

Applications of polymers in medical field

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Abstract

A variety of polymers have been used for medical care including preventive medicine, clinical inspections and surgical treatments of diseases. Among the polymers employed for such medical purposes, a specified group of polymers are called polymeric biomaterials when they are used in direct contact with living cells of our body. Typical applications of biomaterials in medicine are for disposable products (e.g., syringe, blood bag and catheter), materials supporting surgical operation (e.g., suture, adhesive and sealant), prostheses for tissue replacements (e.g., intraocular lens, dental implant and breast implant) and artificial organs for temporary or permanent assist (e.g., artificial kidney, artificial heart and vascular graft). These biomaterials are quite different from other non-medical. This paper explores the various applications of biomedical polymers in the field of medicine.

Keywords: polymers, macromolecules, natural polymers, synthetic polymers, biomedical polymers, polythene

Introduction

The polymers, a word that we hear about it a lot, is very vital and one cannot imagine the life without it. Polymers are macromolecules, versatile in structure, constitution and properties. Product made from polymers are all around us: clothing made from synthetic fibers, polyethylene cups, fiberglass, nylon bearings, plastic bags, polymer-based paints, epoxy glue, polyurethane foam cushion, silicone heart valves and Teflon-coated cookware etc. They have wide range of applications in various fields such as biophysics, medicine, electronics and other branches of science and technology. Among these polymers biomedical polymers are specially mentioned due to their less toxicity in vivo, easy to process and sterilized, better shelf life, light weight and remarkable properties suited to the applications.

The very first reported synthetic polymer for medical use is poly (methyl methacrylate) (PMMA) by a British ophthalmologist, Sir Nicholas Harold, in 1949 for making intraocular lens. Biostability and biodegradability are two important parameters to be noticed to select a polymer for its biomedical use. Homo- and copolymers of polyamides, polyesters, polyanhydrides, poly (ortho esters), poly (amido amines) and poly (β -amino esters) are the important biomedical polymers which are hydrolytically degradable. These are also called biopolymers and smart polymers which are mainly used in biotechnology and medicine. Their applications basically include biorecognition and biocatalysis, in aqueous solutions which involve very fast and reversible chemical and physical changes.

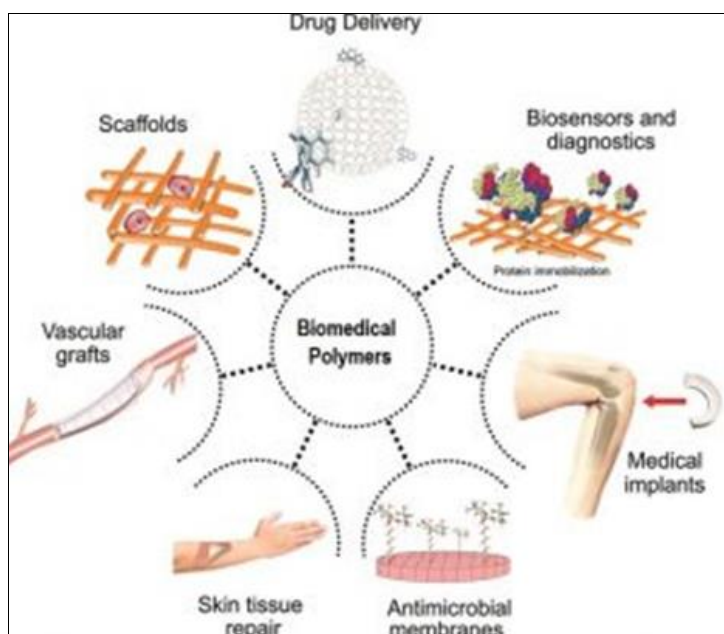


Fig 1: Various biomedical polymers and their applications

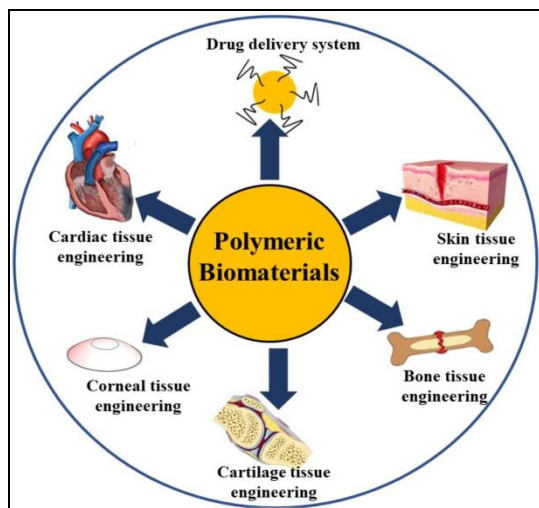


Fig 2: Uses of polymers in medical field

Applications of Polymers in Medical Field

Modern medicine would be impossible without the application of various natural or artificial materials. Among them, polymers, both natural and synthetic, play a key role. The purpose of some of them is to stay in the body forever, but others are only intended for temporary use and historically, these had to be removed or excreted from the body. This step can now be avoided if biodegradable materials are used, after they have served their purpose, they break down and are absorbed by the body. In medicine, biodegradable polymers offer great potential for controlled drug delivery, wound management (e.g., adhesives, sutures and surgical meshes), for orthopedic devices (screws, pins and rods), for dental application (filler after a tooth extraction) and tissue engineering. The main polymers used in medicine are:

Polyolefins

Polyolefins are used for medical devices and pharmaceutical packaging more than any other thermoplastic material. They are increasingly being selected by customers to replace traditional materials such as glass, paper, metal and cardboard. This combination makes them the fastest-growing family of polymers in the world. Polyolefins offer excellent aesthetic characteristics (clarity and gloss), superb organoleptic properties (low taste and odour), inertia to most chemicals and a full range of stiffness and abuse-resistant (even at low temperatures) characteristics. The polyolefins such as polyethylene (PE) and polypropylene (PP) are very inert and hydrophobic materials which do not degrade in vivo. Its main applications are sliding surfaces of artificial joints. The artificial joint has a sliding interface using a combination of hard material Metallic femoral head, Soft material Polytetrafluoroethylene (PTFE) shell Cement material: cold-curing acrylic cement polymethyl methacrylate) to fix the components and to transfer the stress more uniformly.

PE is used in the production of items such as closures, rigid bottles and ampoules, needle sheaths, plunger rods for single-use syringes, mouldings to house diagnostic equipment and collapsible tube shoulders. PP is used in an exceptionally wide range of applications, the most important of which is disposable syringes. Other applications in which its use has been reported are actuator bodies, specimen cups, mouldings to house diagnostic equipment, centrifuge tubes,

multi-well micro-titration plates, trays, pipettes, caps and closures, IV bags and many others.



Fig 3: Materials made from polyolefins

Polytetrafluoroethylene (PTFE) or Teflon

PTFE, commonly known as Teflon, has an ethylene backbone with four covalently bonded fluorine atoms. It is a highly hydrophobic non-degradable material. It is mainly applied as vascular graft, used as a surgical implant material for many prostheses, such as artificial vessels and orbital floor implants, and for many applications in skeletal augmentation and skeletal fixation.

Teflon has diverse medical applications including use in annuloplasty rings, batteries for defibrillators and pacemakers, cardiac patches, vena caval clips, vascular grafts, implantable pumps, implants for impotence, implants for incontinence, prosthetic joints, bone replacements, pledgets, various types of sheeting, dialysis shunts, sutures, myringotomy tubes, valved conduits and in low-temperature chemical reactions.



Fig 4: Materials made from Teflon

Polyvinyl chloride (PVC or Vinyl)

PVC has an ethylene backbone with one covalently bonded chlorine atom. Its fabrication and application requires stabilizers and plasticizers, which are the main reason for medical concerns against this polymer. Plasticizers, most frequently phthalates, turn the rigid PVC to a soft polymer, which is used for extra corporeal tubing or blood storage bags

No other plastic in existence today has the combination of performance qualities that vinyl has. Because of this, vinyl makes it possible to provide exceptional patient care while

controlling healthcare costs. Vinyl medical products have been proven safe and effective worldwide, which is why vinyl is the leading medical plastic in use today. Vinyl is used in hundreds of medical products and devices with more applications continually being developed. Some of the most prevalent uses include: Blood bags and tubing, Cannulae, Caps, Catheters, Connectors, Cushioning products, Device packages, Dialysis equipment and tubing, Drainage tubing, Drip chambers, Ear protections, Examination gloves, Goggles, Inflatable splints, Inhalation masks, IV containers and components, Laboratory ware, Masks, Mouthpieces, Oxygen delivery, Seals, Surgical wire, Jacketing, Thermal blankets and Valves etc.



Fig 5: Materials made from Poly Vinyl Chloride (PVC)

Bioplastics

The bio-plastics that are produced either from fossil material or can be synthesized from biomass or renewable resources, such as Poly-lactic acid (PLA), Polyethylene glycol (PEG) and Poly ϵ -caprolactone (PCL) are been reported as a material of choice for biomedical applications due to their good physical properties such as crystallinity, storage modulus, glass transition temperature and bioresorbable property. These biodegradable polymers have wide applications in tissue engineering, wound management, drug delivery, orthopedic devices, manufacturing of fibrous and porous scaffolds. A biodegradable plastic has many advantages such as reduction in the accumulated hazardous non-degradable synthetic plastic, which will not, consumed by the wild animals as their feedstock and minimizes the injuries to them. Moreover, bioplastics is degrades enzymatically into monomers and oligomers by soil microorganisms, thus productivity of soil will increase randomly.

Silicone

Silicones consist of an $-Si-O-$ backbone with different chain lengths and cross links, which determine mechanical properties from liquid oil via a gel structure to rubber elastomer. The biological response differs for various applications. There is high tolerance in ophthalmologic applications, fibrous capsule formation at breast implants. Silicones are widely used in medical applications, such as extracorporeal equipment in kidney dialyses, contact lenses, finger and foot joints, catheters, drains, shunts, breast implants, tubing, heart valves, ophthalmological implants, and as drug delivery systems. They are often described as

biocompatible, since they are chemically inert, stable against thermal and oxidative influences, and hypoallergenic.

Methacrylates

Methyl methacrylates polymerize to very rigid polymers (PMMA) by radical polymerization and therefore find application in dentistry and in orthopedics. They are used for application with polymerization in situ. Due to the optical properties (Plexi glass) and inertness in the eye, they are also used as intraocular lenses.

The first use of polymethyl methacrylate (PMMA) as a dental device was for the fabrication of complete denture bases. Its qualities of biocompatibility, reliability, relative ease of manipulation, and low toxicity were soon seized upon and incorporated by many different medical specialties. PMMA has been used for (a) bone cements; (b) contact and intraocular lens; (c) screw fixation in bone; (d) filler for bone cavities and skull defects; and (e) vertebrae stabilization in osteoporotic patients.

Polyesters

Biostable and biodegradable polyesters are used in biomedicine. Biostable polyesters containing aromatic groups are poly carbonates (PC), poly (ethylene terephthalate) (PET, dacron). They are used inform of membranes, filaments and meshes. Polyesters are also biocompatible, and biodegradable polymers are used for the manufacturing of different medical devices, such as sutures, plate, bone fixation devices, stent, screws and tissue repairs, as their physicochemical properties are suitable for a broad range of medical applications. Polyesters are also used commercially in controlled drug delivery vehicles.

Polyethers

Polyethers are widely used in medical field because ether bondings are bio stable. Polyethers such as Poly ether ether ketone (PEEK) is used for orthopedic surgery, Medical tubing, Spinal implants, Spinal fusion, maxillo-facial surgery. PEEK materials are an important biomaterials used for bone and cartilage replacement. PEEK can also be used in 3D printing process. Polyether sulfone (PES) is used for dialysis membranes.

Polyamides

Naturally, all proteins consist of units linked by amide bonds and highly repetitive proteins like collagen or silk fibroin can be classified here. The most important synthetic polyamide with clinical application is nylon. For its high tensile strength it is used for suture materials. Synthetic polyamides (nylons) are very important polymers with applications in many fields, and recently their use in biology and medicine has become more and more important. Nylons as biomaterials are used as scaffolds for tissue engineering, membranes and bioactive surfaces.

Polyurethanes

Poly urethanes are synthesized with multiple chemistries and properties. Polyester-polyether-, and polycarbonate-based polyurethanes with aromatic or aliphatic components are in medical use, where aromatic formulations have the better bio stability. Poly ether based poly urethanes, especially aliphatic formulations show rapid softening in the body, making them more comfortable for the patient.

Conclusion

Polymers will be the material of the new millennium and the production of polymeric parts i.e. green, sustainable, energy-efficient, high quality, low-priced etc. will assure the accessibility of the finest solutions round the globe. The applications of polymers in biomedical field are highly significant and more effective. These are safe, less toxic and comparatively simple. The mechanism of the drug delivery and bioseparation are so efficient and reliable. Smart polymers play wide role in various biomedical applications such as oxygenation of blood and also in cardiopulmonary bypass surgery. Their stimulus response nature and sensitivity to the physical conditions are useful in different applications. Their role as suture materials, tissue adhesives, and vascular grafts, materials for cosmetic implants, dental composites, contact and intraocular lenses, etc. The use of polymers in medicine is innumerable.

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