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New frontiers of magnetic materials for regenerative medicine

Ugo D'Amora

Institute of Polymers, Composites and Biomaterials, Italy E-mail: ugo.damora@unina.it

Abstract

The fundamentals of magnetism and magnetic materials have been widely used in medicine in recent years (such as, in drug and gene delivery and hyperthermia treatment of tumors). The idea of applying these concepts to tissue engineering has sparked a burgeoning field of research. Tissue engineering strives to create multidisciplinary approaches to tissue repair and regeneration. The major goal is to use three-dimensional biodegradable and biomimetic "scaffolds" as a template for cell growth and extracellular matrix deposition in order to repair tissues.

The main driving idea behind the development of magnetic scaffolds was to create structures that could be manipulated using magnetic force gradients that attracted bio-aggregates and were linked to magnetic carriers (i.e. vascular endothelial growth factors) to stimulate angiogenesis and bone regeneration. They can also be utilised as hyperthermia agents to provide thermal energy to specific parts of the body. The manufacturing process, as well as the material and scaffold properties, such as morphological, chemical-physical, mechanical, and mass transport performances, have all been given special consideration through topological optimization. Additive manufacturing was used to create entirely biodegradable and magnetic nanocomposite scaffolds in particular. Experimental/theoretical in vitro investigations and in vivo experiments were used to evaluate the scaffolds' properties. MicroTomography and Scanning Electron Microscopy were used to conduct morphological analyses.
Mechanical investigations at the micro, macro, and nanoscale were also performed. A magnetic study was used to evaluate the behaviour of these materials, revealing that they may be magnetised at 37°C with an external magnetic field. Confocal Laser Scanning microscopy and the Alamar . Blue assay were used to examine human mesenchymal stem cell adhesion and viability, while ALP activity was used to determine cell differentiation. Also investigated was the effect of a time-dependent magnetic field on cell-laden constructions. Finally, this research revealed that these materials would be good candidates for bone regeneration.

Since the skeleton plays significant functions in the normal physiological functions of the human body, including as mechanical support, organ protection, and mineral homeostasis maintenance, strategies to enhance bone regeneration have traditionally been the focus of research. Magnetic fields have been found to have a big impact on the regeneration process, which has sparked a lot of interest in using magnetic materials to boost osteogenesis. We attempt a more comprehensive and detailed review of magnetic materials in promoting bone regeneration in this paper, which includes not only the mechanisms of bone regeneration, the history and basic concepts of magnetism, but also the different types of magnetic materials, their influence parameters, designs, and fabrication techniques, with a focus on their use in the field of bone regeneration like 3D printed scaffolds and implants. In addition, we discuss some potential synergistic effects of magnetic and other materials on bone tissue. Finally, we suggest that magnetic materials will continue to grow in the field of bone regeneration in the future. Patients with diseases including fractures, tumours, and osteoporosis, which cause acute aches, bone loss, limb deformations, and mobility constraints, are in desperate need of a more effective and less traumatic technique to speed bone regeneration. Magnetic materials have a lot of potential for being turned into new clinical applications that can improve bone regeneration efficiency.

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