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PROCEEDINGS ABSTRACT

Nanocomposite-based drug delivery systems for targeted anti-inflammatory therapies: a review

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Inflammatory diseases remain a clinical challenge as persistent or dysregulated inflammation contributes to tissue injury and the progression of acute and chronic disorders. Conventional anti-inflammatory therapies, including those using nonsteroidal anti-inflammatory drugs and glucocorticoids, are often limited by systemic toxicity, poor tissue specificity, short biological half-life, and inadequate control of complex inflammatory pathways. However, nanocomposite-based drug delivery systems, particularly polymeric nanoparticle platforms, have emerged as promising strategies to overcome these limitations through targeted, sustained, and disease-responsive drug delivery. The aim of this review was to provide an overview of the role of polymer-based nanocomposite delivery systems in targeted anti-inflammatory therapies, with an emphasis on the influence of polymer composition, functional properties, and disease-specific applications on the therapeutic outcomes. Polymeric nanoparticles are nanoscale carriers fabricated from synthetic or natural polymers, including poly(lactic-co-glycolic acid), chitosan, and polyethylene glycol (PEG). These materials enable the efficient encapsulation and controlled release of anti-inflammatory agents while providing advantages such as biodegradability, biocompatibility, prolonged circulation time, and reduced immune clearance. The physicochemical properties of the selected polymer strongly influence drug-loading capacity, biodistribution, pharmacokinetics, cellular uptake, and overall therapeutic efficacy. Furthermore, hybrid nanocomposite systems that combine synthetic and natural polymers offer enhanced versatility by integrating the favourable characteristics of multiple materials into a single platform. The therapeutic relevance of polymer-based nanocomposites is closely linked to their application across diverse inflammatory disorders. In autoimmune diseases, such as rheumatoid arthritis and inflammatory bowel disease, these systems can facilitate targeted delivery of anti-inflammatory drugs to inflamed tissues and immune cells, thereby improving local therapeutic efficacy while minimizing systemic adverse effects. In acute inflammatory conditions, nanocomposite carriers can be engineered to respond to pathological stimuli, including elevated reactive oxygen species levels, acidic pH, hypoxia, and enzyme overexpression, thereby enabling localized drug release at the inflammation sites. In neuroinflammatory disorders, polymeric nanocarriers offer additional advantages by enhancing transport across the blood–brain barrier, reducing microglial activation, modulating inflammatory cytokine production, and promoting neuronal protection. Beyond functioning as passive drug carriers, polymeric nanocomposites can actively modulate inflammatory pathways. Experimental studies have demonstrated their ability to promote macrophage phenotype reprogramming, suppress excessive cytokine production, inhibit nuclear factor kappa B signalling, and scavenge reactive oxygen species. Surface functionalization with PEG, target-

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ing ligands, peptides, or antibodies can further enhance the selective accumulation within inflamed tissues and activated immune cell populations. In addition, stimuli-responsive polymer designs can provide precise spatial and temporal control of drug release within diseased microenvironments, thereby supporting the development of personalised therapeutic approaches. Overall, the success of any nanocomposite-based anti-inflammatory therapy depends largely on the selection of polymer type and its functional characteristics. Synthetic and natural polymers can each offer distinct advantages, and their rational design has expanded therapeutic opportunities in autoimmune, acute, and neuroinflammatory diseases. Although challenges related to large-scale manufacturing, reproducibility, regulatory approval, and clinical translation remain, polymer-based nanocomposite delivery systems represent a promising approach for improving the safety, the specificity, and the effectiveness of anti-inflammatory treatments.

Keywords

drug delivery; inflammation; nanocomposite systems; polymeric nanoparticles; targeted therapy

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Conflicts of interest statement

None to declare.

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