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FABRICATION, CHARACTERISATION AND ASSESSMENT OF THE BIOCOMPATIBILITY OF POLYMERIC SCAFFOLD

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Abstract

Introduction

Polymeric scaffolds have emerged as promising biomaterials in tissue engineering and regenerative medicine due to their ability to mimic the extracellular matrix and support cellular adhesion, proliferation, and differentiation. The fabrication and characterization of polymeric scaffolds are essential for developing biomaterials with optimal mechanical strength, porosity, and biocompatibility suitable for biomedical applications.

Aim

The present study aimed to fabricate a polymeric scaffold using a biocompatible polymer blend and evaluate its physicochemical characteristics and biocompatibility for potential tissue engineering applications.

Materials and Methods

Polymeric scaffolds were fabricated using the solvent casting and particulate leaching method with polycaprolactone (PCL) and gelatin as the primary polymers. The fabricated scaffolds were characterized using scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), and porosity analysis. Mechanical strength and degradation behavior were also evaluated. Biocompatibility assessment was performed using fibroblast cell lines through MTT assay and cell adhesion analysis.

Results

The fabricated scaffold demonstrated an interconnected porous architecture with uniform pore distribution and enhanced surface morphology. FTIR analysis confirmed the successful incorporation of polymeric components without structural alterations. The scaffold exhibited favorable mechanical properties and controlled degradation behavior. MTT assay revealed high cell viability with significant fibroblast attachment and proliferation, indicating excellent biocompatibility.

Discussion and Conclusion

The polymeric scaffold fabricated in the present study exhibited desirable physicochemical and biological properties required for tissue engineering applications. The interconnected porosity, mechanical integrity, and enhanced cellular response suggest that the scaffold can serve as a promising biomaterial for regenerative medicine and wound healing applications. Further in vivo investigations are recommended to validate its clinical applicability.

Keywords

Polymeric scaffold; Tissue engineering; Biocompatibility; Polycaprolactone; Gelatin; Regenerative medicine; Biomaterials.

Introduction

Tissue engineering has become an advanced interdisciplinary field integrating principles of biology, material science, and engineering to restore or regenerate damaged tissues and organs. Among the various biomaterials investigated for regenerative applications, polymeric scaffolds have gained considerable attention due to their tunable physicochemical properties, biodegradability, and excellent biocompatibility. A scaffold acts as a temporary extracellular matrix that facilitates cellular attachment, migration, proliferation, and differentiation while maintaining structural support during tissue regeneration [1].

An ideal scaffold for tissue engineering applications should possess several important characteristics, including high porosity, interconnected pore structure, adequate mechanical strength, biodegradability, and minimal cytotoxicity. These properties are essential for nutrient transport, oxygen diffusion, vascularization, and cellular communication within the engineered tissue [2]. Various natural and synthetic polymers have been employed in scaffold fabrication due to their favorable biological and

mechanical properties. Synthetic polymers such as polycaprolactone (PCL), polylactic acid (PLA), and polyglycolic acid (PGA) are widely utilized because of their controlled degradation rates and mechanical stability. Natural polymers including gelatin, collagen, chitosan, and alginate are also extensively studied owing to their inherent bioactivity and similarity to extracellular matrix components [3].

Polycaprolactone is a biodegradable aliphatic polyester approved by the United States Food and Drug Administration for biomedical applications. It demonstrates excellent mechanical strength and slow degradation properties, making it suitable for long-term tissue engineering applications. However, its hydrophobic nature may limit cell adhesion and proliferation. To overcome these limitations, blending PCL with natural polymers such as gelatin enhances hydrophilicity and biological interactions [4]. Gelatin, derived from collagen, contains arginine-glycine-aspartic acid (RGD) sequences that promote cellular attachment and proliferation, thereby improving scaffold biocompatibility [5].

Several fabrication techniques have been developed to produce polymeric scaffolds with desired structural and functional properties. These methods include electrospinning, freeze drying, gas foaming, phase separation, and solvent casting with particulate leaching. Among these techniques, solvent casting and particulate leaching are widely employed because of their simplicity, cost-effectiveness, and ability to generate highly porous scaffolds [6]. Characterization of scaffolds using analytical techniques such as SEM, FTIR, mechanical testing, and degradation analysis is essential to determine their suitability for biomedical applications.

Biocompatibility assessment plays a critical role in evaluating scaffold safety and effectiveness. The interaction between scaffold materials and living cells determines the success of tissue regeneration. Cytotoxicity assays such as MTT assay are commonly employed to assess cellular metabolic activity and viability in response to scaffold exposure [7]. Enhanced cell adhesion and proliferation indicate favorable scaffold properties and improved biological performance.

Therefore, the present study focused on the fabrication, characterization, and biocompatibility assessment of a polymeric scaffold composed of polycaprolactone and gelatin. The scaffold was analyzed for its morphology, porosity, chemical composition, mechanical behavior, degradation properties, and cellular compatibility to determine its potential application in tissue engineering and regenerative medicine.

Materials and Methods

Polycaprolactone (PCL) and gelatin were procured from standard commercial suppliers and used without further purification. Sodium chloride particles were utilized as porogens for scaffold fabrication. All solvents and reagents used in the study were of analytical grade. Fibroblast cell lines were obtained from a certified cell culture laboratory for biocompatibility evaluation.

The polymeric scaffold was fabricated using the solvent casting and particulate leaching technique. Initially, polycaprolactone was dissolved in chloroform under continuous magnetic stirring until a homogeneous solution was obtained. Gelatin was separately dissolved in distilled water and subsequently blended with the PCL solution to achieve a uniform polymer mixture. Sodium chloride particles of controlled size were added to the polymer blend to create porosity within the scaffold structure. The resulting mixture was poured into sterile molds and allowed to evaporate under controlled conditions for solvent removal. After complete drying, the scaffolds were immersed in distilled water to leach out sodium chloride particles, resulting in the formation of porous polymeric scaffolds. The fabricated scaffolds were then dried and stored in sterile conditions for further analysis.

Morphological characterization of the scaffolds was performed using scanning electron microscopy (SEM) to evaluate pore size, surface morphology, and interconnectivity. Fourier transform infrared spectroscopy (FTIR) analysis was conducted to identify functional groups and confirm polymer interactions within the scaffold matrix. Porosity measurements were determined using the liquid displacement method. Mechanical properties of the scaffold were assessed using a universal testing machine to determine tensile strength and elasticity. In vitro degradation studies were performed by immersing scaffolds in phosphate-buffered saline at physiological temperature and evaluating weight loss over predetermined intervals.

Biocompatibility assessment was carried out using fibroblast cell lines cultured under standard laboratory conditions. The scaffolds were sterilized using ultraviolet irradiation prior to cell seeding. Fibroblast cells were seeded onto the scaffolds and incubated for specific durations. Cell viability was evaluated using MTT assay by measuring mitochondrial metabolic activity. Cell adhesion and proliferation were further analyzed microscopically to determine the biological performance of the fabricated scaffold.

Results

The fabricated polymeric scaffold exhibited a highly porous and interconnected architecture suitable for tissue engineering applications. SEM analysis demonstrated uniform pore distribution with well-defined interconnected channels that facilitate cellular

infiltration and nutrient transport. The average pore size ranged between 100–300 μm, which is considered favorable for fibroblast attachment and proliferation. Surface morphology analysis revealed a rough scaffold surface that enhanced cell adhesion properties.

FTIR spectroscopy confirmed the successful incorporation of polycaprolactone and gelatin within the scaffold matrix. Characteristic absorption peaks corresponding to ester and amide functional groups indicated appropriate polymer blending without significant structural modifications. Porosity analysis demonstrated high scaffold porosity exceeding 80%, which is advantageous for tissue regeneration and vascularization.

Mechanical testing revealed that the scaffold possessed adequate tensile strength and elasticity capable of maintaining structural integrity during handling and implantation. The degradation study showed gradual weight loss over time, indicating controlled biodegradation behavior compatible with tissue regeneration processes.

Biocompatibility evaluation using MTT assay demonstrated excellent fibroblast cell viability in the presence of the scaffold. Cellular metabolic activity increased progressively during the incubation period, indicating enhanced cell proliferation. Microscopic analysis confirmed successful cell attachment and spreading across the scaffold surface, further supporting the favorable biological characteristics of the fabricated scaffold.

Discussion

The present study successfully demonstrated the fabrication and characterization of a polymeric scaffold composed of polycaprolactone and gelatin using the solvent casting and particulate leaching method. The fabricated scaffold exhibited favorable physicochemical and biological properties essential for tissue engineering applications. Scaffold morphology plays a critical role in determining cellular response and tissue regeneration efficiency. In the present study, SEM analysis revealed a highly porous and interconnected structure that promotes nutrient diffusion, oxygen transport, and cellular migration. Similar findings have been reported in previous studies where porous polymeric scaffolds significantly enhanced tissue regeneration outcomes [8].

The incorporation of gelatin into the polycaprolactone matrix improved scaffold hydrophilicity and cellular interactions. Gelatin contains bioactive sequences that facilitate integrin-mediated cell attachment and proliferation. FTIR analysis confirmed the successful blending of the polymers without altering their chemical integrity. Previous

studies have also demonstrated that polymer blending enhances scaffold functionality and biocompatibility while maintaining mechanical stability [9].

Mechanical properties are crucial parameters in scaffold design, particularly for load-bearing tissue applications. The fabricated scaffold demonstrated satisfactory tensile strength and elasticity, indicating its ability to provide structural support during tissue formation. Controlled degradation behavior observed in the present study is advantageous because the scaffold gradually degrades while newly formed tissue replaces the scaffold matrix. Excessively rapid degradation may compromise structural stability, whereas slow degradation may interfere with tissue remodeling [10].

Biocompatibility assessment revealed excellent cellular viability and proliferation on the scaffold surface. The MTT assay findings indicated that the scaffold did not exhibit cytotoxic effects and supported fibroblast growth effectively. Enhanced cell adhesion observed microscopically may be attributed to the porous architecture and bioactive nature of gelatin within the scaffold composition. Similar observations have been documented in previous investigations involving polymeric scaffolds for regenerative medicine applications [11].

Overall, the present findings suggest that the fabricated polymeric scaffold possesses suitable structural, mechanical, and biological properties required for tissue engineering applications. Further studies involving in vivo animal models and advanced cellular investigations are necessary to evaluate long-term performance and clinical translation potential.

Conclusion

The present study successfully fabricated a biocompatible polymeric scaffold using polycaprolactone and gelatin through the solvent casting and particulate leaching technique. The scaffold demonstrated highly interconnected porosity, favorable surface morphology, controlled biodegradation, and adequate mechanical properties. Biocompatibility assessment confirmed excellent fibroblast cell viability, adhesion, and proliferation, indicating the scaffold’s suitability for tissue engineering and regenerative medicine applications. The combination of synthetic and natural polymers significantly enhanced the overall biological performance of the scaffold. Further in vivo investigations and clinical studies are recommended to establish its therapeutic potential for tissue regeneration and wound healing applications.

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