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An overview of biomedical nanotechnology and its applications

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Abstract
Biomedical Nanotechnology is the most promising field in recent years. Biomedical nanotechnology is a subset of nanotechnology and it is a growing field of medical sciences that are majorly targeted to produce the nano range therapeutics, therapies as well as diagnostic methods that are helpful to improve health care. Nanotechnology is referring to the most innovative technologies that give rise to revolutionary changes in medical sciences. Because of their unique properties nanoparticles are used in many biomedical applications. The several distinct types of nanoparticles like Dendrimers, Liposomes, Nanotubes, Nanocrystals, and Solid Lipid Nanoparticles nanotechnology are used in drug delivery, diagnostics as well as molecular imaging. Nanotechnology is mainly applied as a therapeutic agent for several diseases like cancer, neurogenerative disorders Parkinson's, Alzheimer's disease as well as tuberculosis. Nanotechnology provides important in biomedical science, particularly in oncology. Biomedical nanotechnology is a constantly growing field of developing innovations that changed the world aspect of medical science.

Keywords: biomedical nanoparticles, liposomes, dendrimers, nanotubes, nanocrystals, solid lipid nanoparticles, micelle

Introduction

Biomedical nanotechnology is an emerging field in recent years. Nanotechnology refers to the progression of science as well as technology in which the manipulation of materials on an atomic or molecular scale ranges from nearly 1 to 100 nm [1]. The concept of nanotechnology was first proposed by Prof. Norio Taniguchi from the Tokyo science university in 1974[2]. Biomedical nanotechnology is a subset of nanotechnology and is a rapidly developing field in the area of medical science that mainly target the formation of nano-form therapeutics, therapies as well as diagnostic methods that are useful to improve health care [3]. Nanoparticles refer to the 'solid colloidal materials at the scale of size approximately 10 to 1000 nm. Nanoparticles are mainly useful for biomedical purposes that provide numerous benefits to larger materials like high magnetic characteristics and high ratio of surface-to-volume. The nanoparticles provide several advantages in the biomedical field [4]. There are many distinct types of nanoparticles like Nanotubes, Liposomes, dendrimers, SLN, Nanocrystals [5], and Micelle [6]. The liposomes are spherical vesicles. Liposomes are used in encapsulating other molecules like pharmaceutical drugs [7]. Solid Lipid Nanoparticles (SLNs) are mainly used for protecting chemically labile drugs from degradation into the body as well as managing the continuous release. The nanotubes provide several kinds of applications that are used for drug delivery [8]. Nanocrystals are used for a physical perspective that changes and improves the pharmacodynamic as well as pharmacokinetic characteristics of several kinds of drug molecules [9]. Dendrimers are used for several purposes like catalysts, drug delivery, and medicine [10]. The nanoparticles are mainly useful in the area of medical science for delivering drugs. Nanotechnology is a fastly growing field that offers several applications in medical science. Nanotechnology is majorly helpful in the treatment of several diseases like neurodegenerative disorders, Parkinson's, Alzheimer's disease as well as tuberculosis, and cancer [11]. The establishment of biomedical nanotechnology is based on the nano-ranged from that shows tunable characteristics like surface functionalization, the stimuli-responsive features, simply fabrication as well as tunable features (particularly morphological, electrical, optical, including magnetic characteristics. Nanotechnology is useful in the medical field for drug delivery systems that carry out the location-specific delivery and the drug released to control particular diseases [12]. Nanotechnology provides various applications in the medical field used in the diagnosis of disease, drug delivery as well as drug design. The applications of nanotechnology in the treatment of disease, diagnosis, and monitoring including to management of biological systems are known as 'nanomedicine' [13]. Nanotechnology offers several applications in biomedical sciences used in diagnostics, drug targeting, tissue engineering, managed drug delivery, as well as molecular imaging [14]. This promising field is mainly important for nanomedicine in medical sciences, which provides the prospect of studying biological processes in such a manner that is not earlier possible.

Nanotechnology used in medical sciences consists of the formation of the nanoparticles for diagnostic as well as screening aspects (i.e., Previous cancer detection) The progression of artificial cellular proteins like receptors, DNA as well as sequencing of protein with the use of nanopores including nano sprays, a formation of the special nutrient and drug delivery systems, along with gene therapy it can be applicable in tissue engineering. Nanotechnology gives a wide area of tools able to monitor the cells individually in the extent of the molecules. That allows researchers to explore cellular as well as molecular function monitoring and change the systems deregulated due to disease. This is possible that nanomachines can have the capability to circulate in the bloodstream, kill microorganisms, provide oxygen to the hypoxic organs, and undo tissue injury can one day be delivered to the human body by medicines and even foods [15]. Recently, nanotechnologies are used for the health of humans along with good results, mainly in the treatment of cancer. The notable development through enhancing the efficiency of the regular chemotherapy drugs in a plethora of destructive cancers in humans by the field of nano-oncology. That advances are accomplished by targeting the tumor site along with various functional molecules like nanoparticles, antibodies as well as cytotoxic agents [16]. Biomedical nanotechnology is a constantly growing field of developing innovations and changes the world aspect of the medical field [18].

Briefing of Nanoparticles

Nanoparticles are nowadays in prominent research interest and are an efficient link among the bulk components and molecular or atomic form. The important characteristics of nanoparticles are great because of the higher surface area of the component, which dominates to be involved in the formation of small bulk components. The nanoparticle is generally made of the core of the nanomaterial. That may be useful as an appropriate molecular building surface and can be formed of polymeric as well as inorganic components. They are also like a nano-vesicle covered with the help of a membrane or layer. The structure is commonly spherical but also as a plate, cylindrical as well as other shapes are available [18].

Types of Nanoparticles

The various kinds of nanoparticles like nanotubes, nanocrystals, organic, inorganic as well as polymeric structures like dendrimers. That is mainly useful in research including drug delivery. The most important kinds of nanoparticles such as Nanocrystals, Solid Lipid Nanoparticles (SLNs), Dendrimers, Liposomes, Micelle, and Nanotubes.

1. **Nanotubes:** The nanotubes involved organic as well as inorganic substances and they are produced in the single and multiwalled form involved of self-building sheets of the order of the atoms in the tubes. Radushkevich and Lukyanovich the Russian scientists published images of the carbon nanotubes (CNTs) in 1952, observed in the transmission electron microscope (TEM). In 1991 studies of that substance accelerated, while lijima was established to find out nanotubes increasing without the requirement of a catalyst. The carbon nanotubes are large and cylindrical particles assembled in hexagonally arranged carbon atoms. That wall involved one or several coatings of the graphene. Because of their increased outer surface area, carbon nanotubes can attain the significant loading ability of the chemotherapeutics. Furthermore, they have the capability of cellular internalization that is crucial for CNTs' prominent advantage in biomedicine. Carbon nanotubes can easily incorporate inside the cell for the target drug delivery in the cytoplasm or nucleus. Carbon nanotubes can be functionalized with DNA, Antibiotics, and Proteins [19].

2. **Nanocrystals:** The crystals are less than 1um. The nanocrystals may be useful as a versatile technique for developing pharmacodynamic as well as pharmacokinetic characteristics of low soluble medicines. Furthermore, nanoparticles expand to bioavailability as well as solubility of another molecule. As compared to usual fluorophores, the nanocrystals is a majorly photochemically constant like they have a tunable, narrow symmetric emitting spectrum. The nanocrystals are assembled similar to onion and core covered by a shell, and the latter gives the physical boundary between of outer environment and optically operative core. This structure is formed and it makes a less sensitive to the photooxidation reaction. Nanocrystals are majorly been used to enhance the bioavailability of such drugs by increasing the solubility of the drug [20].

3. **Liposomes:** They were first discovered by Bangham and published in 1964. In the 1970s, liposomes were introduced as a drug delivery system for the first time. Liposomes are spherical vesicles and their size ranges from 30 nm to various micrometers. Liposomes involved one or more phospholipid bilayers surrounding the aqueous phase and polar head groups are situated in external as well as internal aqueous phases. Liposomes are enveloped in hydrophobic as well as hydrophilic materials, prevent to degeneration of constituents, and release it to the set intend. Liposomes are a very well-established carrier for drug delivery at the target site [21]. Liposomes can protect the loaded drug molecules inside them from external damage. The relativity of liposomes to biological or cell membranes can provide a unique approach to drug delivery of molecules in the cell [22]. In medicines, these nanoparticles are used as a carrier and it is already formed accessible, and involved in anticancer, analgesics as well as antifungal drugs [23].

4. **Dendrimers:** Dendrimers are branched and three-dimensional polymeric molecules. Dendrimers were first introduced in 1978 by Fritz Vogtle and by Donald Tomalia with co-workers. Nanoparticles are nanosized, symmetric molecules along with well-known homogeneous including monodisperse form it is commonly

symmetric core, the inner shell as well as outer shell [24]. The dendrimers perform a very essential role in the area of nanotechnology, Pharmaceutical as well as medicinal purposes. Dendrimers are used in several biomedical applications like drug delivery as well as imaging. Dendrimers are a wide range of biomedical applications like anti-cancer drug delivery, transdermal delivery of drugs as well as targeted gene delivery [25]. Dendrimers have precise molecular weight, polyvalency, biocompatibility, and high-water solubility. due to those properties' dendrimers become an ideal carrier for drug delivery [26]. formulation and nano-constructs are the two main approaches followed by dendrimers. In formulation, by using non-covalent interactions, drugs are entrapped physically inside the dendrimers. In the non-construct approach, drugs are covalently bonded to dendrimers [27].

5. **Solid Lipid Nanoparticles (SLNs):** This SLN is described in 1991 and it is a fastly progressing area of nanotechnology and has various promising purposes in drug delivery as well as research. The solid lipid nanoparticles are regarded as the main effective lipid form colloidal carriers and it is a major attractive perspective to enhance the oral availability of less water-dissolving drugs in biological means. They are submicron-sized colloidal carriers and their range is 50 to 1000 nm, they consist of lipid and destruction in the water or aqueous surfactant solutions. The SLN provides significant characteristics like small in size, high surface area, and great drug loading capability that give to increase the efficiency of pharmaceuticals. The SLN offers the major potential to achieve the aim of managing location-specific drug delivery. The major advantage of SLNs includes protecting chemically labile molecules, great biocompatibility as well as enhanced stability of pharmaceuticals [28].

6. **Micelle:** Micelles are the aggregation of several hundreds of atoms, molecules, and ions that are loosely bound and responsible to form a colloidal particle. It is an ultramicroscopic particle that can disperse by some continuous medium. The polymeric micelles have the advantage that it solubilizes hydrophobic and poorly water-soluble drugs inside their core and enhance the bioavailability of drugs. Comparatively, a micelle is a drug delivery technique have two major and unmatchable advantages. One is its comparatively small size which is approximately less than 50nm. Another advantage is its availability and feasibility for large-scale manufacturing. Micelles are used as a carrier for different molecules like proteins, nucleic acids, DNA, hydrophobic drugs of low molecular mass, etc [29].

Application of Nanotechnology in the Biomedical Field

Nanotechnology is an emerging field for biomedical applications. Nanotechnology is used for molecular imaging, tissue engineering as well as drug delivery system. Nanotechnology provides importance in biomedical science, particularly in oncology, and due to that formation of the new research field is known as Nanooncology. The drug-loaded nanoparticles give useful solutions with help of targeted specific tumor cells, therefore preventing the destruction of normal cells [30]. Nanotechnology is a promising technology that is useful for the diagnosis as well as treatment of diseases [31].

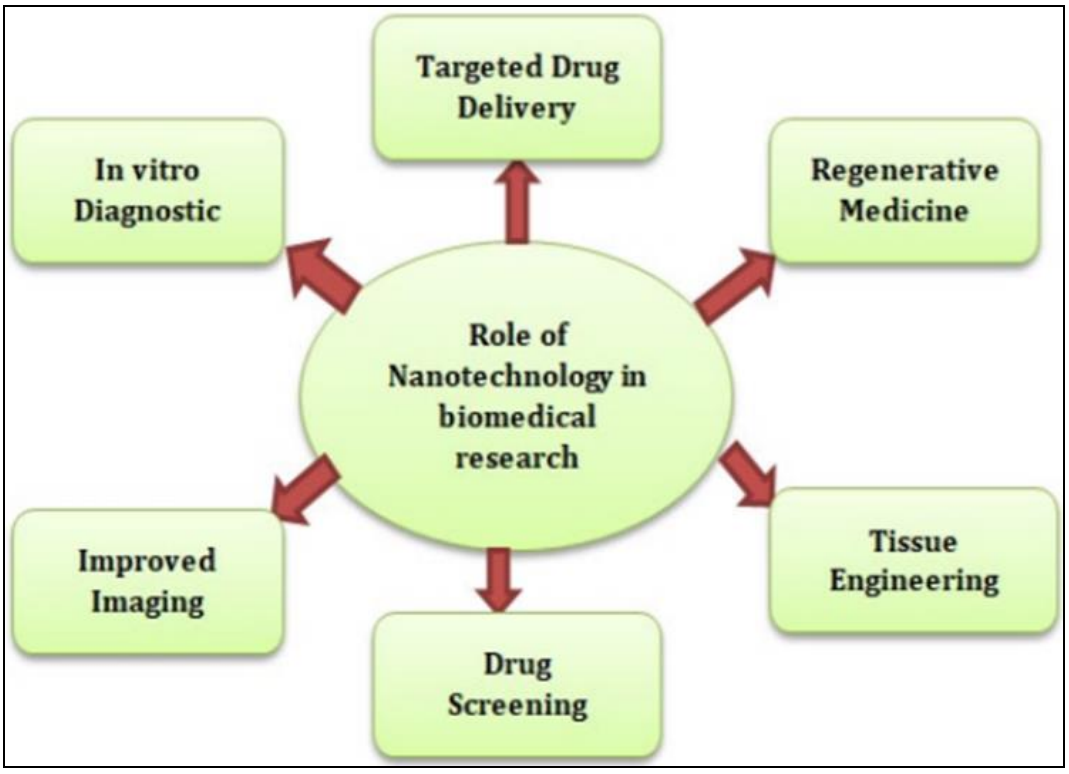

Fig 1: Applications of Nanotechnology in Biomedical Science [32].

Application of Nanotechnology in Molecular Imaging

Several types of nanoparticles like liposomes, dendrimers, micelles as well as inorganic nanoparticles are used for molecular imaging. Molecular imaging is essential to form an appropriate contrast agent that provides a large sensitivity. The great development in nanotechnology gives control of the size, constituents as well as characteristics of nanoparticles. Due to that, nanoparticles provide great achievement in molecular imaging. They are capable of non-invasively visualizing several cellular functions as well as biological processes in the living things and they show the precise disease diagnosis in the early phases. In prosperous molecular imaging, an appropriate contrast agent is necessary for the large sensitivity. As yet, several nanoparticles used in medical imaging techniques are formed as contrast agents. As compared to normal probes, nanoparticles give various advantages such as manageable physical characteristics, facile surface adjustment as well as prolonged circulation time. Nanoparticles are the most useful tool for molecular imaging because they show the intrinsic specific magnetic as well as optical characteristics, that provide the applications for several imaging techniques, and because of prolonged circulation time, it is useful for the targeted delivery. Currently, several research activities form the multiple functional nanoparticles that are useful for treating several diseases [33].

Application of Nanotechnology as a Targeted Drug Delivery Tool

Nanotechnology is a promising technology it forms materials or devices in the nanometer range. It is mostly used for targeted drug delivery [34]. Nanotechnology gives advancement in medical science that delivers drugs to a particular cell with the help of nanoparticles. The total drug consumption, as well as side effects, decreased greatly to deposing of the vital mediums in the morbid area, and no higher dose is required. That greatly particular perspective decreases the costs of human suffering. The examples may be found in the dendrimers along with nanoporous particles. The tools are formed with the use of nanotechnology that can be capable of detecting disease in less quantity of cells or tissue. That is capable to enter including monitoring cells in the living body. Nanotechnology is an emerging approach to the implantable delivery system, that is generally desirable for use of the injectable drugs due to the latter constantly showing first-order kinetics (concentration of blood is increase fastly, but falls exponentially over the time). That fast increase can cause problems of toxicity, and the drug potency may decrease as the concentration of the drug drops below of targeted range [35].

Applications of Nanotechnology as a Tool for Tissue Engineering

Tissue engineering, which is one of the most developing fields in which to make, repair, and replaces cells, tissues including organs with the help of cells as well as a combination of the cells along with bioparticles as well as active biological molecules and useful to form materials that are greatly similar to body' native tissues. Tissue engineering is a promising field interacting with engineering, material science as well as medical biology. Nanotechnology provides a most promising application in tissue engineering. The help of nanotechnology to reproduce and repair damaged tissue. In "Tissue engineering' forms use of the artificially activated cell proliferation with the help of appropriate nanomaterial depends on scaffolds as well as growth factors. Tissue engineering can alternative to the current usual treatments such as organ transplants and artificial implants. The great advancements in tissue engineering provide life expansion [36].

Application of Nanotechnology in Surgical Oncology

Recently, surgery has been a great efficacious way of treatment of human cancers, it is one of the most useful promises for increasing the chances of patients' survival with nearly all cancers is total surgical resection. Nanotechnology is the most promising tool used in surgical oncology and it is useful in tumor location, tumor margin finding, determining the crucial adjacent structures as well as sentinel lymph nodes mapping. Therefore, the needs to form new as well as inventive technologies are useful for a surgeon that describe tumor margins detects the residual tumor cells including micrometastases, and identify the total removal of the tumor. This technology is useful for several organ sites like breast, lung, brain, pancreatic, ovarian as well as prostate cancers. The basic explanation is that nano-ranged particles like colloidal gold, quantum dots, as well as polymeric liposomes, show structural with functional characteristics that are absent in the distinct molecules and bulk particles. Where it is conjugated to the targeting ligands like monoclonal antibodies, peptides, and small particles, nanomaterials are useful for the malignant tumor cells as well as microenvironments of tumor (like stroma including vasculatures of tumor) with great specificity along with affinity. The "mesoscopic" scale is 10 to 100 nm in diameter, the nanoparticles give a high surface area and conjugate with numerous diagnostics including therapeutic agents. That usefulness creates a new opportunity in the integrated diagnostic imaging as well as therapy (known as "theranostics") of cancer [37].

Applications of Nanotechnology in Diagnostics

Nano diagnostics is a newly emerging term it explained the use of nanotechnology methods as well as techniques for the application of diagnostic. Nano diagnostics is the growing perspective in the nanoscale technology that is useful for clinical diagnostics, detecting diseases stage, pathology of the state as well as detection of the causative organisms. Through nanotechnology, diagnosis is performed at a nano-scale that brings about new development and uses the handheld devices it is simple to use. Nano diagnostics is an emerging area of molecular diagnostics and gives several applications. They are usefully altering the procedures of the laboratory, they are giving new methods for the estimation of patient's sample as well as early identification of the disease

biomarkers in addition to improved sensitivity with specificity. The study of the nanoparticles along with their specific characteristics provides several applications in distinct fields, particularly in medical diagnosis [38].

Applications of Nanotechnology as A Tool for Neurodegenerative Disorders Treatment

Nanotechnology is also applicable to neurodegenerative disorders treatments. To deliver the CNS therapeutics, several nanocarriers like liposomes, dendrimers, nanoemulsions, nano-gels, solid lipid nanoparticles, polymeric nanoparticles as well as nanosuspension are studied.

- **Parkinson Disease**
  Central nervous system disorder is termed Parkinson's disease which mainly affects movement. The goal of nanotechnology is the regeneration as well as neuroprotection of CNS and that is a great advantage in the nanotechnology research carried out in parallel to development in neuropathology, neurophysiology as well as cell biology. The research is mainly emphasizing the design, biometric incentives along with the development of intracranial nano-enabled scaffold device (NESD) for location-specific delivery of the dopamine in the brain, like an approach peptide as well as peptidic nanoparticles.

- **Alzheimer's Disease**
  The main common cause of dementia is Alzheimer's disease. Nanotechnology provides great importance in neurology. The main perspective depends on early Alzheimer's disease diagnosis in addition to treatment is available to design as well as engineering the plethora of the nanoparticle entities including large specificity to the brain capillary endothelial cells.

- **Tuberculosis Treatment**
  The deadly infectious diseases include tuberculosis. A long period of treatment along with pill load majorly affects the patient health and the formation of multiple drug-resistant (MDR) strains. Nanotechnology is an emerging perspective on the formation of efficacious medicines. Development in the nano-depend system of drug delivery to the encapsulation by releasing of the TB resistant drugs that give great advancement in more efficacious as well as inexpensive TB pharmacotherapy [39].

Conclusion

This study emphasizes the different types of nanoparticles which are having medicolegal applications. Different types of nanoparticle carriers and nano devices are studied in this article. Along with the different types, this article also provides the biomedical applications of different nanoparticles and nanomaterials. In the future, this study may help to find and study different nanoparticle devices and their applications.

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