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Original Article

Oral Disintegrating Tablets Biodegradable Polymers for Drug Delivery

Khatode Sahil*, Navale Sonali, Kharat Ajit, Dr. Jha Urmilesh, Dr. Mansuk Avinash

Dr. Ithape Institute of Pharmacy, Sangamner. Department of Pharmacy

ABSTRACT

Biodegradable polymers have emerged as a promising tool for controlled and targeted drug delivery, offering a unique combination of biocompatibility, biodegradability, and versatility. This review article provides a comprehensive overview of recent advances in biodegradable polymers for drug delivery, including natural, synthetic, and hybrid polymers. We discuss the properties and applications of these polymers, including their use in controlled release, targeted delivery, and tissue engineering. Recent advances in nanotechnology, stimuli-responsive polymers, and 3D printing are also highlighted, along with their potential to revolutionize drug delivery. Furthermore, we identify current challenges and future directions for research in this field, including the need for improved polymer design, enhanced biocompatibility, and more effective targeting strategies. This review aims to provide a valuable resource for researchers, clinicians, and industry professionals seeking to develop innovative and effective biodegradable polymer-based drug delivery systems.

Keywords: Biodegradable polymers, Drug delivery, Controlled release, Targeted delivery, Tissue engineering, Nanotechnology, Stimuli-responsive polymers, 3D printing

INTRODUCTION

The development of effective and targeted drug delivery systems has been a long-standing challenge in the field of pharmacology. Traditional drug delivery methods often suffer from limitations such as poor bioavailability, rapid clearance, and non-specific targeting, which can lead to reduced efficacy and increased side effects. In recent years, biodegradable polymers have emerged as a promising solution to these challenges, offering a unique combination of biocompatibility, biodegradability, and versatility. Biodegradable polymers are a class of materials that can be degraded by biological processes, such as enzymatic degradation or hydrolysis, into non-toxic and easily eliminated products. These polymers can be designed to have specific properties, such as controlled degradation rates, tailored mechanical properties, and targeted release profiles, making them ideal for a wide range of biomedical applications, including drug delivery. (1,2, 3, 5, 6)

Fig No: 1 Oral Disintegrating Tablet.

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The use of biodegradable polymers in drug delivery offers several advantages over traditional methods, including improved bioavailability, reduced toxicity, and enhanced therapeutic efficacy. Biodegradable polymers can be used to create a variety of drug delivery systems, including nanoparticles, microparticles, and implantable devices, which can be designed to release drugs in a controlled and targeted manner.

SCOPE:

Properties and applications of biodegradable polymers in drug delivery. Recent advances in nanotechnology, stimuli-responsive polymers, and 3D printing. Potential applications of biodegradable polymers in various disease areas. Future perspectives and challenges in the development of biodegradable polymer-based drug delivery systems

Classification of Biodegradable Polymers for Drug Delivery

A. Natural Polymers

Natural polymers can be classified into four main categories:

1. Polysaccharides

Glycosaminoglycans: Hyaluronic acid, Chondroitin sulfate
Plant-derived polysaccharides: Cellulose, Starch, Pectin
Algal-derived polysaccharides: Alginate, Carrageenan

2. Proteins

Animal-derived proteins: Collagen, Gelatin, Albumin
Plant-derived proteins: Zein, Gluten, Soy protein
Insect-derived proteins: Silk fibroin, Chitin

3. Polynucleotides

DNA: Natural and modified DNA for gene delivery
RNA: Natural and modified RNA for gene delivery

4. Lipids

Phospholipids: Liposomes for drug delivery
Glycolipids: Natural and modified glycolipids for drug delivery. (7, 8, 9, 10)

B. Synthetic Polymers:

Synthetic polymers can be classified into four main categories:

1. Aliphatic Polyesters

Poly (lactic acid) (PLA): Derived from lactic acid, used in sutures and implants
Poly (glycolic acid) (PGA): Derived from glycolic acid, used in sutures and implants
Poly(ε-caprolactone) (PCL): Derived from ε-caprolactone, used in tissue engineering and drug delivery

2. Aromatic Polyesters:

Poly (hydroxyalkanoates) (PHA): Derived from bacterial fermentation, used in packaging and biomedical applications.
poly (butylene succinate) (pbs): Derived from succinic acid and butanediol, used in packaging and biomedical applications

3. Polyurethanes:

Biodegradable polyurethanes (BPU): Derived from polyethylene glycol and poly (lactic acid), used in tissue engineering and drug delivery.

4. Polyorthoesters:

Polyorthoesters (POE): Derived from orthoesters and polyols, used in drug delivery and tissue engineering. (13, 14, 15, 16)

C. Hybrid Polymers:

Hybrid polymers can be classified into four main categories:

1. Blends

Natural-synthetic blends: Combinations of natural polymers (e.g., collagen) with synthetic polymers (e.g., PLA)
Synthetic-synthetic blends: Combinations of different synthetic polymers (e.g., PLA-PGA)

2. Graft Copolymers

Natural polymer backbone with synthetic polymer grafts: Modification of natural polymers (e.g., chitosan) with synthetic polymer grafts (e.g., PCL)
Synthetic polymer backbone with natural polymer grafts: Modification of synthetic polymers (e.g., PLA) with natural polymer grafts (e.g., collagen) (11, 12)

3. Interpenetrating Networks (IPNs)

Natural-synthetic IPNs: Combination of natural polymers (e.g., gelatin) with synthetic polymers (e.g., PCL) in a network structure
Synthetic-synthetic IPNs: Combination of different synthetic polymers (e.g., PLA-PGA) in a network structure.

4. Composite Materials

Polymer-ceramic composites: Combination of biodegradable polymers with ceramic materials (e.g., hydroxyapatite) for bone tissue engineering.
Polymer-nanoparticle composites: Combination of biodegradable polymers with nanoparticles (e.g., silver nanoparticles) for antimicrobial applications.

Properties of Biodegradable Polymers:

I. Biodegradability

Biodegradable polymers exhibit unique properties that enable them to degrade in a controlled and predictable manner:

Degradation Mechanisms

1. Hydrolysis: Chemical reaction with water, leading to chain scission and degradation.

2. Enzymatic degradation: Breakdown by enzymes, such as proteases, lipases, and glycosidases.

3. Oxidative degradation: Reaction with oxygen, leading to chain scission and degradation.

Degradation Rates

1. Fast degradation: Polymers that degrade rapidly, such as polyglycolic acid (PGA).

2. Slow degradation: Polymers that degrade slowly, such as polycaprolactone (PCL).

3. Tunable degradation: Polymers whose degradation rate can be controlled, such as poly (lactic-co-glycolic acid) (PLGA).

Factors Influencing Degradation

1. pH: Affects hydrolysis and enzymatic degradation rates.

2. Temperature: Influences degradation rate and mechanism.

3. Enzyme presence: Affects enzymatic degradation rates**.**

4. Moisture: Influences hydrolysis and degradation rates.

Degradation Products

1. Toxicity: Biodegradable polymers should produce non-toxic degradation products.

2. Biocompatibility: Degradation products should be biocompatible and not cause adverse reactions.

II. Mechanical properties

Tensile Properties

1. Tensile strength: Measures the maximum stress a polymer can withstand before breaking.
2. Tensile modulus: Measures the stiffness of a polymer.
3. Elongation at break: Measures the percentage of deformation a polymer can undergo before breaking.

Compressive Properties

1. Compressive strength: Measures the maximum stress a polymer can withstand under compression.
2. Compressive modulus: Measures the stiffness of a polymer under compression.

Viscoelastic Properties

1. Viscosity: Measures the resistance of a polymer to flow.

2. Elasticity: Measures the ability of a polymer to return to its original shape after deformation.

Factors Influencing Mechanical Properties

1. Molecular weight: Affects tensile strength, modulus, and elongation at break.
2. Crystallinity: Influences tensile strength, modulus, and compressive strength.
3. Cross-linking: Affects tensile strength, modulus, and compressive strength.
4. Moisture: Influences mechanical properties, particularly tensile strength and modulus.

Importance of Mechanical Properties in Drug Delivery

1. Implant stability: Mechanical properties ensure the stability of implants in the body.
2. Drug release: Mechanical properties influence the release of drugs from biodegradable polymer matrices.
3. Tissue integration: Mechanical properties affect the integration of biodegradable polymers with surrounding tissue.

III. Biocompatibility

Definition of Biocompatibility

Biocompatibility refers to the ability of a material to interact with the body without eliciting an adverse response.

Key Aspects of Biocompatibility

1. Cytotoxicity: The ability of a polymer to cause harm to cells.
2. Immunogenicity: The ability of a polymer to trigger an immune response.
3. Inflammatory response: The ability of a polymer to cause inflammation.
4. Tissue compatibility: The ability of a polymer to integrate with surrounding tissue.

Factors Influencing Biocompatibility

1. Chemical composition: The type and amount of chemical groups present on the polymer surface.
2. Surface topography: The physical structure of the polymer surface.
3. Molecular weight: The size of the polymer molecules.
4. Degradation products: The byproducts of polymer degradation.

Biocompatibility Testing

1. In vitro testing: Cell culture-based testing to assess cytotoxicity and cell adhesion.
2. In vivo testing: Animal-based testing to assess tissue compatibility and inflammatory response.
3. Clinical trials: Human-based testing to assess safety and efficacy.

Importance of Biocompatibility in Drug Delivery

1. Safety: Ensures that the polymer does not cause harm to the patient.
2. Efficacy: Ensures that the polymer delivers the drug effectively.
3. Tissue integration: Ensures that the polymer integrates with surrounding tissue.

Application of Biodegradable Polymers In Drug Delivery

Biodegradable polymers have been widely explored for their potential in drug delivery due to their ability to degrade in the body, eliminating the need for surgical removal. Some of the key applications of biodegradable polymers in drug delivery include:

1. Controlled Release Systems

1. Microspheres: Biodegradable polymers can be formulated into microspheres that release drugs in a controlled manner.
2. Nanoparticles: Biodegradable polymers can be used to create nanoparticles that release drugs in a targeted and controlled manner.
3. Implants: Biodegradable polymers can be used to create implants that release drugs over a prolonged period.

2. Targeted Drug Delivery

1. Tumor targeting: Biodegradable polymers can be designed to target tumor cells, reducing side effects and improving efficacy.
2. Cell-specific targeting: Biodegradable polymers can be designed to target specific cells, such as immune cells or stem cells.

3. Tissue Engineering and Regenerative Medicine

1. Scaffolds: Biodegradable polymers can be used to create scaffolds that support tissue growth and regeneration.
2. Wound healing: Biodegradable polymers can be used to create dressings that promote wound healing.

4. Oral and Parenteral Drug Delivery

1. Oral delivery: Biodegradable polymers can be used to create oral delivery systems that release drugs in a controlled manner.
2. Parenteral delivery: Biodegradable polymers can be used to create parenteral delivery systems that release drugs in a controlled manner.

5. Ophthalmic and Ocular Drug Delivery

1. Eye drops: Biodegradable polymers can be used to create eye drops that release drugs in a controlled manner.
2. Intraocular implants: Biodegradable polymers can be used to create intraocular implants that release drugs over a prolonged period.

6. Vaccine Delivery

1. Vaccine carriers: Biodegradable polymers can be used to create vaccine carriers that deliver antigens in a controlled manner.

7. Gene Delivery

1. Gene carriers: Biodegradable polymers can be used to create gene carriers that deliver genetic material in a controlled manner. (18, 19)

Recent Advances and Future Perspectives

Recent advances in biodegradable polymers for drug delivery have been significant, with a focus on improving their properties, applications, and future prospects. Biodegradable polymers have been engineered to have tailored properties, such as controlled degradation rates, mechanical strength, and biocompatibility. These properties make them suitable for various drug delivery applications, including:

Controlled Release Systems: Biodegradable polymers can be formulated into microspheres, nanoparticles, or implants that release drugs in a controlled manner.

Targeted Drug Delivery: Biodegradable polymers can be designed to target specific cells, tissues, or organs, reducing side effects and improving efficacy.

Tissue Engineering and Regenerative Medicine:

Biodegradable polymers can be used to create scaffolds that support tissue growth and regeneration. The future of biodegradable polymers in drug delivery looks promising, with ongoing research focused on:

Developing New Polymers: New tailor-made biodegradable polymers are being developed to address specific needs in drug delivery, such as nucleic acid therapy.

Improving Transfection Efficiency: Biodegradable polymers are being designed to improve transfection efficiency and reduce cytotoxicity.

Combination Devices: Combination devices that incorporate therapeutic agents and mediate local drug release at the device implant site are being developed. (17)

CONCLUSION

Biodegradable polymers have emerged as a promising tool for drug delivery, offering a unique combination of biocompatibility, biodegradability, and controlled release capabilities. Recent advances in the design and engineering of biodegradable polymers have significantly expanded their potential applications in drug delivery. As research continues to evolve, biodegradable polymers are poised to play an increasingly important role in the development of personalized medicine and targeted therapies. Ultimately, the integration of biodegradable polymers with emerging technologies, such as gene editing and immunotherapy, holds great promise for transforming the field of drug delivery and improving human health

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