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Exploring cutting-edge hydrogel technologies and their biomedical applications

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Hydrogels have emerged as three-dimensional biomaterials with potential biomedical applications in numerous fields including drug delivery and tissue engineering. They have particularly garnered great interest from researchers due to their excellent biocompatibility, ability to encapsulate, protect, and deliver bioactive therapeutics, capacity for sustained release, and their ability to act as implantable scaffolds and support tissue regeneration.

This special issue, consisting of eight papers, addresses some of the greatest challenges in hydrogel technology and showcases its capabilities, focusing on the applications of hydrogels in bone regeneration [1] [2], stem cell therapy [3], hemostasis [4], stroke [5], cancer treatments [6] [7], and biological activities in general [8].

Bai et al. outline the advantages and challenges of existing hydrogel-based bone regeneration technologies as well as design prerequisites for future prospects [1]. One such hydrogel system for bone repair based on multilayered composite nanoparticles was designed with various stimuli-responsive layers, biofunctional surfaces, and adjusted gelation times. This system allowed for controlled release of rhBMP-2 from periosteum-mimetic structures and *in vivo* formation of bone tissue [2].

Due to their resemblance to soft biological tissues, hydrogels are well-suited for cell encapsulation and delivery. *Deepthi* et al. produced fibrin hydrogels composed of alginate nanobeads by manipulating the injectability of these hydrogels as well as their *in situ* gelation ability. Results showed that the hydrogels were able to completely fill the defect areas and successfully encapsulated mesenchymal stem cells. Additionally, the mechanical strength of the hydrogels was comparable to that of soft tissue elasticity and thus advantageous for application in soft tissue reconstruction [3].

Hydrogels can also be used to induce blood clots. *Meena* et al. developed a cryogel-based approach that can potentially induce hemostasis. The authors synthesized nontoxic chitosan-dextran cryogels reinforced with locust bean gum that demonstrated hemostatic potential to stop severe blood loss in traumatic injuries, thus offering a novel solution to overcoming the limitations of current hemostatic technologies [4].

Meanwhile, thrombolysis therapy is an important treatment for stroke. *Teng* et al. has shown that the controlled release of the anti-clotting factor urokinase from hollow nanogels enhances its thrombolysis efficiency as well as prolongs its circulation duration [5]. Additionally, nanogels can efficiently preserve urokinase in the blood-brain barrier without increasing the risk of hemorrhagic transformation and therefore can be used as an alternative treatment for acute ischemic stroke [5].

Hydrogel-based approaches can also be utilized for the treatment of cancers. For instance, polypeptide hydrogels for localized co-delivery of DOX/IL-2/IFN-ɣ have been developed and hold promise for the treatment of melanoma [6]. *Lv* et al. reported that this local hydrogel delivery system achieved superior antitumor efficacy and displayed good biodegradability and biocompatibility. In another study, intrinsically photoluminescent, highly photostable Doxorubicin-loaded nanogels were prepared and utilized to pinpoint the cytoplasmic regions of the prostate cancer cells and induce apoptosis in those cells [7].

Finally, to improve the bioactivity of hydrogels, *Dorsey,* et al. studied hydrogel photochemistry kinetics, examining the photochemical reactions and parameters (e.g. photoinitiators and UV exposure times) affecting the fabrication of photocrosslinkable hydrogels and their relationship to undesired protein damage and cell death [8]. The authors also investigated the effects of varying these parameters on the encapsulation efficiency, bioactivity, and stiffness of the hydrogels.

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