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Degradability, Biological Properties of PMMA Bioglass towards Regenerative Applications

P. Titus Lalith Antony[1], S. Praveen Kumar[2], Chitra S[1], Saheb Ali[3], Lakshmi Thangavelu[2], Dhanraj Ganapathy[1*]

[1]*Department of Prosthodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India*
[2]*Centre for Global Health Research (CGHR)Saveetha Medical College ,Saveetha Institute of Medical and Technical Sciences, Saveetha University ,Chennai, Tamil Nadu, India*
[3]*Department of Periodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India*
Email: dhanraj@saveetha.com

PMMA borate bioglass thin films have drawn growing interest in regenerative medicine because of their special mix of biodegradability and advantageous biological characteristics. These thin films are built from polymethyl methacrylate (PMMA) matrix mixed with borate bioactive glass, resulting in a synergistic biomaterial platform with enormous potential for tissue engineering and wound healing applications. PMMA's regulated biodegradability enables its slow breakdown and fusion with regenerated tissue, while the borate bioactive glass component releases vital bioactive ions including calcium, silicon, and sodium to support cellular responses and tissue regeneration.In this review, we examine the bioglass thin films made of PMMA and borate and highlight their biological characteristics that are pertinent to regenerative medicine. According to experimental research, over time, these films experience controlled PMMA hydrolysis and the release of bioactive ions, allowing for a synchronized disintegration process that matches the rate of tissue recovery. The thin films also exhibit outstanding cytocompatibility, promoting cell adhesion, proliferation, and differentiation—all essential processes for tissue growth and regeneration.The addition of borate bioactive glass to the thin films improves their bioactivity while also increasing angiogenesis and osteogenesis, which aid in tissue integration and bone and cartilage regeneration. These thin films serve as a link between biomaterials and regenerative medicine, and further study and improvement could lead to the discovery of novel approaches to tackle difficult medical problems and enhance patient outcomes.

Keywords: biodegradability, disintegration, angiogenesis, differentiation, regenerative.

1. Introduction

In the realm of regenerative medicine, degradable biomaterials are essential because they provide creative answers to the complicated problems posed by tissue repair and regeneration(Ravarian et al. 2013). PMMA bioglass composites, one of these biomaterials, have drawn a lot of attention because of its distinctive combination of biological and degradable qualities. Bioglass, a bioactive substance recognized for its capacity to stimulate osteointegration and tissue regeneration, is combined with PMMA, a biocompatible and frequently used synthetic polymer. A flexible platform with enormous potential for diverse regeneration applications is produced by this synergistic combination(Samavedi et al. 2014). Biomaterials must be able to degrade in order for regenerative applications to be successful. Because of their regulated degradability, PMMA bioglass composites are excellent options for temporary implants and scaffolds(Yu et al. 2015). In physiological fluids, the bioglass component progressively dissolves, releasing vital bioactive ions like calcium and silicon that promote cellular activity and tissue regeneration. Parallel to this, the PMMA matrix goes through controlled hydrolysis, causing the composite to gradually disintegrate and ultimately negating the need for invasive removal techniques(Zheng et al. 2021).The biological characteristics of PMMA bioglass composites have a crucial role in how regenerative they can be. The bioactive glass component promotes osteointegration and bone regeneration by assisting in the creation of a hydroxyapatite layer at the material-tissue contact. This property is especially useful in applications involving bone tissue engineering, where the composite's capacity to foster the growth of new bone speeds up the healing process and improves the structural integrity of the regenerated tissue(Gohil et al. 2017).Furthermore, minimum adverse reactions are guaranteed by the biocompatibility of PMMA and bioglass, which also permits flawless interactions with host tissues. This trait is essential for preventing inflammatory reactions and promoting cell adhesion and proliferation, which are essential elements for effective tissue repair and regeneration(Idumah et al. 2019).PMMA bioglass composites' special fusion of biodegradability and biological attributes opens up a wide range of regenerative applications. These composites can be used as bone scaffolds in orthopedics, offering a short-term mechanical support that gradually fuses with the surrounding tissues as it deteriorates(Abodunrin et al. 2023). Additionally, the composite's capacity for promoting cellular activity is improved by the regulated release of bioactive ions from the bioglass component, providing a supportive environment for tissue regeneration. PMMA bioglass composites have applications in soft tissue engineering in addition to bone regeneration. They provide continuous therapeutic release to aid in the repair of chronic wounds and tissue abnormalities thanks to their customizable surface characteristics and customized degradation profiles(Baino et al. 2016).PMMA bioglass composites are potential biomaterials for regenerative applications because of their biodegradability. They are positioned as adaptable platforms in the search for efficient tissue repair and regeneration due to their regulated disintegration, bioactivity, and biocompatibility(Deshmukh et al. 2020).

2. Materials and Methods:

2.1 Materials

PMMA, also known as polymethyl methacrylate, is a high-grade polymer that has a known molecular weight and purity and is utilized as the matrix material.Borate Bioactive Glass: As the reinforcing phase, silicon (Si), calcium (Ca), and phosphorous (P)-containing bioactive glass particles are chosen because of their specific composition.Organic solvents, such acetone or chloroform, are used to dissolve PMMA and make the manufacturing of composites easier.

2.2 Methods

The PMMA and borate bioactive glass are dissolved in a solvent to create a uniform combination, which is then used to create a solution. Then added 100 mg of prepared bioglass poured in petri-plate kept at 18 °C, overnight for casting.

2.3 Characterization Techniques:

Synthesized Bioactive materials were characterized to further analyse the properties of the prepared materials. X-ray diffraction patterns used to study the crystalline phases with the wavelength of Cu Kα (Bruker D8 advance). Functional group properties were analyzed through Raman spectroscopy (WITEC ALPHA300 RA – Confocal Raman Microscope with AFM). To investigate the morphological and elemental analysis by FE-SEM and EDS [JEOL (JSM -IT 800) { FE-SEM }] and Oxford Instrumentations [EDS].

3. Results

3.1 Degradation:

Degradation features was observed and compared to pure PMMA, and borate infused PMMA shows higher degradation. Utilize a suitable method, such as profilometry or ellipsometry, to measure the thickness of the thin films prior to immersion and at each time point. Insights into the degradation process can be gained through changes in thickness. Utilize SEM to examine the thin films' microstructure at various phases of deterioration. Surface morphological changes, such as erosion and deterioration, as well as pores in the PMMA borate thin film's surface, can be seen in SEM pictures. For the design and development of biomaterials with controlled and tailored degradation profiles, making them suitable for various biomedical applications, including tissue engineering, wound healing, and drug delivery systems, it is crucial to comprehend the degradation behavior of PMMA borate bioactive thin films(Gupta et al. 2021).

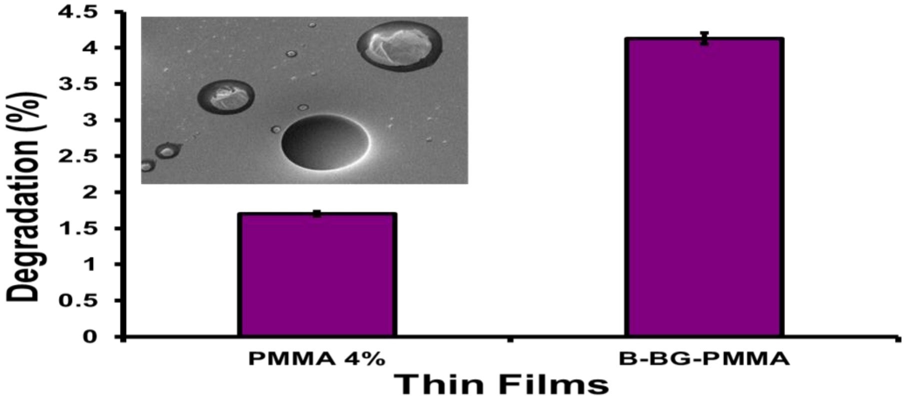

Figure 1: Degradation of PMMA and PMMA borate bioglass

3.2 Blood Compatibility:

The hemolysis test assesses a thin film made of PMMA and borate for its capacity to burst red blood cells. Red blood cells are in contact with the film, and the amount of haemoglobin released is measured. Good blood compatibility is indicated by a low hemolysis percentage. Synthesized PMMA Borate thin film showed optimal compatibility with blood cells.The outcomes of these tests aid in deciding if the thin films are suitable for usage in various biomedical settings where they might come into contact with blood components, such as bandages for wounds, scaffolds for tissue engineering, and drug delivery systems. The successful application of PMMA borate bioactive thin films to practical regenerative medicine and biomedical applications depends on ensuring blood compatibility(Aslankoohi et al. 2019).

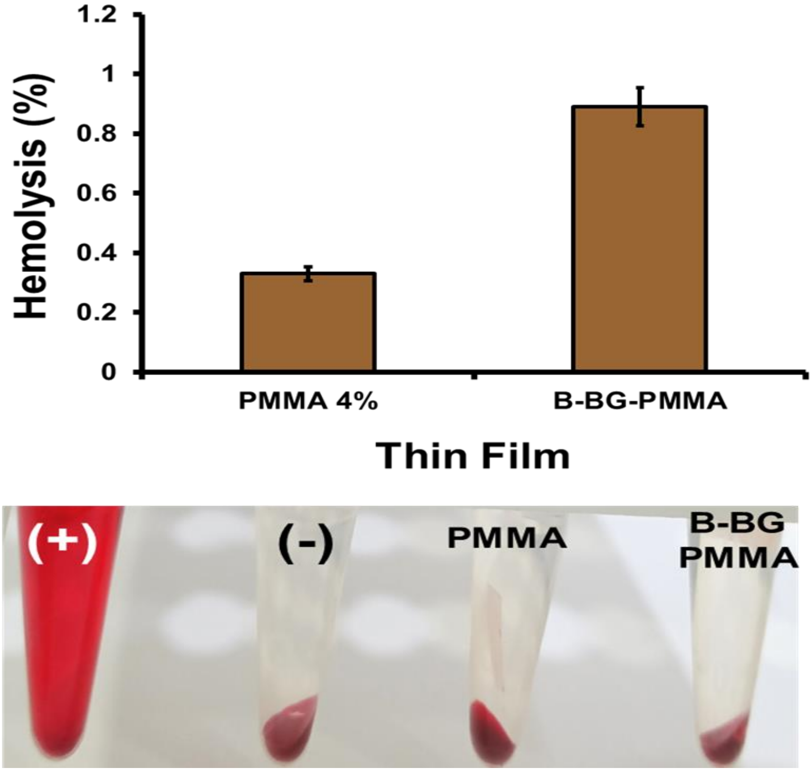

Figure 2: Blood Compatibility of PMMA and PMMA borate bioglass

3.3 Cytocompatibility

The viability of macrophages in contact with the thin film is evaluated using cell viability tests, such as the MTT assay or live/dead staining. This test assesses if the movie induces cytotoxic effects or boosts macrophage survival. It is essential to comprehend the cytocompatibility with macrophages when creating biomaterials that support positive tissue responses and effective tissue regeneration while minimizing negative immunological reactions. In order to create PMMA borate bioactive thin films with increased biocompatibility for regenerative applications, the results of these studies will be helpful(Majumdar et al. 2022).

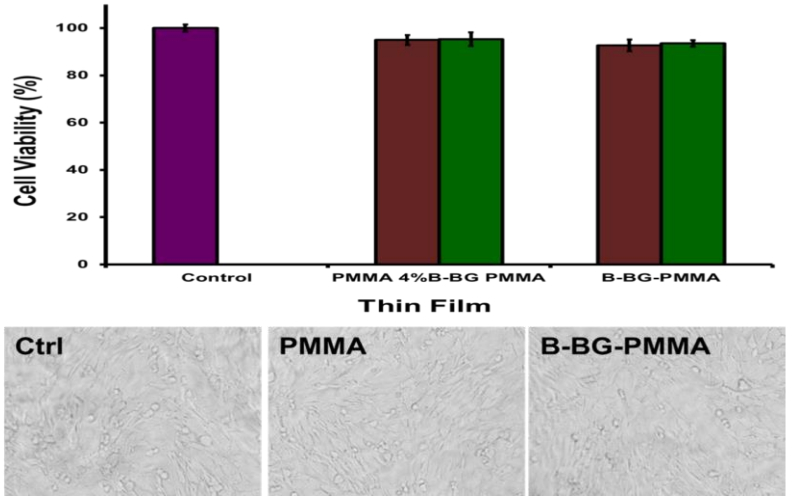

Figure 3: Viability of macrophages in PMMA and PMMA borate bioglass.

4. Discussion

PMMA borate thin films' biodegradability and degradation have a number of intriguing uses in regenerative medicine. These thin films degrade over time, fostering a favorable environment for tissue repair and regeneration.Biodegradable tissue engineering scaffolds can be made out of PMMA borate thin films. The films slowly dissolve after being implanted at the location of tissue damage or injury, offering ad hoc mechanical support while encouraging the formation of new tissue(Alsharabasy 2018). Enhancing cellular activity and the growth of new tissue, the borate bioactive glass component releases bioactive ions that aid in tissue regeneration.PMMA borate thin films can be utilised as biodegradable bandages for wounds. The films can be put on wounds directly, where they act as a barrier of protection and hasten healing. The thin films break down, releasing bioactive ions that speed up wound healing and foster the best milieu for tissue restoration(Cheah et al. 2021).PMMA borate thin films can be used in bone regeneration techniques. Because of the films' biodegradability and capacity to discharge bioactive ions, osteogenesis is encouraged and new bone tissue is supported(Dasan and Chandrasekar 2023). They can be applied as scaffolds for bone abnormalities or as coatings for implants, promoting bone repair and fusion with the surrounding tissue(Furtos et al. 2016).Cartilage Repair: PMMA borate thin films can be used in cartilage tissue engineering as biodegradable matrices to assist chondrocyte proliferation and differentiation. The films' ability to degrade promotes the growth of cartilage tissue while releasing bioactive ions that aid in cartilage regeneration(Shearer et al. 2023).Controlled Release of Growth Factors: PMMA borate thin films can be created to encapsulate growth factors, such as bone morphogenetic proteins (BMPs), and release them in a controlled manner during disintegration. This controlled release of growth factors helps speed up the healing and regeneration of damaged tissue(Xu et al. 2021).The biodegradability of PMMA borate thin films is useful in all of these applications because it eliminates the need for invasive removal methods once the regeneration process is over. Additionally, the bioactivity of the films is increased during degradation, which makes them more receptive to cellular responses and supportive of tissue integration(Cannio et al. 2021). Overall, the regulated degradation and biodegradability of PMMA borate thin films are used in regenerative medicine to enable tissue repair and regeneration in a controlled and biocompatible way. These applications have the potential to improve patient outcomes in many clinical settings and advance regenerative medicine tactics(Sharma et al. 2021).

5. Conclusion:

PMMA borate bioglass thin films, in conclusion, show encouraging degradability and favorable biological characteristics that make them extremely appropriate for diverse regenerative medicine applications. These films' ability to provide temporary mechanical support while encouraging tissue regeneration and healing is largely due to their regulated biodegradation. Their bioactivity is further increased by the addition of borate bioactive glass, which enables interactions with cells and tissues to speed up the regeneration process.PMMA borate bioglass thin films undergo controlled hydrolysis of PMMA and release of bioactive ions from the borate bioactive glass component, according to experimental investigation of the degradation behavior of the films. With a regulated degradation profile, the films are guaranteed to degrade progressively over time, synchronizing with the rate of tissue regeneration and reducing the possibility of unpleasant reactions.PMMA borate bioglass thin films are excellent candidates for tissue engineering scaffolds, wound dressings, drug delivery systems, and applications in bone and cartilage regeneration due to their degradability and biological characteristics. As a result of their adaptability and controlled degradation profile, customized therapeutic techniques are made possible, enabling focused and localized treatments.As a biomaterial platform for regenerative medicine, PMMA borate bioglass thin films show great promise. They are an effective tool for fostering tissue regeneration, healing, and restoration in a variety of therapeutic contexts due to their capacity to progressively degrade, release bioactive ions, and encourage cellular responses. The development of regenerative medicine will surely benefit from continued study and improvement of these thin films, which will provide creative answers to difficult medical problems and enhance patient outcomes.

Conflict of interest:

There are no conflicts to declare.

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