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# A REVIEW ON OPTHALMIC DRUG DELIVERY SYSTEM RECENT IN ADVANCE

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## ABSTRACT

Ophthalmic drug delivery is a significant area of pharmaceutical study since it is difficult to transport medications to the eye effectively because of blinking, nasolacrimal drainage, fast tear drainage, and other anatomical and physiological barriers. Conventional eye drops often have low ocular bioavailability and a short drug residence time, necessitating repeated administration. Enhancing drug retention, controlled release, ocular targeting, and patient compliance have been the main goals of recent developments in ophthalmic drug administration. Nanoparticles, liposomes, nanoemulsions, nanomicelles, hydrogels, in-situ gels, drug-eluting contact lenses, ocular implants, microneedles, iontophoresis, and stimuli-responsive delivery systems are examples of novel techniques. These technologies can deliver drugs to the anterior and posterior parts of the eye in a sustained and focused manner. Systems based on nanotechnology are especially promising since they can enhance the solubility, permeability, stability.

**KEYWORDS:** Ocular drug delivery, Controlled drug delivery, Hydrogel-based delivery, Microneedle-based ocular delivery, Drug-eluting contact lenses.

## INTRODUCTION

Recent advances in ophthalmic drug delivery have focused on overcoming the anatomical and physiological barriers of the eye and improving drug bioavailability, therapeutic efficacy, and patient compliance. Conventional eye drops have limited ocular retention because of tear drainage and blinking, resulting in low bioavailability and the need for frequent administration. To overcome these limitations, several advanced delivery platforms have been developed, including long-acting implants, in situ-forming implants, nanoparticles, contact lenses, electrospun patches, microneedles, hydrogels,

liposomes, nanomicelles, microparticles and iontophoresis.[1]

Overcoming the anatomical and physiological obstacles of the eye and enhancing medication bioavailability, therapeutic efficacy, and patient compliance have been the main goals of recent developments in ocular drug administration. Due to blinking and tear drainage, conventional eye drops have poor ocular retention, low bioavailability, and frequent administration. Long-acting implants, in situ-forming implants, nanoparticles, contact lenses, electrospun patches, microneedles, hydrogels, liposomes, nanomicelles, microparticles, and iontophoresis are some of the sophisticated delivery systems that have been created to get around these restrictions.[1]

The cornea, conjunctiva, aqueous humor, iris, ciliary body, and lens are among the ocular tissues that make up the anterior portion of the eye, which is involved in refraction and vision, while the vitreous humor, choroid, retina, and posterior sclera make up the majority of the back segment of the eye. In order for the eye to see the outside world, the posterior segment detects light signals and sends them through the optic nerve. These specialized ocular tissues can be impacted by a variety of long-term eye conditions.[2]

A tight corneal–epithelial interface, reflex blinking and tearing, ocular tissue/s metabolism, tear turnover, nasolacrimal drainage, efflux transporter pumps, and the blood–aqueous barrier are some of the obstacles to treating anterior segment illnesses.[2]

**Importance**

Improving bioavailability, Minimizes adverse effect, Improve patient compliance, Reduces dosing frequency, Provides targeted drug delivery.

**Insitugel system**

Drops of an in-situ ocular gel are injected into the eye. It goes through a sol-gel change after coming into contact with tears, creating a gel that stays on the surface of the eye longer and delivers medication for a longer period of time. For instance, glaucoma in-situ gel containing timolol maleate.

Benefits: Increases the duration of a drug's stay in the eye, Enables controlled and prolonged medication release, Decreases the frequency of dosing, Increases the bioavailability of drugs, Minimize medication loss by draining tears.[3]

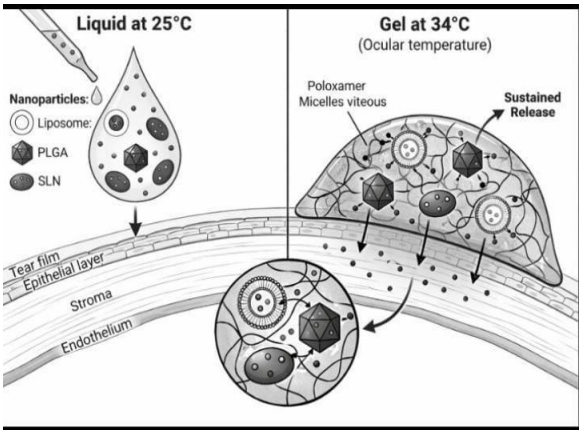



**Fig:Insitu Gel System.[4]**

The in situ gelling system represents a straightforward method that ensures precise dosing, is easy to produce, and is cost-effective. Utilizing these systems can help prevent drug leakage into adjacent ocular tissues, thereby increasing therapeutic effectiveness, enhancing patient comfort, and improving adherence to the prescribed treatment. In situ gels, which are also referred to as free-flowing liquid solutions, are especially advantageous for ocular use as they convert to gels under physiological conditions, while the polymers utilized display pseudoplastic behavior, meaning their viscosity diminishes under shear conditions such as blinking allowing the drug-polymer solution to disperse evenly across the eye surface.[4]

**Hydrogel based on ocular delivery systems**

Hydrogels are hydrophilic, cross-linked polymer networks that can absorb significant amounts of water. Upon exposure to aqueous environments, hydrogels can exhibit swelling behavior without compromising structural integrity. The unique swelling response of hydrogels renders them highly useful for a wide variety of applications. In the pharmaceutical industry, hydrogels have garnered popularity because of their ability to trap within the cross-linked matrix a wide array of therapeutic agents that range in size and water solubility. Sustained and targeted drug delivery can easily be achieved by modifying hydrogels' various features such as swelling rate, porosity, biocompatibility, and mechanical strength. Additionally, many hydrogels have been engineered to respond to specific changes in the environment. Given that many ocular diseases are characterized by changes in pH, temperature, or ion concentrations.[5]

Hydrogels can be highly effective in detecting abnormal physiological changes and providing timely pharmaceutical interventions. Importance: Prolonged drug retention, Controlled drug release, Improved bioavailability, Better patient compliance, Improved therapeutic effect. Hydrogels are networks of cross-linked, hydrophilic polymers that have a high water absorption capacity. Hydrogels can swell when exposed to watery environments without losing their structural integrity. Hydrogels distinct swelling reaction makes them extremely beneficial for a wide range of applications. Hydrogels have been popular in the pharmaceutical business due to their capacity to encapsulate a variety of medicinal substances with varying sizes and water solubility within the cross-linked matrix. Hydrogels are networks of cross-linked, hydrophilic polymers that have a high water absorption capacity. Hydrogels can swell when exposed to watery environments without losing their structural integrity. Hydrogels' distinct swelling reaction makes them extremely beneficial for a wide range of applications. Hydrogels have been popular in the pharmaceutical business due to their capacity to encapsulate a variety of medicinal substances with varying sizes and water solubility within the cross-linked matrix.[5]

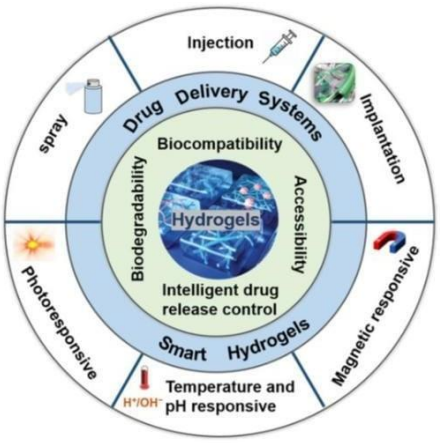



**Fig: Hydrogel based on ocular delivery systems.[6]**

**Microneedle Based Ocular Drug Delivery System**

Microneedles are tiny needles that can pierce the superficial ocular tissues with little discomfort or tissue damage. They are typically hundreds of micrometers length. They can enhance drug absorption and residence time and aid in delivering medications to particular areas of the eye. Benefits: Prolonged drug release Enhanced drug bioavailability. Targeted drug delivery, Able to administer medications to particular ocular tissues, Could lessen the frequency of eye drops.[7]

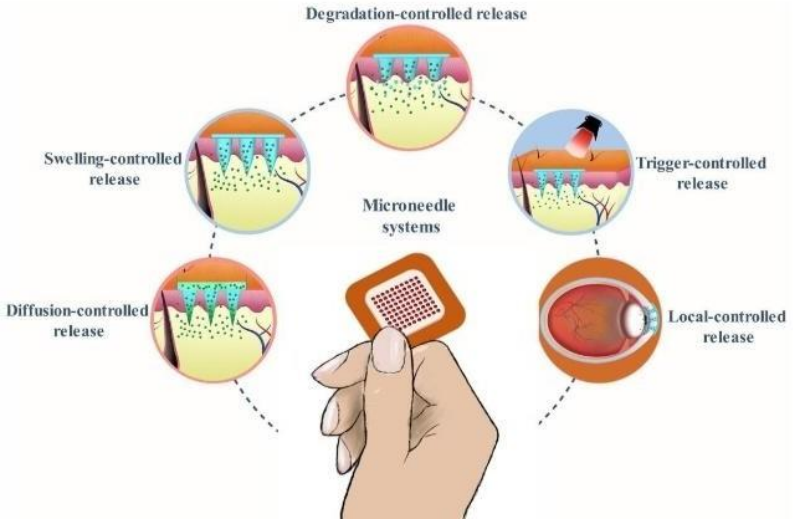



**Fig: Microniddle ocular drug delivery system.[8]**

**Drug Eluting Contact Lenses**

Via blinking, non-specific absorption, nasolacrimal drainage, and tear dilution, medicatins administered through eyedrops are quickly eliminated from the ocular surface.Citation Preservatives and non-physiological pH are common requirements for eye drops, which have both immediate and long-term effects on patient acceptance and adoption. Furthermore, eye drops that have been instilled may easily fall out of the eye, resulting in a considerable fluctuation in the dose given and possibly inconsistent treatment results.Citation To get around this, eye drops must be administered several times a

day to guaranty sufficient drug concentration, which causes problems with patient compliance, annoyance, and systemic side effects. Importance**:** Improve therapeutic efficacy, Convenient for chronic eye disease, Reduces drug wastage, Target drug delivery, Improve drug bioavailability.[9]

**Advanced Biological Delivery System**

**Nanotechnology**

Nanotechnology means the study of structures or useful materials that're at the nanoscale and these are made using either physical or chemical ways or both. Nanobiotechnology is a word that shows how nanotechnology meets biology and it is very useful in health care and biotechnology. This field has become a research area in decades because the tiny materials have special chemical, electric, light, life and magnet qualities. When combined with ideas nanotechnology now has many uses in medical imaging, test kits, life sensors, dentistry, cleaning of medical device surfaces and many other areas. In detail nanotechnology usually includes the use of the following materials, which have uses in health care and medical study.[10]

Nanoparticles: Nanoparticles used as antimicrobials, antifungals, sensors and for diagnostic imaging.

Carbon nanotubes: Carbon nanotubes used to deliver proteins into cells to carry genes and to treat bone diseases and breast cancer.

Dendrimers: Dendrimers used for gene delivery as agents, for cancer therapy and to treat eye diseases.

Nanofilms: Nanofilms used as sensors, in devices to release drugs in a controlled way and as nanopatches to close wounds after surgery.

Quantum dots: Quantum dots used in diagnostics for real-time bioimaging to deliver RNA and to deliver drugs.

Nano-diamonds: Nano-diamonds used for targeted drug delivery to treat bone diseases for imaging and detecting cancer and to treat brain and breast cancers.

Liposomes: Liposomes used for drug delivery to protect drugs from breaking down and to enclose antitumor drugs in cancer treatment.[11]

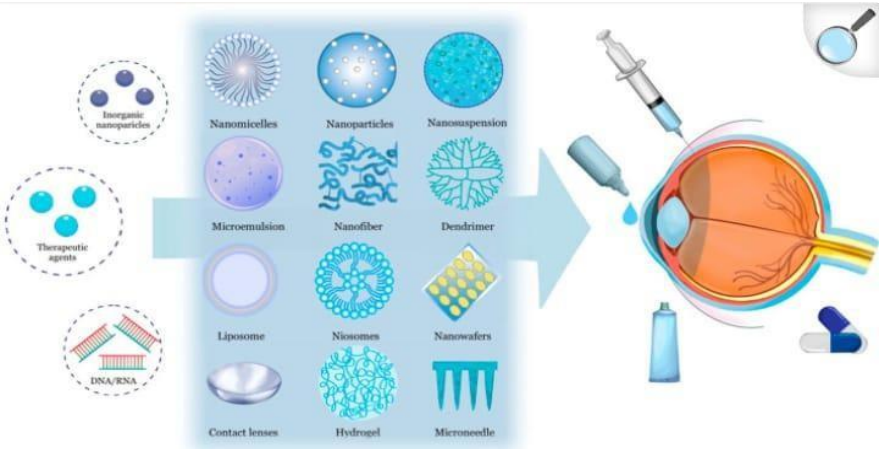



**Fig: Nanotechnology Based on Ocular Drug Delivery System.[12]**

**Novel Physical Method**

The use of novel drug delivery and targeting techniques, such as implanted drug delivery systems (DDSs) or devices (DDDs), stimuli-responsive advanced biomaterials, multimodal nanomedicines, cell treatment modalities, and medical bioMEMs, has greatly advanced ocular targeted therapy. These technologies address a number of ocular conditions, including inflammation-based conditions (such as scleritis, keratitis, uveitis, iritis, conjunctivitis, chorioretinitis, choroiditis, retinitis, retinochoroiditis), ocular hypertension and neuropathy, age-related macular degeneration, and mucopolysaccharidosis (MPS) brought on by the buildup of glycosaminoglycans (GAGs). Although some incapacitating eye diseases and disorders require much more effective, biocompatible, noninvasive therapies, such therapies seem to offer the best solutions.[13]

- Occuserts: Occuserts are positioned at a dead end. The medication is released over an extended period of time when these sustained release inserts gradually dissolve. The first medication to be developed as an ocusert was pilocarpine, an anti-glaucoma medication that lowers intraocular pressure for more than a week. It is made up of a pilocarpine reservoir that is encircled by two membranes made of the copolymer ethylene vinyl acetate, which permits pilocarpine to diffuse slowly at a rate of about 40 µg/h. Benefits: Extend the duration of drug-conjunctival contact, Long-term medication release to lower the frequency of doses, Better disease control due to less drug level variations.[14]

- Collagen Barriers: Collagen shields are made from bovine or pig collagen and resemble corneal bandages. They have been shown to promote medication delivery, improve stromal and epithelial repair, and lessen corneal inflammation in cases of microbial keratitis . Collagen shields containing gentamicin and dexamethasone have also been studied. Benefits: Improve medication delivery, The reduction in administration frequency, Improving patient adherence.[14]

**Future Prospective**

1. The development of safe, targeted, long-lasting, and patient-friendly delivery methods that can get beyond the anatomical and physiological barriers of the eye is the main goal for the future of ophthalmic drug delivery systems. Nanoparticles, nanomicelles, liposomes, hydrogels, microneedles, nanowafers, drug-eluting contact lenses, and ocular implants are examples of advanced technologies that have great potential to increase drug bioavailability and extend drug residence duration.
2. Drug retention, ocular bioavailability, and therapeutic efficacy could be greatly enhanced by advanced systems such nanoparticles, liposomes, nanomicelles, hydrogels, in-situ gels, drug-eluting contact lenses, microneedles, and ocular implants. Targeted distribution to the posterior region, which includes the retina and choroid, where traditional eye drops are ineffective, is the focus of future study.

3. Targeted distribution to the posterior region, which includes the retina and choroid, where traditional eye drops are ineffective, is the focus of future study. While gene therapy and cell-based therapies may offer novel treatment options for complex and chronic eye illnesses, nanotechnology may enable controlled and site-specific medication delivery.

4. Advanced manufacturing techniques like 3D printing and customized ophthalmic formulations may further enhance therapy results, patient compliance, and dosage precision. However, before these cutting-edge systems can be extensively employed in clinical practice, substantial preclinical and clinical research is still needed to show long-term safety, efficacy, manufacturing viability, and regulatory approval.

5. Advanced systems like nanoparticles, nanomicelles, liposomes, hydrogels, in-situ gels, drug-eluting contact lenses, implants, and microneedles are receiving more attention because conventional eye drops have drawbacks like quick precorneal clearance, low ocular bioavailability, and frequent dosing.

6. Systems based on biomaterials may improve drug permeability, ocular tissue targeting, and controlled release even more. While nanotechnology can offer better drug stability, penetration, and site-specific administration, microneedle technology offers potential minimally invasive delivery to both anterior and posterior parts of the eye. New methods for treating complicated ocular illnesses include bioinspired biomaterials, 3D-printed customized dosage forms, and gene and nucleic acid delivery. Long-term safety, toxicity, sterilization, production, regulatory approval, and clinical translation, however, continue to be significant obstacles.[15]

## CONCLUSION

Nanoparticles, liposomes, nanomicelles, hydrogels, in situ gels, microneedles, drug-eluting contact lenses, ocular implants, iontophoresis, and gene delivery are examples of novel techniques that have demonstrated encouraging potential for improving ocular drug penetration, bioavailability, targeted delivery, and sustained drug release. Advances in drug delivery systems have significantly improved the limitations of conventional eye drops. The new ophthalmic drug delivery system extends residence time increases drug bioavailability improves effectiveness and boosts patient compliance. Novel ophthalmic drug delivery systems, such, as systems, in-situ gels, microneedles, drug-eluting contact lenses, implants, nanoparticles, liposomes and advanced biological delivery systems, release drug in a controlled and sustained way while lowering dosing frequency. In-situ gel systems are ways to deliver medicine. These, in-situ gel systems work better than medicines because the liquid turns into a gel right after you use it. Because the in-situ gel systems turn into a gel they help the medicine stay in the body longer. This means the medicine releases slowly and steadily. In-situ gel systems also help more of the medicine get into the body so patients do not have to take medicine. This makes it much easier for patients to follow their treatment plans.

We can make these in-situ gel systems using polymers that react to changes in temperature, pH or ions. Because of this in-situ gel systems could be used for eyes, noses, mouths or through injections. I believe in-situ gel systems have a future. We still need to do more work. We need to make sure in-situ gel systems are stable, safe and can hold medicine. We also need to find ways to make, in-situ gel systems in amounts so more people can use them in hospitals. Microneedle-based ocular drug delivery systems are an exciting way to make treating eye diseases. These tiny needles can help get medicine into the eye, than older methods. They can push medicine directly into the cornea or other parts of the eye. This method can make medicine work better longer. Have fewer side effects. Various kinds of microneedles, like ones, hollow ones, coated ones and dissolving ones have been studied for delivering medicine where its needed.

## REFERENCES


1. Patel A, Cholkar K, Agrahari V, Mitra AK. Ocular drug delivery systems: An overview. World J Pharmacol. 2013;2(2):47–64. Gade S, et al. Ocular Drug Delivery: Emerging Approaches and Advances.
2. Recent Advances of Ocular Drug Delivery Systems: Prominence of Ocular Implants for Chronic Eye Diseases - PMC *https://share.google/gmW6xAKChyNv0uGNi*
3. content://com.whatsapp.provider.media/item/e5d5eac6-dd05-4d40-8e6e-38dd32da5eec
4. content://com.whatsapp.provider.media/item/849f6b30-e483-48db-ab04-58cb57d6da8a
5. Hydrogel-based ocular drug delivery systems for hydrophobic drugs.Torres-Luna C, et al.Eur J Pharm Sci. 2020.PMID: 32745587Review.
6. *https://share.google/SI44wKvqwZDFE8v2J*
7. Bhatnagar S, Gadeela P R, Thathireddy P, Venuganti V V K. J Chem Sci. 2019;131:90. doi: 10.1007/s12039-019-1666-x. [DOI] [Google Scholar]
8. *https://encryptedtbn0.gstatic.com/images?q=tbn:ANd9GcTpdKGF2XYKVVFbQDUmG2VvZTedvt6LbY9LPA&s*
9. Full article: Drug releasing contact lenses and their application to disease presentations https://share.google/szIWtkwG23V6utUZp.
10. Overview of Recent Advances in Nano-Based Ocular Drug Delivery - PMC https://share.google/AxMgYfTcR3Una6dOY
11. Advances and limitations of drug delivery systems formulated as eye drops J control release (2020)
12. Li S., Chen L., Fu Y. Nanotechnology-based ocular drug delivery systems: Recent advances and future prospects. J. Nanobiotechnol. 2023;21:232. doi: 10.1186/s12951-023-01992-2. [DOI] [PMC free article] [PubMed] [Google Scholar]
13. View the complete, open-access research text archived on PubMed Central (PMC).
14. (PDF) Novel ocular drug delivery methods https://share.google/LPnReTf1Jy3K5fCid
15. *https://www.sciencedirect.com/science/article/pii/S0022356525402511*