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Commentary

Nanotechnology in Orthopedic Applications

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DESCRIPTION

Numerous unique applications of nanotechnology are available, but one that stands out is the use of nanoparticles as scaffolds to promote a better connection between orthopedic implants and natural bone. Orthopedic surgery diagnostics and treatment could be revolutionized by nanotechnology, yet little is known about the long-term health implications of nanomaterial's, and more research is required to ensure clinical safety.

Innovation and disruptive technology have long promised to lead to better patient outcomes. One of these areas with ground-breaking potential to assist in the diagnosis and treatment of complicated medical issues is the science of nanotechnology. The National Nanotechnology Initiative originally defined nanotechnology as the study and controlled manipulation of individual atoms and molecules between the sizes of 1 and 100 nm, but the term has since expanded to encompass a wider range of research projects and applications. Numerous cutting-edge orthopedic remedies have made use of "Nano medicine," the application of nanotechnology to medicine. Targeted drug administration, implanted components, vertebral disc regeneration, and diagnostic tools are a few examples of clinical applications.

Nanotechnology is the result of interdisciplinary research involving several scientific fields, such as surface science, molecular biology, microelectronics, and tissue engineering. In some cases, standard macro-materials may have entirely different physical and chemical properties when they are synthesized into considerably smaller nanosized particles. In particular, phenomena like the quantum size effect become more noticeable as particulate matter size declines to 100 nm or smaller. When a material's electrical characteristics alter as a result of appreciable particle size reductions, this concept is evident. For instance, when scaled down to the nanoscale, materials that are insulators at the macroscale may become conductive at the nanoscale. Due to an increasing surface area to volume ratio as particle size is lowered, changes in mechanical characteristics may occur in addition to changes in electrical properties. This is important because nanophase materials can maintain relatively high surface area to volume ratios, which allows for more beneficial interactions with neighboring structures. This enables more interaction between an implant and native bone, like in the case of orthopedic implants, which promotes more efficient osseointegration. The ability of nanotechnologies to enable more precise therapeutic applications at the subcellular level accounts for a large portion of their prospective medical benefits. Nano engineered materials offer the potential to target and alter cellular processes since many chemicals involved in these processes interact fundamentally at the nanometer scale. Applying this idea to orthopedics, bone naturally contains hydroxyapatite and collagen nanostructures when it is broken down to the nanoscale. A wide variety of options, both inside and outside the medical industry, have seen advances in functionality and performance as a result of the actual implementation of these ideas and understanding of these links.

Loss of spinal mobility, degenerative post-discectomy spondylosis, and disc herniation recurrence are frequently reported side effects of surgical therapies for degenerative disc disease such as discectomy and fusion. The need for nanotech research, including novel cell-based therapies, including tissue engineering for Intervertebral Disc (IVD) regeneration, has arisen as a result of inconsistent results and side effects with present treatments.

Nanotechnology has the potential to promote spinal fusion, nerve regeneration, and disc preservation without the expense or potential drawbacks of recombinant human Bone Morphogenetic Protein (rhBMP). In comparison to standard smooth implants, surface modifications to titanium spinal implants using nanoparticles such as titanium oxide and zirconia have shown promise in fostering greater bone growth and decreased resorption.

Major obstacles still exist in the treatment of osteosarcoma and Ewing sarcoma, including cytotoxicity and diminished selectivity of chemotherapy, drug resistance, and pharmacokinetic issues. Through the use of special carrier molecules that help in drug distribution, nanotechnology might be able to address some of these problems. At the implant-tissue interface, nano-selenium implants are also used to promote good bone function while preventing the formation of malignant osteoblasts.

The development of implantable materials that can work safely

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and effectively while extending the average lifespan of implants and reducing infection is the main goal of nanotechnology in arthroplasty. To improve implant osseointegration, osteoblast function and development have been enhanced using nanotextured implant surfaces. Common cement materials like Polymethyl Methacrylate (PMMA) may benefit from the addition of nanotechnology-based antibiotic carriers such as lipid nanoparticles, silica, and clay nanotubes to improve medication transport and enable timed release. Even with recent advancements in surgical technique and post-operative care, adhesion formation following tendon surgery continues to be a serious concern. An interesting alternative to enhancing extrinsic and intrinsic tendon repair may be provided by developments in nanotechnology and medication delivery.