Biodegradable Polymer Materials In Medicine

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Abstract: This paper provides an overview of the current state of research in the field of the use of biodegradable polymers for medical purposes. The relevance of the research topic is noted, current trends in the development of biodegradable polymers, the creation of polymer protective coatings, polymers with shape memory effect for medical devices for various applications are described. The classification of modern biodegradable polymers, features of synthetic and natural biopolymers is presented, their advantages and disadvantages are indicated. Biodegradable polymers for drug encapsulation and delivery, the possibility of creating nanostructured polymers for pharmaceuticals are presented. The prospects for the future development of the use of biodegradable polymers in medicine are analyzed and described.

Keywords Biodegradable polymer, Bioactivity, Biocompatibility, Synthetic polymers, Natural polymers, Medical materials, Medications, Nanostructures for drug delivery.

1. INTRODUCTION

In the last decade, there has been an increasing interest in biodegradable materials for use in ecology, medicine and other areas of the national economy. The development of modern medical technologies would be impossible without the use of various materials with special properties. Biodegradable polymers are widely used in medicine as surgical suture materials, for the manufacture of orthopedic products, drug delivery, and matrixes for tissue engineering [1, 2]. Due to the widespread use of biodegradable implants in orthopedics [3], materials based on magnesium alloys are often used for these purposes, which have good corrosion resistance and biocompatibility, which improves the bone regeneration process [4]. These polymers also have a reduced response to inflammation and foreign bodies, which leads to their use for the development of new polymer coatings on magnesium alloys [5].

Biodegradable polymers are high molecular weight compounds that are found in the waste products of biological organisms: cellulose, protein, starch, nucleic acid, natural resin, etc. In a biologically active environment, biodegradable polymers undergo significant changes, as a result of hydrolysis and photochemical destruction, they decompose into natural components: water, carbon dioxide and biomass. The advantages of biopolymers include their biodegradability, in contrast to analogues from petrochemical raw materials.

This paper provides an overview of some of the current publications on the use of biodegradable polymers for medical purposes. This review can be useful for researching and analyzing current trends and predicting the development of biodegradable polymers in the field of medicine and healthcare. Consider publications devoted to their use, the classification of modern biodegradable polymers, as well as recent studies on the implementation of nanostructured systems for controlled drug delivery for the treatment of many diseases of modern human society.

2. CURRENT TRENDS

The review [6] presents the main areas of application of nanostructured polymer and composite materials in medicine. Today, there is an urgent need for products made of biocompatible materials for general and cardiovascular surgery, for the manufacture of pins and stents, blood vessel prostheses, artificial heart valves, heart-lung systems, for orthopedics, traumatology and dentistry [7]. They are also in demand for cellular and tissue engineering associated with reconstructive surgery, with the development of artificial organs and tissues, or for the restoration of the functions of damaged organs.

The review [8] presents current research in the field of biodegradable polymeric materials based on renewable raw materials. Trends and prospects for the development of the production of biodegradable polymeric materials are stated.

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The study [4] summarizes the latest advances in the production of polymer coatings based on magnesium alloys. Methods for improving corrosion resistance and future possibilities are discussed [9, 10]. Ultimately, the main problems and difficulties arise in the development of materials for polymer-coated magnesium-based implants [11].

Surface modification with coatings is a practical option as it not only improves corrosion resistance, but also prepares the treated surface for bone regeneration and cell attachment. Unlike durable materials, biodegradable polymers are usually biocompatible. Due to their biodegradability, biocompatibility, magnesium-based biomaterials have great potential in orthopedic applications.

In this regard, a composite coating may be a possible option for increasing the adhesion force of organic biopolymer coatings [12, 13]. In addition, the formation of composite coatings not only improves corrosion resistance, but also imparts potential bioactivity and biocompatibility to magnesium alloys during long-term use. In Figure **1** shows the main properties of polymer coatings based on magnesium: bioactivity, biodegradability, corrosion resistance, biocompatibility [4].

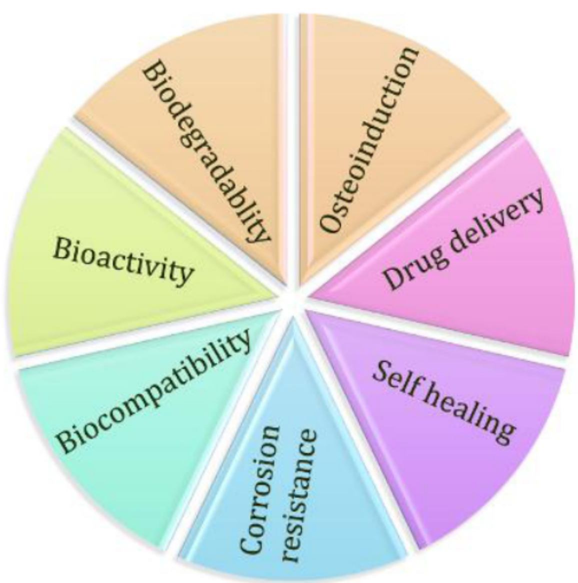

Figure 1: Functionality of polymer coatings for biodegradable magnesium alloys.

Shape memory polymers also have great potential for applications in various fields, including aerospace, textiles, robotics, and biomedicine, due to their mechanical properties (softness and flexibility) [14, 15]. Biodegradable shape memory polymers have the unique advantages of long-term biocompatibility and the formation of waste-free by-products, as the final products are absorbed through metabolism or enzymatic digestion [16]. It can also prevent biofilm formation or internal tissue damage due to the implant and the subsequent need for secondary surgery [17, 18].

In a study [19], new biodegradable and biocompatible amphiphilic polymers were obtained by modifying polyesters with organosilicon substituents. Organosilicon fragments of polymers are formed by silatranes and exhibit hydrophilic and hydrophobic properties, respectively [20]. These properties affect the biological activity of macromolecules; the antifungal activity of these polymer structures is also noted.

3. CLASSIFICATION OF BIODEGRADABLE POLYMERS

New polymer materials are constantly being developed for modern therapeutic applications. Review [21] is devoted to the use of varieties of biodegradable polymers. Various types of biodegradable polymers, their properties and characteristics, as well as their promising applications in pharmaceuticals are presented in detail [22]. Depending on the purpose, modern polymers can be divided into polymers with original and different structural bases [23]. The original bases have synthetic and natural polymers; polymers with carbon (polyvinyl) and heterocyclic bases (polypropylenes) belong to another category (Figure **2**).

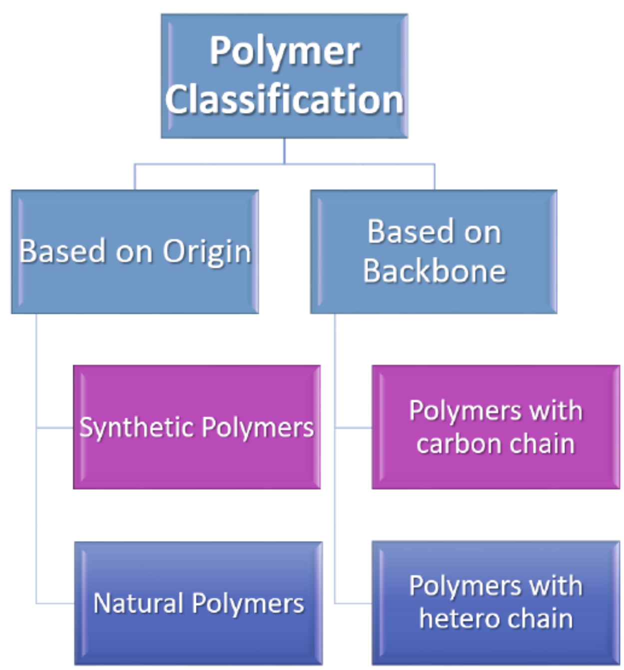

Figure 2: Scheme of classification of modern polymers.

Synthetic polymers can also be **biodegradable** and **non-biodegradable** (Figure **3**). Mainly **non-biodegradable** polymers include acrylic polymers, cellulose derivatives, silicones. Of the acrylics, it can be noted: Polymethacrylate, Polymethyl metactylate, Polyhydro ethyl methacrylate. On the basis of cellulose, there are non-biodegradable polymers: Cellulose acetate, Carboxy methyl cellulose, Ethyl cellulose. Silicones include: Polydimethyl siloxanes, Colloidal silica. Additional polymers include: Ethyl vinyl acetate, Polaxamers, Polaxamine, Polyvinyl pyrrolidone.

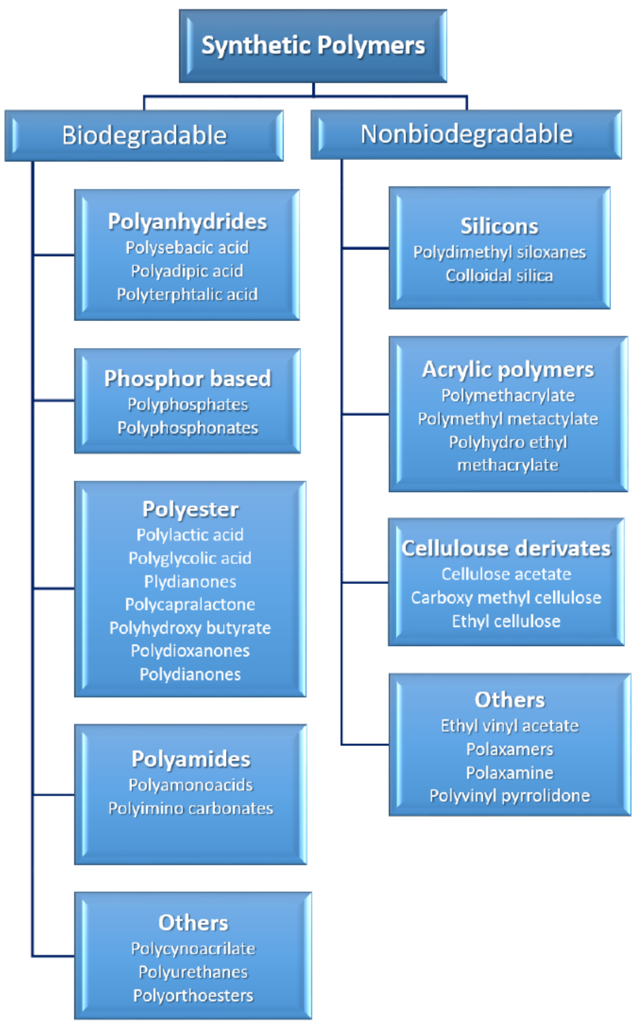

Figure 3: Varieties of synthetic polymers.

It should be noted about the use of polymethyl methacrylate, which is a non-biodegradable acrylic-based polymer, mainly used for implantation as bone cement or in the form of beads. Despite the fact that polymethyl methacrylate is widely used, it has many disadvantages, low biocompatibility, is not biodegradable, and can become an attractive breeding ground for bacteria [24].

Biodegradable polymers (Polyanhydrides, Phosphor based, polyester, polyamides) decompose and form a harmless biocompatible by-product [25]. Polyanhydrides include: Polysebacic Acid, Polyadipic Acid, Polyterphtalic Acid. Biodegradable polymers are based on phosphorus: Polyphosphates, Polyphosphonates. Polyesters have a more extended list: Polylactic acid, Polyglycolic acid, Plydianones, Polycapralactone, Polyhydroxy butyrate, Polydioxanones, Polydianones. From the family of polyamides, it is possible to note: Polyamonoacids, Polyimino carbonates. There are also other biodegradable polymers: Polycynoacrilate, Polyurethanes, Polyorthoesters.

It should be emphasized that biocompatible polymers have good therapeutic properties, do not have an inflammatory effect, and show good permeability [21, 23].

Natural polymers are divided into polymers based on protein and polysaccharides. Protein-based polymers exist: gelatin, albumin, collagen, and polysaccharide-based ones are: chitosan, hyaluronic acid, agarose, cyclodextrin, dextral (Figure **4**). These natural polymers are very often used in drug delivery systems, let's take a look at them in more detail.

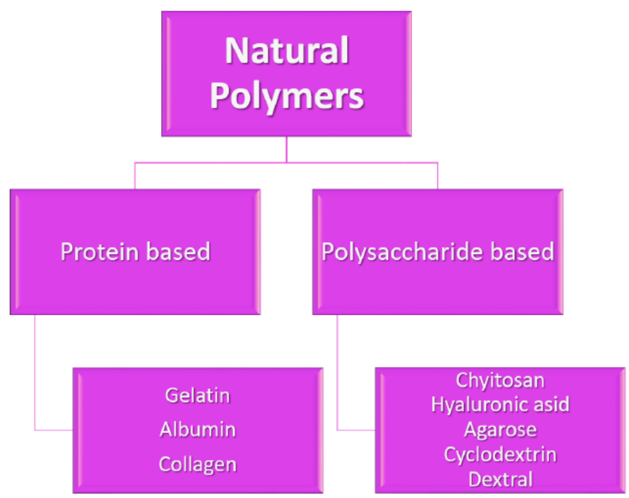

Figure 4: Varieties of natural polymers.

4. BIODEGRADABLE POLYMERS FOR DRUG DELIVERY

Biodegradable polymers are promising materials for the development of new methods of encapsulation and drug delivery. In the last decade, controlled delivery of drugs, enzymes, gene delivery, local delivery, delivery of anticancer drugs and vaccines has been more widely used [26]. At the same time, new and modified chemical compositions of polymers are identified and evaluated, which provide new forms of drug carriers, in the form of nanoparticles, microparticles, microspheres, matrices. Modern biopolymers have improved bioavailability, biocompatibility and lower toxicity.

The review [23] investigates the use of natural biodegradable polymers for local or controlled release of drugs in severe diseases. Consider some biodegradable polymers that are often used in drug delivery systems (Figure **4**).

Chitosan is a polysaccharide with glucose units, it is obtained by partial deacetylation of chitin. Chitin has good mechanical strength, is biocompatible, biologically active, and biodegradable, but its use is limited due to its low solubility [27]. Chitin is extracted from marine organisms such as lobsters and shellfish, as well as from the shells of crabs, insects.

Alginates are a group of the most important biopolymers, which are unbranched polysaccharide anionic polymers [28]. The modified form of alginates has found wider application in the biomedical and pharmaceutical industries as an effective drug carrier [29, 30]. Alginate is extracted from brown algae and soil bacteria.

Albumin is a natural, water-soluble protein and an attractive macromolecular carrier that is biodegradable. Albumin is non-immunogenic, non-toxic and biocompatible [31, 32]. A large number of drugs can be included in the matrix of nanoparticles, since albumin molecules have different binding options [33], and are successfully used to treat cancer [32]. Commercially available forms of albumin are ovalbumin (egg white), human serum albumin, albumin extracted from soybeans, albumin present in bovine serum capsules, grain and milk albumin [34].

Hydroxyapatite is widely used in biomedicine and is considered the best option in the pharmaceutical field due to its superior bioactivity and biocompatibility [35]. Hydroxyapatite is obtained from mineral compounds of human bones, teeth and hard tissues [32].

Hyaluronic acid is an anionic polysaccharide [36, 37], it is also known as hyaluronan, it is present in the synovial fluid of the joints, in the extracellular matrix, in the skin and is evenly distributed in the tissues of the vertebrate body [38, 39]. It has good biocompatibility, greater viscoelasticity, biodegradability, and is also used for the delivery of anticancer drugs [40, 41].

The considered natural biocompatible and biodegradable polymers in the form of nanostructures were investigated for therapeutic use. Nanoforms are superior to macro- or conventional drug delivery systems [42]. They can infect infected areas, organs, tumor sites, and tissues in the body. Biodegradable and biocompatible polymers are suitable materials for the development of new drug delivery systems.

5. ANALYSIS AND FUTURE PROSPECTS

It should be noted that nanostructured, biodegradable, biocompatible polymers are promising for the creation of new generation dosage forms. Controlling the molecular structure of polymers allows one to regulate not only their physicochemical properties, but also to change their ability to interact with living tissue.

The advantages of biodegradable polymers include the possibility of converting them into small debris, which can be easily excreted from the body. However, there are opportunities to study biodegradable polymers for advanced biomedical applications. To identify side effects, it takes time to study the non-toxic degradation of polymers in the body. Adapting nanocarriers to everyday clinical practice will require a multidisciplinary approach based on clinical, ethical and social considerations [43]. It can be predicted that in the very near future, people will benefit from nanotechnology-based nanomedicine for the management and treatment of many serious diseases.

6. CONCLUSION

In this paper, a review was made of the current state of research in the field of the use of biodegradable polymers for medical and pharmaceutical purposes. The current trends in the development of nanostructured, composite polymers that make it possible to create biosafety medical devices are noted. The classification of modern biodegradable polymers, their disadvantages and advantages, as well as their areas of application are presented. Described biodegradable polymers for drug delivery, the possibility of creating nanostructures based on these polymers for pharmaceuticals and medicine.

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