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Preparation, characterization, and in vitro performance evaluation of polymeric scaffolds containing sodium alginate microspheres with methotrexate for controlled drug delivery

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ABSTRACT

This study explores the development and characterization of polymeric scaffolds containing sodium alginate microspheres loaded with methotrexate for controlled drug delivery. We fabricated scaffolds using hexamethylene diisocyanate and polyelectrolyte, incorporating drug-loaded microspheres, scaffolds were thoroughly characterized using various analytical techniques, including FTIR, XRD and SEM, drug release kinetics were evaluated under physiological conditions, demonstrating sustained release profiles over 150 hours, examinations of void spaces unveiled highly permeable structures conducive to cellular penetration and nutrient circulation. Decomposition patterns were evaluated in oxidizing and enzymatic settings, demonstrating steady disintegration across multiple weeks. Our discoveries indicate that these frameworks show potential for utilization in pharmaceutical administration and biological tissue construction, providing adjustable characteristics and regulated discharge abilities.

1. Introduction

Advanced medication administration systems have emerged as innovative strategies to boost therapeutic effectiveness and reduce unwanted side effects linked to traditional drug delivery methods [1-3], These approaches aim to administer medicinal compounds at the optimal rate and timeframe, while sustaining ideal drug levels at the intended location [4,5], Among various regulated drug delivery platforms, polymer-based frameworks have attracted considerable interest [6,7] due to their adaptability [8], biocompatibility [9,10] and potential for localized and sustained drug release [11,12]. Polymeric scaffolds are three-dimensional, porous structures fabricated from biocompatible and biodegradable polymers [13,14], these scaffolds serve as matrices for incorporating drug-loaded nanoparticles or microparticles, facilitating controlled and localized drug delivery [15,18], The porous design of these frameworks plays a vital role in facilitating efficient drug loading, cell penetration, nutrient flow, and tissue assimilation, making them particularly appealing for tissue engineering and regenerative medicine applications [19], The creation and advancement of polymer-based frameworks involve meticulous material selection, refinement of manufacturing techniques, and incorporation of functional elements to customize their properties for specific therapeutic uses. Aspects such as permeability, surface features, degradation speed, and structural integrity significantly impact the performance of these frameworks in drug delivery and tissue regeneration [20], researchers have explored various strategies to enhance the drug delivery capabilities of polymeric scaffolds, these include the incorporation of functional components such as nanofillers, polyelectrolytes, or other functional polymers to modulate the scaffold's physicochemical properties and drug release kinetics such as graphene oxide [21] or hydroxyapatite [22] to modulate the scaffold's physicochemical properties and drug release kinetics. Additionally, the use of polyelectrolytes [23] or other functional polymers can impart desirable characteristics as improved mechanical strength, controlled degradation, and tailored drug release profiles, the selection of biomaterials and optimization of fabrication techniques have been extensively studied to tailor the scaffolds' properties for specific therapeutic applications, the creation and refinement of polymer-based frameworks necessitate meticulous attention to various elements,

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