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Potential Devices of Nanostructured Nanomaterials in Drug Delivery Systems

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Abstract

With advancement in medicines, Nanomaterials have tremendous potential in the drug delivery system. The usage of polymeric and non-polymeric nanomaterials has attracted much attention because of its different compositions and extensive use for the gene and drug delivery. The drugs face several barriers during their movement inside the human body to reach their target site. The biological environments need to understand and get tuned to the interactions of nanomaterials with the human body such as targeting cell-surface receptors and drug release mechanisms. The polymeric nanomaterials such as hydrogels, micelles, liposomes and polymeric nanoparticles and non-polymeric nanomaterials such as quantum dots, carbon nanotubes, metallic nanoparticles etc are used for the formulations of several drug deliveries. In this review, we have reviewed on the prospective of polymeric and non-polymeric nanomaterials in drug delivery systems.

Keywords: Polymers; Nanomaterials; Nanoparticles; Drug delivery system

Abbreviations: FDA: Food and Drug Administration; PLA: Polylactide; PGA: Polyglycolide; PEGs: Polyethylene Glycol; PNIPAM: (Poly(N-isopropylacrylamide); CNT: carbon nanotubes; AFM: Atomic Force Microscopy; SEM: Scanning Electron Microscopy; TEM: Transmission Electron Microscopy; PMs: Polymeric Micelles; NPs: Polymeric Nanoparticles; DDS: Drug Delivery Systems; QDs: Quantum dots

Introduction

Nanomaterials are excellent tools to develop the device for the drug delivery. In these materials drugs can be placed inside, combined or attached for the specific target diseased cells for its sustained release in the human body. The size of the nanomaterials is so small, that it can pass through from one organ to another, across the blood brain barrier too [1]. They must cross many critical barriers of kidney, blood stream, plasma membrane, nuclear membrane etc. The conventional medicines have some disadvantages such as low bioavailability, toxicity and rapid clearance. The traditional methods of drug delivery, like injections or pills etc. In most cases it is having adverse reactions towards the patients. The injectable drug delivery devices which can carry the Nanomedicine need further attention and development. The biodegradable polymers are playing an important role in the drug delivery by providing controlled release of drugs by crossing the physiological barriers of the patients.

Nanomaterials with high surface-to-volume ratio of different types make them ideal carriers for drug delivery [2-5]. The Food and Drug Administration (FDA) is the federal regulatory agency responsible for evaluating the potential health risks of nanomaterials with drug combinations. The types of nanomaterials for the drug delivery need its approval for the specific delivery route such as inhalation, dermal, ingestion, injection and environmental impact. The polylactide (PLA), polyglycolide (PGA) and chitosan (biodegradable polymers), polyethylene glycol (PEGs), poly (2-oxazoline), Poly(N-isopropylacrylamide) (PNIPAM) (hydrophilic polymers), Au, Ag, iron oxide nanoparticles, graphene oxide and carbon nanotubes (conjugated nanomaterials) are the different materials which are useful in drug delivery.

The potential designed devices of polymeric nanomaterials are hydrogels, micelles, liposomes, dendrimers, nanoparticles, carbon nanotubes (CNT), fullerenes, quantum dots and graphene oxide etc. The surface of the nanomaterials can be modified with the addition of chemical compounds such as hydroxyl groups, peptides, or proteins to get the more soluble, less toxic and immunogenic molecules as functionalized materials.

The polymeric and non-polymeric devices loaded with drug are characterized based on their size, shape, morphology, physical stability, chemical compositions, size distribution etc. the advanced microscopic techniques such as atomic force microscopy (AFM), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) are the tools to evaluate the properties of the nanomaterials devices. The differential scanning calorimetry for carrier-drug interaction, zeta potentiometer for charge determination, ion mass spectroscopy for surface chemical analysis, chemical analysis of drug to know the drug stability, contact angle measurement and in-vitro studies are used to determine the various other characteristics of nanomaterials devices.

As such, nanomaterials are poised to take advantage of existing cellular machinery to facilitate the delivery of drugs. Highly efficient drug delivery, based on nanomaterials, could potentially reduce the drug dose needed to achieve therapeutic benefit, which, in turn, would lower the cost and/or reduce the side effects associated with a drug. Moreover, size and surface characteristics of nanoparticles can be manipulated to achieve both passive and active drug targeting. Site-specific targeting can be achieved by attaching targeting ligands, such as antibodies or aptamers, to the surface of particles, or by using guidance in the form of magnetic nanoparticles. Nanoparticles can also control and sustain release of a drug during transport to, or at, the site of localization, altering drug distribution and subsequent clearance of the drug to improve therapeutic efficacy and reduce side effects. In this review, the focus is on the usages and application of polymeric and non-polymeric nanomaterials to drug delivery and highlight several areas of opportunity where current and emerging nanotechnologies could enable novel classes of therapeutics. The effort is to explain the challenges and limitations in nanotechnology to defeat in drug delivery. However, this article can only serve to provide a glimpse into this rapidly evolving field, both now and what may be expected in the future.

Polymeric nanomaterials devices for drug delivery systems

Polymers are widely used in the drug delivery systems because of its biocompatibility, easy to design and preparations and deliver the therapeutic agents to the diseased site. There are many tunable polymeric devices which are significantly designed for the drug delivery systems. The water-soluble polymers are used to prepare the cross-linked network like structures called hydrogels with a wide range of chemical compositions and bulk physical properties. Hydrogels are prepared in the form of slabs, micro or nanoparticles, coatings and films which are used in clinical practice and experimental medicine such as tissue engineering and regenerative medicine [6], diagnostics [7], cellular immobilization [8], separation of biomolecules or cells, and barrier materials to regulate biological adhesions [9]. The highly porous structure of the hydrogels can easily be tuned for the aqueous environment, reform their shape, biocompatible in nature.

The limitations of hydrogels result its premature dissolutions because of the low tensile strength and load-bearing restrictions for the target sites of drug delivery. These issues limit the real applications of hydrogel-based drug delivery systems. Micelles are another polymeric device designed for drug delivery route is oral administration because of its simplicity, ease and acceptance by the patient especially during the doses of chronic therapy [10-12]. Many drugs are difficult to attain enough bioavailability when administered (low solubility and low permeability) orally. Polymeric micelles (PMs) can be modified to enhance its drug absorption, by providing protection of the loaded drug from the harsh environment of the gastrointestinal track, release of the drug in a controlled manner at target sites, prolongation of the residence time in the gut by mucoadhesion, and inhibition of efflux pumps to improve the drug accumulation [13]. Polymer micelles used for drug delivery is formed as self-assembly with hydrophobic and hydrophilic surfaces.

Polymeric micelles are used as multifunctional drug delivery devices for poorly water-soluble drugs and is a promising to get the desirable properties as per the pharmaceuticals models drug. Liposomes are also potential polymeric drug delivery devices which are a lipid bilayer structure or membrane. It is having many applications such as delivering enzymes, antibacterial, antiviral drugs, antiparasite drugs, fungicides, transdermal transporters, diagnostic tools and adjuvants for vaccines [14]. Dendrimers are novel three dimensional, hyperbranched globular nanopolymeric architectures. Attractive features like nanoscopic size, narrow polydispersity index, excellent control over molecular structure, availability of multiple functional groups at the periphery and cavities in the interior distinguish them amongst the available polymers. Dendrimers in a biomedicine fields have been much explored because of its three-dimensional structures and its applications in diagnostics and drug delivery. Drug delivery scientists are especially enthusiastic about possible utility of dendrimers as drug delivery tool. Terminal functionalities provide a platform for conjugation of the drug and targeting moieties.

In addition, these peripheral functional groups can be employed to tailor-make the properties of dendrimers, enhancing their versatility. The present review highlights the contribution of dendrimers in the field of nanotechnology with intent to aid the researchers in exploring dendrimers in the field of drug delivery. Polymeric nanoparticles (NPs) containing encapsulated, dispersed, absorbed or conjugated drugs have unique characteristics that can lead to enhanced performance in a variety of dosage forms. When formulated correctly, drug particles are resistant to settling and can have higher saturation solubility, rapid dissolution and enhanced adhesion to biological surfaces, thereby providing rapid onset of therapeutic action and improved bioavailability. In addition, most molecules in a

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nanostructure reside at the particle surface which maximizes the loading and delivery of cargos, such as therapeutic drugs, proteins and polynucleotides, to targeted cells and tissues. Controlled drug delivery systems (DDS) have several advantages compared to the traditional forms of drugs [15].

The drug which is transported to the target site will more have more impact on the desirable place and its side effects can be minimized. Accumulation of therapeutic compounds in the target site increases and, consequently, the required doses of drugs are lower. This modern form of therapy is especially important when there is a discrepancy between the dose or the concentration of a drug and its therapeutic results or toxic effects. Cell-specific targeting can be accomplished by attaching drugs to specially designed carriers.

Non-polymeric nanomaterials devices for drug delivery systems

There are certain devices which can be developed without the polymers for drug delivery devices such as carbon nanotubes, quantum dots and metallic nanoparticles. Carbon nanotubes (CNT) are the promising tiny hollow cylinders in drug delivery fields because of its unique properties and strength. The functionalized CNT have emerged as a new alternative and efficient tool to diving into the cellular uptake mechanisms, biodistribution of the delivery system, and safety concerns on degradation of the carriers and safety carrier of therapeutic agents to the target sites [16]. Quantum dots (QDs) are having great potential in the drug delivery system. It acts as a nano-carrier to detect, monitor and treat the diseased sites. This device helps to improve the stability of the drugs, lengthen circulation time in-vivo, enhance targeted absorption, and improve the distribution and metabolism process of drugs in organization [17].

QDs are versatile in their characteristics because of real time monitoring of drug delivery mechanism. But the direct use of QDs is still questionable because of their toxicity can be reduced by surface modification approaches Non-polymeric nanoparticles (metallic nanoparticles) has the huge potential in the biomedical fields. The synthesized metallic nanoparticles such as Au, Ag, Fe3O4 can be modified with different chemical functional groups to bind with ligand, genes, proteins, antibodies and drugs for the targeted drug delivery. These nanoparticles are unique because of their small particle size, high stability, tunable hydrophilic-hydrophobic balance and the ability to surface features for target specific sites [18].

Conclusion

As research facilitates ongoing improvement in the pharmacological and therapeutic properties of drugs it drives the revolution in novel drug delivery systems. The number of ways to enhance use of therapeutic nanocarriers has been widely investigated to attend the emerging techniques. This article was reviewed the recent developments in the use of polymeric and non-polymeric devices as drug delivery systems to treat a wide variety of diseases. In conclusion, there are immense potential in medical treatments with the novel nanomaterials and drug combinations are presents with increasing opportunities. To work in this emerging field one needs access to information about polymeric and non-polymeric nanomaterials devices for drug delivery, its potential health and safety risks. Understanding the benefits of nanomaterials drug applications is the good decision-making for drug developers, regulators and ultimately the consumers and patients who will use this new drug delivery technology.

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