



# The Next Giant Leap in Spinal Surgery: Is it Nanotechnology?



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## Abstract

Nanotechnology is a novel scientific advancement with potentially breath-taking applications across various fields of medical sciences. Brain and spinal surgeries are potential fields where this technology may revolutionize the management and meliorate the outcome. This article reviews the possible applications of the miniscule nano-particles in the field of Spine Surgery.

## Introduction

Spinal pathologies, which do not respond to conservative management, are traditionally managed with spinal surgeries. While surgical procedures are considered to be the best solutions to spinal ailments, operative interventions alone cannot be the answer to a number of subtler pathologies involving the fine neural elements [1]. Interventions causing alterations at the cellular and subcellular levels of the neural tissues are feasible today; and nanotechnology is one such unique scientific venture which holds a potentially huge prospect in this respect. The current article comprehensively describes the role of nanotechnology in the treatment of spinal ailments.

## Discussion

Nanotechnology enables the creation of novel diagnostic and therapeutic devices by operating on matter at atomic or sub-cellular level. It involves building up complex structures from extremely small-sized particles [2]. There are four basic principles on which this technology works:

- A. Scaffolds of various sizes are built up from small-sized particles.
- B. Diagnostic and therapeutic molecules can be attached to these nano-particles and delivered to appropriate tissues.
- C. They can be delivered across selective barriers, including the blood brain barrier.

D. They have a potential to induce growth and regeneration of tissues, owing to their negative charge [3,4]. Based on the unique physical properties of nanoparticles (including size, shape, charge and surface properties), various clinical applications have been described, which have been described vide-infra [4].

E. Neuro-electromechanical systems: Electrical and mechanical appliances have been developed using nanoparticles, including nano-wires or micro-electrodes, which are clinically capable of measuring the pressures and volumes (eg. CSF pressure) in-vivo [5]. Nano-knives are other tools which can enable interventions with unbelievable precisions [6].

F. Nano-technology-Based Cement: Nanotechnology enables the creation of nano-sized particles of antibiotics or barium sulfate, which can be dispersed evenly onto the cement, without jeopardizing its porosity [7].

G. Nano-technology in Osteoporosis: Carbon nanotubes have been developed, which in combination with hydroxyapatite bio-ceramics, act as scaffolds over which osteoblasts can act, thereby creating trabecular bony masses. This can help enhancing structural support to the matrix in osteoporotic bones [8].

H. Nano-technology in Infections: Silver nanoparticles have been developed, which are coated onto titanium pedicle

screws. Such implants may reduce the formation of bio-films and thereby help in curtailing the growth of methicillin resistant *Staphylococcus aureus* (MRSA) [9].

I. Sutureless Vascular Anastomosis: Iridocyanine green dye-packed nano-shells can enable a controlled heat disposition to the vessels needing anastomosis. These shells can be introduced intra-luminally and minimize greatly the thermal leak to surrounding vital neural structures [10].

J. Molecular Imaging: Nano-particles can be specifically conjugated to cell markers of the target tissues. Apart from the diagnostic implications, this can also have therapeutic applications as tumoricidal agents can be attached to these particles to target the pathological tissues [11]. SPIONs (Superparamagnetic iron oxide nanoparticles) and quantum dots are two specific nanoparticles, which are used in nano-imaging [12].

K. CNS drug delivery: Nanoparticles can serve as useful vectors enabling the delivery of appropriate drugs across the blood brain barriers onto the specific neuronal cells/ tissues [13].

L. Neuronal regeneration: Nano-scaffolds and carbon nanotubes can provide a structural framework over which the axons may regenerate in an organized fashion. Graphene is an atomic-scale monolayer lattice of carbon, which can create nano-composites for neuronal regeneration [14]. These scaffolds can also help deliver the stem cells to the specific sites of regeneration, thereby enabling healing [15].

M. Disc regeneration: Nano-particles with polyvinyl alcohol-polyvinyl pyrrolidone (PVA-PVP) composite are excellent replacement materials for intervertebral (IV) disc tissues [16]. Nano-scaffolds prepared using electrospinning technology can mimic architectural morphology of the IV discs. These nano-polymers can be attached to mesenchymal stem cells and get targeted to IV tissues, thereby enabling disc regeneration [17].

N. Theranostic medicine: Nano-particles can facilitate simultaneous diagnostic as well as therapeutic interventions, especially in oncology where the tumoricidal agent can be delivered to tissues; as well as get utilized for the real-time visualization of the tumor cells for monitoring treatment response and toxicity [18].

O. Reducing Cicatrization: Electro-spun, nano-fibrous membranes can control inflammation and reduce post-operative cicatrization [19].

P. Spinal Fusion: Nano-technology also offers specialized interbody cages (nano-roughened titanium cage) which can stimulate the osteogenic mesenchymal cells and thereby aid in enhancing fusion [20]. Bio-absorbable polymeric nano-enhanced cages are also viewed currently as replacements of the current technology of interbody implants [21].

## Conclusion

Nanotechnology is still in its nascence; nevertheless the potential benefits offered by the unique properties of these molecules in spine surgery are immense. These molecules have the unique capability of providing complex scaffolds, delivering substances to specific, difficult target tissues, as well as inducing tissue regeneration. Such special properties definitely make them the particles to look out for in the future of Spinal Surgery.

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