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Editorial

Combined Nanoparticles in Tissue Regeneration - An Emerging Challenge

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Abstract

Nanoparticles widely used in the fields of drug delivery, *in vitro* diagnostics, biomaterials, therapy techniques and tissue engineering. They are endowed with unique properties and offer a plethora of advantages that include enhanced therapeutic efficacy, discovery of newer therapeutics and higher sensitivity biomarkers, development of non-invasive theranostics, effective tracking of carriers, improving compatibility of biomaterials, helping fabricate scaffolds at the nanoscale and so forth. Among the myriad applications of nanoparticles, drug delivery and tissue regeneration are two areas which are expected to witness tremendous growth in the near future although engineered nanoparticles present a multitude of toxicological challenges.

Keywords: nanoparticles, tissue engineering, theranostics, biomaterials

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Nanoparticles (metallic, ceramic, magnetic, polymeric and glass) have revolutionized the fields of drug delivery, invitro diagnostics, biomaterials, therapy techniques and tissue engineering. They are endowed with unique properties and offer a plethora of advantages that include enhanced therapeutic efficacy, discovery of newer therapeutics and higher sensitivity biomarkers, development of non-invasive theranostics, effective tracking of carriers, improving compatibility of biomaterials, helping fabricate scaffolds at the nanoscale and so forth[1]. They are in a position to mimic natural nanoscale moieties and can be suitably functionalised to permeate the cell membrane. Despite the above-mentioned advantages, engineered nanoparticles present a multitude of toxicological challenges. Systematic characterisation of nanoparticles, control of dosage regimes, precise understanding of nano-pathways, effective monitoring of physiological impact on cells and effective cell assays could help alleviate these difficulties[2]. Among the myriad applications of nanoparticles, drug delivery and tissue regeneration are two areas which are expected to witness tremendous growth in the near future.

The National Science Foundation defines “tissue engineering” as the development of biological substitutes by understanding and applying principles of life sciences and engineering. There are numerous reviews which have explored the synthesis, characterisation and functionalisation of various nanoparticles and their capacity towards tissue engineering[1,3-5]. While these nanoparticles and nano scaffolds are being considered for the challenge, issues that include immune response, potential toxicity and ability to emulate the extracellular matrix (ECM), etc., need to be addressed more clearly. The ECM constituted by hierarchally organised nanofibers control and direct cell behaviour and plays a pioneer role in the release and activation of cell soluble and biological factors to enhance cell integration and growth promoting better biocompatibility. Different fabrication methods have been utilised to design nano scaffolds with groves and ridges that mimic the nano-architecture of ECM. This has facilitated the manipulation of cell adhesion, differentiation, proliferation and facilitated controlling and elongation of different cell types and has led to a wider understanding of how cells respond to nanostructures. In addition, the controlled delivery of therapeutics and angiogenic factors in the vicinity of regenerating tissue could promote enhanced vascularisation in developing tissues.

It is widely acknowledged that the ability of nanoparticles modified with suitable ligands can specifically target cells and negate complex side-effects of conventional treatment regimes. The presence of targeting ligands leads to greater intracellular therapeutic concentration followed by augmented efficacy. It is also particularly important in the transcytosis of nanodrugs across the blood brain barrier and in the controlled release of biological factors such as vascular endothelial growth factors crucial for tissue regeneration. Despite great strides in nanoparticle-based drug delivery the ability to ensure sustained and targeted release of myriad biological factors from engineered nano-scaffolds still remains a challenge as it involves myriad events including host immune response and cellular maturation and integration. The fabrication of these targeted nano-scaffolds requires multiple steps and careful selection of ligands which in turn is controlled by cell specificity, ligand biocompatibility and binding affinity. Advances in ligand engineering, controlled and sustained release of biological factors and newer fabrication methods would serve as the key for tissue regeneration in the near future.

In addition, stem cell therapy wherein the damaged cells are replaced by new ones can enhance repair and pave the way towards accelerated tissue regeneration. Of late the only approved Food and Drug Administration stem cell products are the hematopoietic progenitor cells and numerous companies are probing to merge artificial intelligence (AI) and stem cells to provide benefits that include cellular morphology identification, viability, biosafety, bio efficacy and precise therapeutic effects. Though stem cell therapy is currently considered experimental various studies are being conducted with the belief that AI could change the future of regeneration. A recent review[6] on the applications of AI in stem cell therapy discusses in detail the concerns and significant advantages associated with AI and their role in the future of modern medicine.

Nanotechnology which possesses tremendous potential has ushered in a new era in the reconstruction of complex implantable tissue. It is envisioned that the concepts of nanotechnology can improve conventional therapies and enable the design and development of nano scaffolds to mimic tissue architecture. Further the controlled release of biological factors from these scaffolds could eventually lead to the development of the ideal tissue construct. As a variety of products successfully complete clinical trials and clear Food and Drug Administration market approvals, their revenues are expected to grow substantially. The global healthcare market stands at around 270 billion dollars in 2022[6] and is expected to grow annually at a rate of 8%[7]. Significant developments have facilitated the use of nanoparticles in the medical devices industry but escalating costs of nanodevices could hamper their commercialisation. However, it is anticipated that several government initiatives to fortify healthcare could pave the way for the industry to overcome this challenge.

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Conflicts of Interest
The authors declared no conflict of interest.

Author Contribution
Both authors contributed to the manuscript and approved the final version.

Abbreviation List
AI, Artificial intelligence
ECM, Extracellular matrix

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