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Mini Review

Imperative Role of Nanostructure Surfaces in Orthopedic Implants

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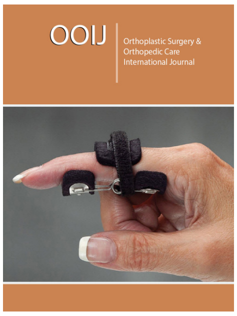

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Abstract

Nanotechnology has spread around the world due to its large range of uses, as well as its original and distinctive qualities. Nanomaterials of many types have been studied since their properties are largely determined by the size, shape, and composition of the materials, which are frequently used in the biomedical area. The application of nanotechnology in medicine, particularly in the field of orthopaedics, is a hot topic of debate. Our study gives a complete overview of the existing and prospective future applications of nanotechnology in orthopaedic subspecialties. Nanotechnology has a wide range of innovative uses, including the use of nanoparticles as scaffolds to improve the interface between orthopaedic implants and native bone. Nanotechnology has the potential to transform orthopaedic surgery diagnostics and therapy. Various biomedical devices, such as dental implants consisting of titanium, magnesium, cobalt, and other metals, are surgically implanted in the jawbone where teeth are missing. The replacement of a prosthetic implant for the hip joint is done by surgical procedures. Pacemakers for artificial heart valves or prosthetic implants, stents put inside the body, and other cardiovascular implants are examples. In addition, we will expand on the basic considerations of employing nanomaterials in implantable devices, dental implants/prosthodontics, spine, orthopaedic implants, hip and knee replacements, cardiovascular implants, and others phakic intraocular lens and cosmetic implants in this paper.

Keywords: Orthopedics; Engineering technology; Nanotechnology; Disease-related problems; Implantable materials; Therapeutic applications; Biomaterials; Tissue engineering

Abbreviations: PMMA: Polymethylmethacrylate; PLA: Poly Lactic Acid; NP: Nanoparticle

Introduction

Disruptive technology and innovation have long been touted as having the potential to improve patient outcomes. One of these sectors with breakthrough potential for identifying and treating complicated medical conditions is nanotechnology. The National Nanotechnology Initiative originally defined nanotechnology as the study and controlled manipulation of individual atoms and molecules with sizes ranging from 1 to 100 nanometers, but the definition has since evolved to encompass a broader range of research endeavours and applications [1]. Nearly six decades ago, Richard Feynman was the first to recognise the possibilities of nanotechnology. "A field in which nothing has been done, but in which an incredible amount can be done in principle [2]," he wrote in 1959. Nanotechnology's applications have dramatically grown since then, including food packaging, cosmetics, water purification, and medicine [3]. Nanomedicine, or the application of nanotechnology to medicine, has been used in a number of innovative therapies in the field of orthopedics. Targeted medication delivery, implantable materials, spinal disc regeneration, and diagnostic modalities are only a few of the clinical uses [4]. Previous reviews of nanotechnology in orthopaedics [5,6] have offered comprehensive overview of the many biomaterials that have been investigated and utilised. Our review is unusual in that it is organised by orthopaedic subspecialty, with a particular emphasis on the therapeutic applications of nanotechnology in orthopaedics. While specialist classifications are arbitrary, they are beneficial for emphasising the therapeutic value of specific advances, with the understanding that future uses in other sub-specialties are likely. Our main goal is to educate orthopaedic surgeons and musculoskeletal researchers about the current state of nanotechnology and its future potential.

In each section, we'll also list any nanotechnology investigations that are now undergoing clinical trials. Nanotechnology fundamentals Surface science, molecular biology, microelectronics, and tissue engineering are just a few of the scientific fields involved in nanotechnology. In some cases, ordinary macro-materials can be manufactured into considerably smaller nano-sized particles with radically distinct physical and chemical properties. The quantum size effect, for example, becomes more noticeable as the size of particulate matter reduces to 100nm or smaller [7]. When the electrical characteristics of a material change as a result of considerable particle size reductions, this principle is observed. When materials are reduced to the nanoscale, they may have conductive characteristics that are insulators at the macroscale. Changes in mechanical qualities may occur as a result of an increased surface area to volume ratio as particle size is lowered, in addition to changes in electrical properties. This is significant because nanophase materials can keep their surface area to volume ratios relatively high, allowing for more favourable interactions with surrounding structures. This allows for a larger degree of interaction between an implant and native bone in the case of orthopaedic implants, resulting in more effective osseointegration [8]. The fact that nanotechnology may allow for more precise therapeutic applications at the subcellular level [9] accounts for a large part of nanotechnology's potential utility in medicine. Nanoengineered materials have the theoretical ability to target and influence cellular processes since many molecules involved in these processes exist and interact fundamentally at the nanometer scale [10]. When it comes to orthopaedics, bone is naturally a nanostructure composition of collagen and hydroxyapatite when broken down to the nanoscale [11]. The practical application of these ideas, as well as an understanding of these linkages, has resulted in advances in the functionality and performance of a wide range of goods, both inside and outside the medical profession. The possible applications of nanotechnology in several orthopedic subspecialties are summarised in (Figure 1)

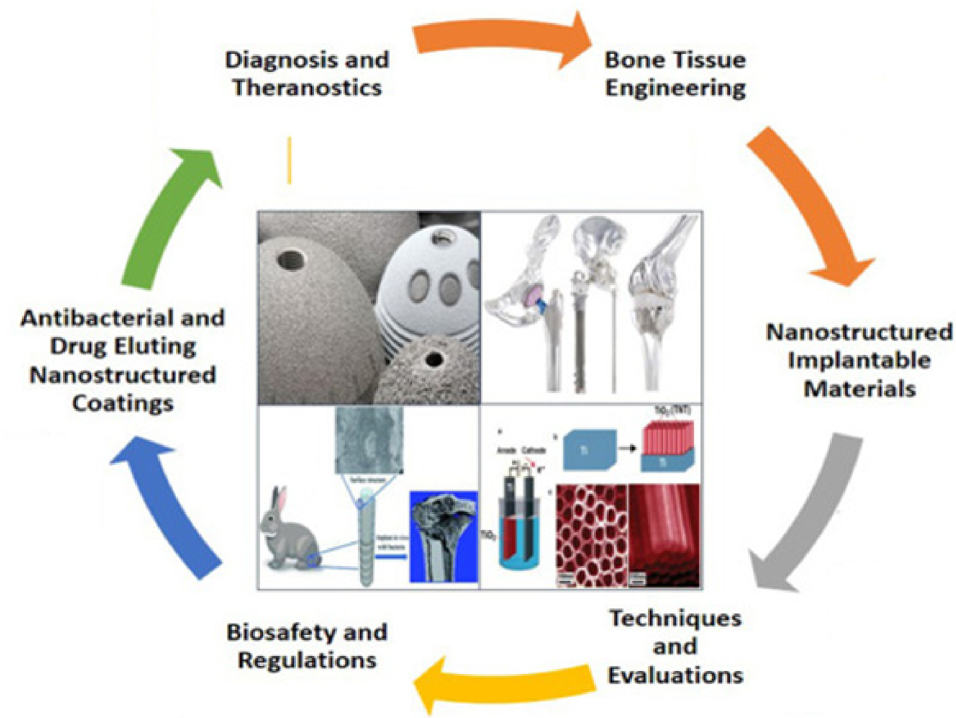

Figure 1: Orthopedic namedicine.

Nanotechnology integrates engineering technology with biology, physics, and chemistry in a variety of domains of study. Nanotechnology refers to the application of science that "pushes the envelope" of miniaturisation. In general, as the size of a piece of solid material shrinks, its chemical and physical properties change, and it becomes completely different from the same substance in bulk form. This research topic can be outlined, as well as the constraints imposed on its new properties and strategies for developing properties of controllable size [12]. The study of materials at the atomic, molecular, and macromolecular scales is known as nanoscience. Furthermore, nanoparticles' characteristics might differ dramatically from those of larger-scale materials. Nanotechnologies are systems, devices, and structures that have been designed, manufactured, and characterised to have a regulated shape and size at the nanoscale scale.

The nanotechnology market was divided into three categories in general:

A. Materials

B. Devices

C. Tools

Nanomaterials are materials made up of one or more components having at least one dimension in the range of 1-100nm, such as nanoparticles, nanofibers, nanotubes, nanocomposite materials, and nanostructured surfaces. Nanoparticles (NP) are single particles with a diameter of fewer than 100 nanometers. Nanofibers are a type of nanoparticle with two dimensions of less than 100 nanometers. Their third dimension (axis) can, however, be compared to those of these particles [13,14]. In this chapter, we'll look at a variety of nanomaterials and the technologies that go into making them, as well as how they are employed in bio implantable devices.

Conclusion

Nanomedicine, or the application of nanotechnology to medicine, tries to solve disease-related problems at the nanoscale, where the majority of biological molecules exist and function. The response of host organisms to nanoparticles at the protein and cellular level differs from that of ordinary materials. There is a huge need and demand in orthopedic applications for the creation of a bioactive bone substitute with material qualities equal to natural and healthy bone. Nanostructured ceramics, polymers, metals, and composites have recently received a lot of attention in the field of bone tissue engineering. Nanoceramics and nanopolymers are mostly employed as covering constituent materials for orthopaedics, but they can also be coupled with other biomaterials to generate nanocomposites appropriate for implant applications. As previously stated, bone is a real nanocomposite, making nanocomposites superior to other nanostructured materials. Preliminary research suggests that nanobiomaterials have potential in orthopaedic applications; however, more research is needed before they can be used in clinical settings.

The goal is to create bioactive scaffolds for bone regeneration that can temporarily replace native tissues while interacting with their environment, responding to environmental changes, and actively directing cellular activities for faster bone creation, faster healing, and faster return to function.

Future research will most likely focus on improving design techniques to take use of nanomaterials and cutting-edge fabrication technology. Understanding the molecular mechanisms of cell–nanobiomaterial interactions is crucial. Furthermore, confirming the biosafety of nanomaterials and reducing their negative effects should be treated seriously. Stainless steel alloys, cobalt–chrome alloys, titanium alloys, magnesium alloys, HA, alumina, zirconia, Polymethylmethacrylate (PMMA), Poly (Lactic Acid) (PLA), carbon fiber/polyetheretherketone, and carbon fiber/ultra-high molecular weight polyethylene are examples of implantable biomaterials that provide structural support as bone substitutes.

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