The Emerging Nanoweapon of Orthopaedic Surgery.

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Nanotechnology refers to the manipulation of structure and properties of materials at the nanometer scale(individual atoms ,molecule and supramolecular level) through biological, physical and chemical routes.[1] This tiny alteration at the molecular level can cause a larger change. The surface area of nanoparticles ranges from 1 to 100nm and they demonstrate altered or enhanced biological response in contrast to particles with micrometer size surface area.[2] The host organism tends to have different response to nanomaterials at cellular and protein level than shown for conventional particles.[3] The concept of Nanotechnology was first introduced by Richard Feynman in 1959 and he is known as Father of Nanotechnology.[4]

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What is the rationale for developing nanoparticles bioactive Orthopaedic materials? The answer is the structure of the bone itself. Bone is a composite of nanostructured Hydroxyapatite(20 to 80 nm long and 2 to 5 nm thick) and collagen fibers(with <500nm diameter) causing the natural adaptation of bone to nanoparticles.[5] Nanomaterials are increasingly being investigated for Orthopaedic applications because of their unique characteristics which include their high strength to weight ratio, antimicrobial potential, high wear and corrosion resistance, enhanced tissue integration, drug release potential and regeneration capacity. The clinical application of nanotechnology in Orthopaedic surgery include diagnostic modalities, targeted drug delivery, regeneration of vertebral disk and implantable materials.[6]

Nanotechnology is used to design biocompatible bone graft substitutes.[7] Tricalcium phosphate nanoparticles have been used in synthetic bone graft with the added advantage of high porosity,larger surface area and enhanced vascular invasion and bioresorption.[8] Nanotechnology is used to detect cancer at the earliest stages and can personalized cancer treatment.[9,10] Nanospheres containing anti inflammatory or steroids when injected into the joint results in prolonged local action and avoids crystal induced pain.[11] Li and Laurencin[12] have shown that osteoblastic proliferation and adhesion is enhanced when a scaffolds of nanofiber polymer is utilized. Carbon nanotubes are used in biosensors for diagnosing Osteoporosis, Paget's disease and renal osteodystrophy.[13] Carbon nanotubes have also been used as synthetic conduits in peripheral nerve repairs and they are superior to autografts in terms of nerve regeneration and restoration of electrical properties of myelin sheath.[14]

Orthopaedic infections is major cause of morbidity particularly those infections where bacteria are resistant to antibiotics due to biofilms on Orthopaedic implants in situ.[15] Orthopaedic implants coated with Silver nanoparticles(Ag NP) have been designed because Silver nanoparticles(Ag NP) have been shown to have bactericidal activity against gram positive, gram negative and some antibiotic resistant strains of bacteria.[16] Silver nanoparticles also have anti inflammatory properties and can enhance osteogenesis and osteointegration when used as coating on Orthopaedic implants.[17,18]

Gold nanoparticles have been shown to have scaffolding and osteogenic properties.[19] Studies have shown that gold nanoparticles can be used to deliver drugs, proteins, peptides, DNA and RNA.[20] Copper nanoparticles have been used to design bioactive Orthopaedic implants with antimicrobial potential.[21] Orthopaedic implants coated with Zinc nanoparticles have demonstrated excellent bactericidal activity against gram positive and gram negative bacteria besides enhanced corrosion resistance.[22] Alumina nanoparticles also possess antimicrobial properties and when added to bone cement(PMMA) results in reinforcing the nanocomposites of PMMA causing an increase in tensile strength, hardness and flexural strength of PMMA.[23,24] Wang and Zhao[25] showed that calcium phosphate nanoparticles can be used as a scaffold for stem cell attachment and proliferation and inducing osteogenesis because of its similarities to the inorganic components of bone. All these

metallic and metallic oxide nanoparticles are harmless in low therapeutic concentrations but adverse effects have been recorded when used in higher concentration.[26]

Nanotechnology is used to facilitate spinal fusion and avoids the cost and complications associated with Recombinant Human bone morphogenetic protein(rhBMB). Titanium oxide and Zirconia nanoparticles are added to titanium spinal implants which results in increased bone formation when compared with conventional smooth spinal implants.[27] Federal Drug Agency(FDA) had approved the first interbody spinal fusion device incorporating nanotechnology in 2014.[28]

Nanotechnology is an emerging Nanoweapon of Orthopaedic Surgery. Although the application of nanotechnology in Orthopaedic surgery is still in infancy the initial in vivo and in vitro results are very encouraging. It is a rapidly growing field. It will revolutionized the diagnostic and treatment modalities of Orthopaedic surgery in near future. The potential risk to the human health and environment however should not be overlooked. The reports of earlier researchers [29] indicating pulmonary damage and internal organ damage with nanoparticles warrants further research. Research studies focusing on the safety, cost and regulatory challenges of nanotechnology are therefore mandatory.

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