RESEARCH PAPER

Nanotechnology-Driven Innovations in Drug Delivery: A Focus on Ocular Therapeutics

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ABSTRACT
Nanotechnology—a express derived from the Nano is a Greek term that means dwarf—applies the concepts engineering, electronics, physical and material science, and manufacturing. The materials at the nanoscale may be supra-molecular structures, complexes, composites, or devices or systems. "That domain in science and technology where tolerances and dimensions fall between 0.1nm to 100nm," according to Albert Franks, an early proponent of nanotechnology. It has been projected that nanotechnology would significantly advance common medicinal applications, such as genetherapy, drug-transport, imaging, and innovative drug discovery methods. Many aspects of our world might be transformed by nanotechnology, which is being touted as-new-generation of technology. This covers almost every facet of daily living, such as health and medical treatment, the creation and utilization of resources and equipment, and the preservation of the environment. It's claimed to-be ableto drastically lower expenses while greatly increasing productivity. Nanotechnology'll-result in smaller, lighter, less expensive, and more functional products that use less energy and raw materials to produce. However, the "revolution" will take time, and significant research and development expenditures will be needed along the way.
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INTRODUCTION

Nano-technology in drug delivery

Nanotechnology has a significant impact on the creation of delivery networks for tiny molecules, proteins, and DNA, which has resulted in the creation of entirely new and somewhat unpredicted fields. Innovative drug delivery methods are a critical instrument for the pharmaceutical industry to grow its drug markets. The technique can solve problems with existing medications, such prolonging their shelf life, or it can improve their performance and acceptance by boosting efficacy or enhancing patient safety compliance. (4) Drugs that are extremely unstable or insoluble in water in a biological setting can now be delivered thanks to this method. The following benefits come from medication nanosizing:

- Increased solubility
- A higher dissolution rate
- A higher level of oral bioavailability
- A quicker start to the therapeutic effect,
- Reduced the required dosage
- Less variation in fed/fasted
- Less variation from patient to patient

Significance of drug delivery and targeting

The limited ability of several therapeutic medicines to reach the target tissue has resulted in their failure. In addition, the faster growth opportunities are expected in developing delivery systems for anti-cancer drugs, hormones, and vaccinations due to inadequacies in their traditional methods of delivery in terms of safety and effectiveness. For instance, cytostatic medications used in cancer chemotherapy harm both healthy and cancerous cells. Therefore, there is an urgent need for a medicine delivery method that focuses on the malignant tumour. The biological instability of drugs environment and early drug loss due to quick metabolism and clarity are further issues. Similar to this, some medications, including protease inhibitors, have significant protein binding that restricts their capacity to permeate other organs, including the brain. less potent ones, as the bigger dosage would require a more complicated drug delivery system that would be challenging to give.

NANOPARTICLES

Particulate-dispersions or solid-particles with a size between 10 and 1000 nm are referred to as nanoparticles. The medication is encapsulated, dissolved, trapped, or bonded to a matrix of nanoparticles. To gain the drug's site-specific activity at therapeutically-ideal dosage and pace-regimen, the main objectives of Controlling the size,surface properties, and release-of pharmacologically-active compounds are the main goal of creating The use of

nanoparticles for distribution vehicle, Although lipo-somes have been employed as potential-carriers with special benefits, such as preventing drug degradation, focusing on the site/action, and lowering toxicity or adverse effects, their uses are restricted because of innate issues like poor storage stability, low encapsulation efficiency and quick water-soluble medication leakage when blood is presentcomponents. However, polymeric-Nanoparticles-offer a-number of benefits. over liposomes, such as improving the stability of medications and proteins and having practical controlled release capabilities. The benefits of utilizing nanoparticles as a drug-delivery system include the following**:**

- It is simple to control the size/surface traits associated with nanoparticles to produce both-passive and active medication targeted following parenteral delivery.
- They modify the drug's organ distribution and subsequent clearance to boost effectiveness of treatment and decrease side effects by controlling and maintaining the drug's release during transportation as well as at the location.
- The selection of matrix ingredients allows for easy modulation of controlled-release and particle-degrading characteristics. Relatively high drug loading and the ability to incorporate pharmaceuticals into systems without causing a chemical reaction are crucial for maintaining drug activity.
- Targeting ligands can be attached to particle surfaces or magnetic guiding can be usedto accomplish site-specific targeting.
- System canbe administered orally, nasally, parenterally, or intraocularly, among other methods.

OCULAR DRUG DELIVERY SYSTEM

The eye's drug disposition properties make it the most intriguing organ. In most cases, topical treatment is better than systemic treatment for eye conditions. The precorneal barriers must be crossed by any drug molecule supplied through the ocular route before it can reach the cornea's anatomical barrier. These initial barriers, which are made up of the conjunctiva and tear film, impede the entry of an active component into the eye. About 50–75µL of traditional ophthalmic solution is delivered by a standard dropper, and a portion of these drops rapidly drain until the eye returns to its typical resident volume of 7µL. There is a very limited amount of medication that can reach the cornea and inner tissue of the eye because to this loss at the front of the eye. The medication has a very low actual corneal permeability, and the implanted solution has a very short corneal contact period of 1-2 minutes in humans.

The best ophthalmic medication delivery system must possess the ability to upholdthe drug's release and stay close to the front of the eye for an extended amount of time. Therefore, optimizing ocular medication delivery is essential.

Parameters to optimize ocular drug delivery system

- Adequate penetration of the cornea.
- Extended interaction with corneal tissue.
- The patient's ease of administration
- Comfortable and non-irritating shape
- suitable viscous system concentrations and rheological characteristics.

In recent years, numerous alternate There have been attempts at dosage forms, to circumvent the deficiencies of the traditional ophthalmic dosage form; However, each has been demonstrated to be inadequate in one or more aspects. (10)

Conventional ocular drug-delivery system

Traditional ocular drug-delivery methods, such as solutions, suspensions, and ointments, are no longer enough to meet the modern demands of delivering a steady rate of administration for an extended-period of time.

Reaching the ideal medication concentration at-the siteaction is a significant challenge in ocular therapies. Precorneal loss variables, such as tear dynamics, non-productive absorption, temporary residency duration in the cul-de-sac, and the relative impermeability of the corneal epithelial membrane, are the primary cause of poor bioavailability of medications from ocular dosage forms. Only a little portion of the medication—roughly 1% or less of the administered dose—is absorbed through the eyes as a result of these physiological and anatomical limitations. By-changing the medicine's potency, volume, or dosage frequency, inaddition to ,the duration of time the medication is in contact with the eye's surface, the effective dosage of an ophthalmic medication can be changed.

Disadvantages of conventional ophthalmic formulations

1. Low bioavailability as a result of increased lacrimation, normal tear turnover, conjunctival absorption, quick precorneal elimination, and solution drainage by gravity.
2. Regular instruction
3. The presence of viscous autos may cause blurred eyesight.
4. The metabolism of enzymes
5. Absorption of drugs systemically

OCULAR DRUG DELIVERY SYSTEM NANOPARICULATE

In order for ophthalmic therapy to be effective, a sufficient quantity of the substance must be administered and kept at the eye's site of action. An effective defence against ocular diseases is provided by the eye's defensive physiological process and anatomical structure. medication administration. The anterior segment tissues of the eye frequently get only one or a small portion of the medication dose that was administered.

Numerous restrictions reduce the efficacy among the most popular dose forms, such as ocular suspensions and solutions. Many medications have poor penetration through the lipophilic corneal barrier when in solution form. Quick

nasolacrimal A brief duration of action and undesired entry into the systemic circulation result from the drug's drainage from tear fluid and effective absorption through the conjunctiva.

When administered in the form-solution, many medications have low ocular bioavailability due to precorneal variables such as tear turnover and drug binding to tear fluid proteins. The medicine is initially absorbed from the tear fluid to the ocular tissues at a high rate, but this rate quickly drops. Before the next dose is given, there is a prolonged time of subtherapeutic levels due to the quick loading of the drug, which causes a brief period of overdose and the related risk of side effects. In order to localize and prolong medication activity at its site of action, A technique for delivering drugs to the eyes that is as convenient as a drop is clearly needed. Ocular medication delivery can be improved in a number of ways. Drugs can be targeted to ocular tissues using nanoparticles, which are innovative dosage forms that extend the encapsulating drug's residence duration in the eye. [11]

Increasing the duration of the drug's interaction with the conjunctiva is the primary goal of optimizing ocular drug delivery. Since colloidal carriers like liposomes and nanoparticles have-been shown to be effective in extending the corneal contact period, They are becoming more and more being explored for ocular medication delivery.

A variety of polymers, including polylactic-co-glycolic acid, polymethylmethacrylate, albumin, chitosan, gelatin, polyalkylcyanoacrylate, ε-caprolactone, and polyacrylamide, are utilized in the creation of nanoparticles. Pilocarpine-loaded nanospheres of polymethylmethacrylate acrylic acid copolymer were used in the first nanosphere study. They created pilocarpine-sensitive latex nanoparticles that were sensitive to pH, and the outcome was encouraging. In a different investigation, pilocarpine's binding to poly (butyl) cyanoacrylate nanoparticles increased the mitotic response by roughly 22% to 33%. [12,13] Because of their possible biocompatibility with the ocular tissues, natural polymers are favored among the several polymers utilized to create nanoparticles for ocular administration.[14]

Standards for the best polymeric carriers for medication delivery systems using nanoparticles

- Simple to characterize and synthesize
- Affordable
- Both biodegradable and biocompatible
- The absence of immunogenicity
- Innocent

Delivery techniques for nanoparticles

- Easy and affordable to scale up and manufacture.
- They are prepared without the use of heat, strong shear pressures, or chemical solvents.
- Repeatable and steady.
- Widely applicable to proteins, polynucleotides, small compounds, and medications
- The capacity to lyophilize, After administration, stable
- Non-toxic

Types of polymer-based ocular particulate dosage forms

The polymer	Medication	Finding
Albumin	Piroxicam	Increased bioavailability compared to retail eye drops
Albumin	Ganciclovir	The length of stay is extended.
Chitosan	Cyclosporin A	For at least 48 hours, therapeutic concentrations in the cornea and conjunctiva
Chitosan PEO insert	Ofloxacin	Aqueous humor concentration rose.
Chitosan	Fluorescent label	high concentrations of nanoparticles in the conjunctival and corneal epithelia
Pectin	Piroxicam	Increased bioavailability in water-based humor compared to eye drops
Carrageenan gelatin	Timolol	Superior bioavailability in aqueous humor in contrast to store-bought eye dropsand in-*situ* gelling system
Cellulose acetate phthalate	Pilocarpine	Extended miosis
Eudragit	Ibuprofen	Enhanced bioavailability of the eyes
Poly(butyl)cyonoacrylate	Amikacin	Enhanced bioavailability of the eyes
Polylactic acid	Chloramphenicol	Increased bioavailability in water-based humor compared to eye drops

CONCLUSION

Nanotechnology has a significant impact on the creation of delivery networks for tiny molecules, proteins, and DNA, which has resulted in the creation of entirely new and somewhat unpredicted fields. Innovative drug delivery methods are a critical instrument for the pharmaceutical industry to grow its drug markets. Nanotechnology offers a transformative approach in ocular drug delivery by overcoming the limitations of conventional formulations such as low bioavailability, rapid tear drainage, and poor corneal penetration. Nanoparticle-based delivery systems, particularly those using biocompatible and biodegradable polymers like chitosan, provide enhanced drug stability, sustained release, targeted delivery, and increased residence

time at the ocular site. In this study, ganciclovir-loaded chitosan nanoparticles demonstrated superior physicochemical characteristics, high encapsulation efficiency, and prolonged drug release compared to standard eye formulations.

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