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Applications of synthetic polymers in clinical medicine

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Abstract

Multiple biological, synthetic and hybrid polymers are used for multiple medical applications. A wide range of different polymers is available, and they have further the advantage to be tunable in physical, chemical and biological properties in a wide range to match the requirements of specific applications. This review gives a brief overview about the introduction and developments of polymers in medicine in general, addressing first stable polymers, then polymers with degradability as a first biological function, followed by various other functional and responsive polymers. It is shown up that biomedical polymers comprise not only bulk materials, but also coatings and pharmaceutical nano-carriers for drugs. There is subsequently an overview of the most frequently used polymer classes. The main body of the review then is structured according to the medical applications, where key requirements of the applications and the currently used polymer solutions are indicated.

Keywords: Polymer; Medicine; Implant; Review

Contents

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1. Introduction

The basic principle of polymers, that is multiple assemblies of simple structural units for the formation of a 3-dimensional construct, has wide distribution in all biological systems. This ranges from intracellular filaments and cytoskeleton via structural proteins of the soft extracellular matrix and matrices with mechanical function in ligaments or cartilage to keratin of skin and hairs at the human surface interface with the environment and insects can produce silk polymers even for external constructions. Such natural polymers like horn, hair, or cellulose have been utilized by human since beginning of manhood, and they have found application in medicine, e.g. as suture material also for long time [1].

Man-made synthetic polymers are almost as manifold as the natural ones, although the most progress in development only started about in the Second World War. Newly developed polymers rapidly entered medical application, such as the polyesters and polyamides as synthetic suture materials.

Synthetic polymers gained high attraction for technical as well as for medical application for various reasons. A wide range of physical and chemical properties can be achieved based on the monomer units, polymerization reaction and formation of co-polymers consisting of different components at adjustable concentrations [2]. Technologies for synthesis and formation also of complex shaped devices are mostly established. These types of polymers mainly fulfill structural and mechanical properties. Mechanical self-reinforcement is achieved by integration of oriented fibers of the same material into the matrix [3,4]. There are also highly advanced mechanical properties, such as shape memory polymers, which can be freely deformed and return to their original shape upon a special stimulus, which can be pH, temperature, magnetic field or light. They found application in biomedicine in drug delivery devices, vascular stents, sutures, clot removal devices, for aneurysm or ductus arteriosus occlusion, and orthodontic therapy as reviewed elsewhere [5,6].

Besides the mechanical properties also specific functional characteristics of polymers are used. Semipermeable membranes of biopolymers (cellulose) or polymers are used for hemodialysis or as drug delivery systems. Swelling or collapsing of pores of the membrane in response to pH, temperature or other stimuli leads to membranes for responsive drug release [7].

Due to their carbon based chemistry, polymers are closer to biological tissue than inorganic materials. This can be used for targeted interaction between the material and the body, but may also cause problems due to an interference of rest-monomers, degradation-products or additives with biochemical pathways. Reactive groups in the Polymers usually also offer the possibility for biofunctionalization of the surface, either because they provide reactive groups by themselves, or e.g. plasma technologies can be used to create such groups for covalent anchorage of molecules on the surface. The surface modification techniques allow independent optimization of the mechanical properties of the bulk and biocompatibility properties of the surface.

Functional types of polymers evolved for biomedical applications. Biodegradable polymers ideally stay in the body only as long as they serve their function and then they disappear without the need of a second surgical intervention [8–10]. Orthopedic fixation and ligament augmentation were the primary motivation for biodegradable polymers [11]. Since