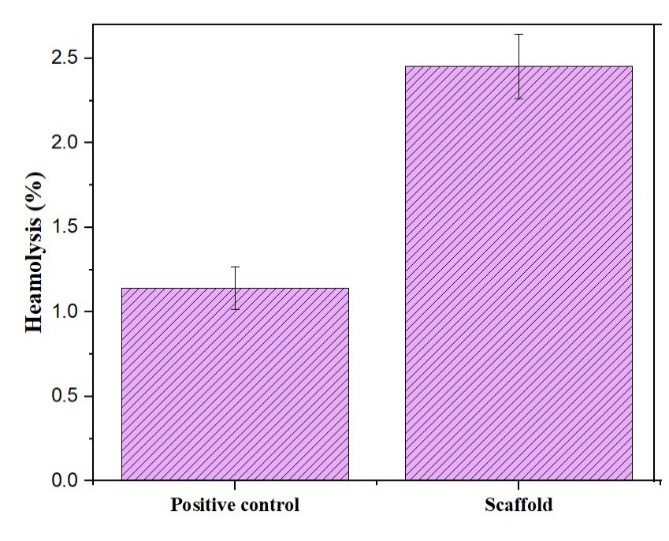
**Fig 9:** Contact angle of PMMA (79.8°)



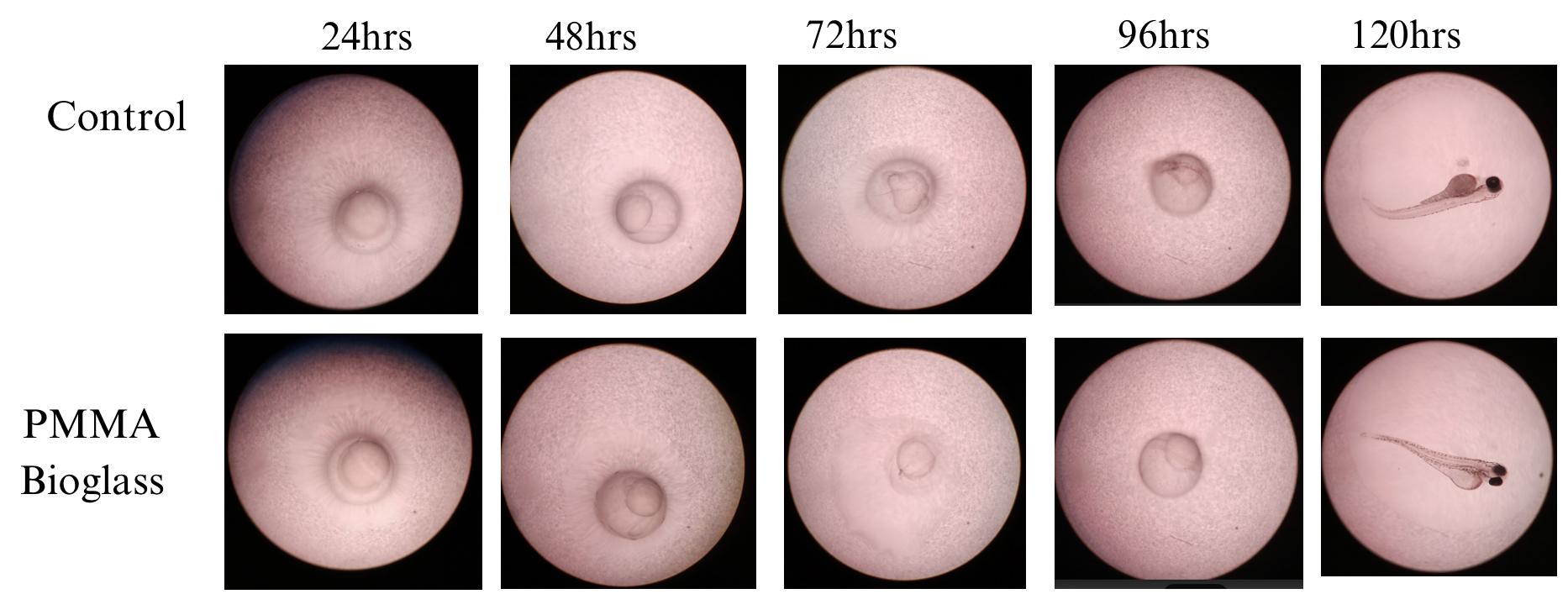
**Fig 10:** Contact angle of PMMA Bioglass (64°)



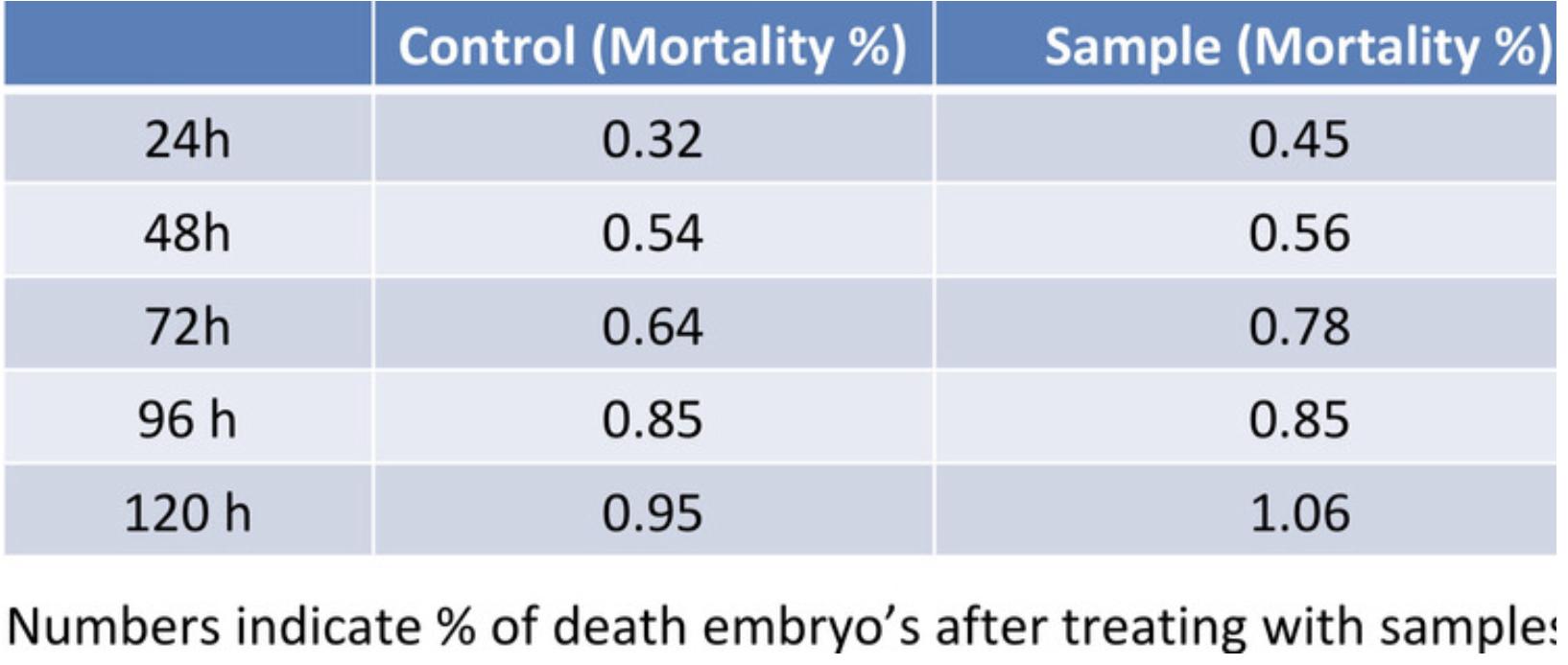
**Fig 11:** Hemocompatibility test of the scaffold



**Fig 12:** Hemocompatibiliy of the scaffold



**Fig 13 :** Zebrafish toxicology analysis of PMMA bioglass



**Fig 14:** 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 . [(Kasabwala et al., 2021; Rajeshkumar & Lakshmi, 2021; Varghese et al., 2023)](https://paperpile.com/c/EZYPll/H0DUE+2dORN+E8j5H) 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.[(Ramakrishnan et al., 2023; Shenoy & Maiti, 2023; J. S. Sindhu et al., 2023)](https://paperpile.com/c/EZYPll/YOCNJ+vkj6c+cyTTm)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/EZYPll/yQQ9+GTC8).Future studies can be carried out by optimisation of composite composition and also by assessing long term performance.[(Ajay et al., 2023; Chokkattu et al., 2023; Padarthi et al., 2023)](https://paperpile.com/c/EZYPll/QoEri+wEpx2+ThNyF) 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.[(Dharman et al., 2023; S. Sindhu et al., 2023; Sreenivasagan et al., 2023)](https://paperpile.com/c/EZYPll/CQUq7+ilC7P+9IP9U) 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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