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Review Article

Evaluation of properties for synthetic polymers in medicine

Fatma İrem ŞAHİN[1], Nil ACARALI[1,*]

[1]Department of Chemical Engineering, Yildiz Technical University, Esenler, İstanbul, 34220, Türkiye

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ABSTRACT

Today, the transformation of polymers into useful structures for the human body in medical field has been an interesting subject that affected everyone. Synthetic polymers have a wide range of uses in the health sector such as coating, cardiovascular, orthodontic surgery, tissue engineering, implant, and drug carrier with the development of technology. These polymers are known as polymers with various characteristics and applications artificially synthesized in accordance with chemical and thermodynamic laws. The polymers in health sector have a share of 41% in drug and release studies, 18% in treatment with therapy applications, 10% in vaccine production, 31% in studies on new approaches in this field. Synthetic polymers have ability to be produced cheaply and easily in large quantities. In this study, synthetic polymers such as polyethylene glycol, polyvinyl alcohol, polyurethane, polyolefin, polytetrafluoroethylene, silicone, polyvinyl chloride, poly-methyl methacrylate, polyester, polyamide and poly-lactic acid were investigated and details regarding the applications with explications of polymers were provided. It was seen that synthetic polymers could be evaluated in treatment of cancer and chronic diseases by determining the most appropriate methods and techniques with biocompatible, biodegradable, non-toxic materials.

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INTRODUCTION

The macromolecules referred to as polymers were synthesized by the chemical bonding of numerous smaller molecules, or repeating units known as monomers. In history, polymers were used to bind wooden parts together. Natural rubber used as one of the first polymers was a biopolymer. It was obtained as an adhesive from a tree species. In the 19th century, its properties were developed by Charles Goodyear and started to be evaluated for tire production. The first synthetic polymer was synthesized in 1907 as Bakelite. Later, it was turned into a commercial product and used in the production of molded parts such as handles, pipes, valve parts, knives, and buttons [1, 2].

Polymers were basically divided into two categories as natural and synthetic. Starch, lignin, cellulose, and rubber were just a few of the natural polymers that had been present since the existence of life. Synthetic polymers could be described as relatively modern materials as the polymers entered daily life after technological developments. The greatest progress in man-made synthetic polymers occurred in the 20th century. As components of many objects,

***Corresponding author.**
*E-mail address: nbaran@yildiz.edu.tr

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polymers took place in many sectors such as textiles, paints, maintenance products, electrical tools, coatings and automotive sector in the daily life of modern society [3].

While engineering-based properties such as hardness, tensile stability and elasticity were often the primary properties in the selection of the polymer, toxicity and biocompatibility aspects were also considered especially in polymers for use in healthcare. Many natural and synthetic polymer types were encountered in the literature [4, 5] (Table 1).

In this study, general properties and usage areas of synthetic polymers such as polyethylene glycol, polyvinyl alcohol, polyurethane, polyolefin, polytetrafluoroethylene, silicone, polyvinyl chloride, poly-methyl methacrylate, polyester, polyamide and poly-lactic acid were described with an emphasis. In addition, it was aimed to form an idea about the application areas in the health sector and the latest developments in this field. Different from the literature, the studies conducted separately in the health sector were evaluated in drug and release studies, treatment, therapy, vaccine production, and new approaches in this field. It was thought that it would raise awareness about studies on cancer and chronic diseases in the field of medicine.

SYNTHETIC POLYMERS

Beverage bottles, cleaners, rugs, rubbers, adhesives, paints, toys, films, packaging materials, lubricants, food packaging, pharmaceuticals, and many common household items were produced from synthetic polymers. Polymers, some of which were in the form of composites to strengthen their structures, were being used as protective and structural materials by replacing wood and metals [6].

Staudinger realized that natural rubber had very high molecular weights in 1920. The modern era of synthetic polymers began with the discovery of nylon by Carothers in 1937. The fastest progress in the historical development of synthetic polymers occurred during World War II. With the invention of devices with improved technical features, an environment had been prepared for synthesizing more complex polymers. Recently, studies showed that advanced polymers as shape memory polymers could change control mechanism according to the magnetic field, light, temperature, and pH [7].

Synthetic polymers, unlike natural polymers, were not readily available and obtained under laboratory conditions through hydrocarbon building blocks. Synthetic polymers were an important component of biomaterials used as implant materials, cardiovascular therapeutic stents, orthodontic treatments, drug delivery devices, and tissue engineering scaffolds or hydrogels [8, 9].

The deterioration of polymers could be done in a controlled attitude. It was also physically sound, with features such as higher modulus strengths, sensitive ability to flex and flexibility, confidence in chemicals, and recyclability. According to their properties, molecular weight and structure, polymerization, connectivity, functionality, and easy synthesis could be distinguished. They could be classed in accordance with hydrophobicity, hydrophilicity and degradability. Polyethylene glycol, polyvinyl alcohol, polyurethane, polyolefin, polytetrafluoroethylene, silicone, polyvinyl chloride, poly-methyl methacrylate, polyester, polyamide and poly-lactic acid which had very advantageous due to the properties of synthetic polymers could be easily changed according to the type of application to be made [3].

Ethylene glycol monomer was a colourless, odourless, low-viscosity liquid. Polyethylene glycol was a linear polyether generally described by a molar mass of less than 20 000 g. Its usage included a broad range of industries, including cosmetics, pharmaceuticals, food producing, and inks. It was used as a thickening agent such as hydro alcoholic gels

Table 1. Overview of Natural and Synthetic Polymers

Type	Polymer	Properties & Applications	References
Natural	Natural Rubber	Biopolymer, adhesive, in tires	[1-5]
	Starch	Biodegradable, in food and pharmaceuticals	
	Lignin	Structural component in plants, in paper and biofuels	
	Cellulose	Found in plant cell walls, in textiles, paper, and as a food additive	
Synthetic	Polyethylene Glycol (PEG)	Water-soluble, in pharmaceuticals, cosmetics, and medical devices	[3-5]
	Polyvinyl Alcohol (PVA)	Water-soluble, in adhesives, coatings, and as a film former	
	Polyurethane	Versatile, in foams, coatings, and elastomers	
	Polytetrafluoroethylene (PTFE)	Non-stick, chemical resistant, in coatings and gaskets	
	Silicone	Flexible, heat-resistant, in medical implants and sealants	
	Polyvinyl Chloride (PVC)	Rigid or flexible, in pipes, cables, and medical devices	
	Poly-methyl Methacrylate (PMMA)	Transparent, in lenses and displays	
	Poly-lactic Acid (PLA)	Biodegradable, in packaging and medical implants	

and special lubricants in medical products. It was commonly found in medical treatments and vaccines. Polyethylene glycol had optimal biological and physicochemical properties. Especially in the field of biopharmaceuticals, it was used as a hydrophilic and anti-fouling polymer due to its good biocompatibility. It was preferred as a skeleton material due to the facility. It had a limited capacity for protein binding, cell adhesion, immunogenicity, and antigenicity. It offered a significant opportunity for usage in applications involving wound healing. Today, drugs with polyethylene glycol-modified were approved for clinical applications [10-12].

Polyvinyl alcohol was an alcohol compound with a significant number of hydroxyl groups along its molecular chain as hydrophilic polymer. Polyvinyl alcohol was non-toxic and had good biocompatibility. It was a great ingredient for film-forming [13]. It was widely used in the biomedical field as a component of hydrogels. Polyvinyl alcohol was biocompatible, inexpensive, and could be degraded by organisms [14]. It was utilized to create the nanofibers required for tissue engineering and wound healing when mixed with other polymers like chitosan and polyhydroxy butyrate. In addition, polyvinyl alcohol microneedles were preferred for single-step DNA polyplex vaccine encapsulation as it had high transfection efficiency [15].

A type of polymer substance called polyurethane was formed, when polyol and combined isocyanate in combined polyether reacted. Polyurethane had superior durability and im-permeability compared to conventional building materials. It had a high rate of foaming and expansion, environmentally friendly, highly adaptable, low density [16]. Various chemical and physical characteristics were used to create polyurethanes. Polycarbonate-based polyurethanes containing aromatic or aliphatic components were utilized in medicine when aliphatic compounds had less biologic stability, polyester and polyether. Thermoplastic polyurethanes were flexible without the need for plasticizers. Polyurethane was polymer that had the widest working area and it was used in various combinations because of its high degree of flexibility and capacity to change into biodegradable forms like polyester-urethane urea. Polyurethanes, an important member of polymers, were widely utilized in several applications from fibers, foams to electronic devices, coatings, adhesives, elastomers and biomedical technologies [16, 17].

Polyolefins were shaped by the polymerization of olefin monomer molecules such as ethylene, styrene and vinyl chloride [18]. Both polyethylene (PE) and polypropylene (PP) were extremely stable. Polyethylene was generated in dissimilar molecular weights and crystallinity. Polyolefin elastomers were widely used in packaging, adhesives, and automotive equipment due to low price, good machinability, and flexibility. High-density polyethylene with a similar molecular weight was used to create stable devices for implantation. Its primary applications were the sliding surfaces of artificial joints. Polypropylene had similar features with polyethylene, and it was used as surgical suture substances [19].

Polytetrafluoroethylene had high chemical resistance, high temperature stability and insulation properties. It also had many useful features such as a non-wetting surface, a low coefficient of friction and poor adhesion [20, 21]. Polytetrafluoroethylene had an ethylene structure as for 4 covalently bonded fluorine molecules. It was widely used in industries, pharmaceuticals and laboratories. It was a non-degradable, highly hydrophobic material. It showed some tissue growth and inflammation in body. It was used as a vascular graft in medical industry [22].

Silicon existed in various silicate structures in bonded form with oxygen. The mechanical properties of silicones influenced by a gel structure and varied chain lengths and crosslinks in their -Si-O structure were transferred to rubber elastomer and side chains were altered. The most typical ones were polydimethylsiloxane. Silicones were hydrophobic and bio-stable elastomers that they did not need plasticizers. Although the material structure varies according to the connected group, it basically had properties such as low surface tension, corrosion resistance and water repellency. Silicones were used for plastic surgery, intraocular lenses, dialysis membranes, and intraocular lenses [23].

Polyvinylchloride (PVC) was one of the thermoplastic polymers with the highest demand volume. PVC was a polymer with an ethylene structure containing a covalently bonded chlorine. It was thermally unstable at processing temperatures. It was one of the most widely used polymeric materials in the production of medical devices. It required an appropriate amount of stabilizer and plasticizer in order to achieve the desired flexibility and softness in its production and application. Stabilizers were needed to avoid the autocatalytic cleavage of HCl and polymer degradation after heat treatment. Strict PVC was transformed by plasticizers into a supple polymer which was employed for extracorporeal tubing [24, 25].

Polymethyl methacrylate (PMMA) was synthesized with methyl methacrylate monomers by using the exothermic polymerization technique between two glass plates. It was found application in dentistry and orthopedics as it was transformed into very hard polymers through radical polymerization. Since it was easy to maintenance and had low production costs, it also found use in the paper, paint, and automobile industries. It was also used as a coating on contact lenses. Nanotechnology was shown great importance in developments such as dental materials and biomaterials. PMMA could replace inorganic glass with its low-density optical transparency, high mechanical properties, and recyclable thermoplastic properties. PMMA was biocompatible with human cells as more appropriate for transplants and dental use [26, 27].

Polyester (PET) was the world's largest synthetic substances in manufacturing. It had low manufacturing costs and numerous applications. Polyesters were preferred for biomedical areas due to their simple degradability by non-enzymatic hydrolysis at ester bonds. Biologically stable and biodegradable polyesters were used in biomedicine, and most of the biodegradable polymers belong to the polyester family. These polymers were used for a wide range of purposes from solid bodies for orthopedic areas to medication coatings on vascular stents [28].

Polyamides offered properties such as good stability, stiffness, high tensile strength, flexibility, and shock resistance with balanced chemical and mechanical properties. Nylon was the most prominent synthetic polyamide in medical field. The flexibility of polyurethanes and the strength of nylon were combined in polyamide block copolymers with soft segments for improved elasticity as catheter balloon materials for angioplasty. Polyamides could be preferred to form skin contact due to feature of biocompatibility. It has recently been employed to create porous scaffolds for bone regeneration which has been highly load bearing [29, 30].

Acetaldehyde and lactic acid polymerization could be used to create poly-lactic acids (PLA) synthetically. It contained features including the incorporation of several chemicals such metals, metal oxides, natural substances, antibiotics, and antibacterial activities. Additionally, attributes like mechanical performance and low immunogenicity made it a popular choice for film synthesis for biomedical devices and food packaging. PLA was a biocompatible and degradable polymer with thermal stability and favourable mechanical properties. It was preferred due to usage of in vivo as it degraded directly by hydrolysis without the use of catalysts or enzymes [2, 31, 32]. Popular synthetic polymers as poly(ethylene glycol), poly(vinyl alcohol), polyolefins, polyurethane, silicone, polyacrylates and polyamides were used in various applications [8, 33, 34] (Table 2).

Table 2. General Properties and Fields of Common Synthetic Polymers

Polymer	General Properties	Field	References
Polyethylene Glycol (PEG)	Colorless, odorless, low-viscosity liquid, hydrophilic, biocompatible, in medical treatments and vaccines	Cosmetics, pharmaceuticals, food producing, inks, medical products, biopharmaceuticals, wound healing	[10-12]
Polyvinyl Alcohol (PVA)	Non-toxic, hydrophilic, good biocompatibility, film-forming	Biomedical field, hydrogels, tissue engineering, wound healing, single-step DNA polyplex vaccine encapsulation	[13-15]
Polyurethane	Superior durability, impermeability, high rate of foaming and expansion, environmentally friendly, low density, flexible	Various chemical and physical characteristics, building materials, biomedical technologies, electronic devices, coatings, adhesives, elastomers, biomedical technologies	[16-17]
Polyolefins	Low price, good machinability, flexibility, stable	Packaging, adhesives, automotive equipment, artificial joints, surgical sutures	[18-19]
Polytetrafluoroethylene (PTFE)	High chemical resistance, high temperature stability, insulation properties, non-wetting surface, low coefficient of friction, poor adhesion	Industries, pharmaceuticals, laboratories, medical industry	[20-22]
Silicone	Hydrophobic, bio-stable elastomers, low surface tension, corrosion resistance, water repellency	Plastic surgery, intraocular lenses, dialysis membranes	[23]
Polyvinyl Chloride (PVC)	Thermally unstable at processing temperatures, requires stabilizers and plasticizers for flexibility and softness	Medical devices, extracorporeal tubing	[24-25]
Polymethyl Methacrylate (PMMA)	Low-density optical transparency, high mechanical properties, recyclable thermoplastic	Dentistry, orthopedics, paper industry, paint industry, automobile industry, contact lenses	[26-27]
Polyester (PET)	Low manufacturing costs, biodegradable	Biomedicine, orthopedic areas, medication coatings, vascular stents	[28]
Polyamides (Nylon)	Good stability, stiffness, high tensile strength, flexibility, shock resistance	Medical field, angioplasty catheter balloons, skin contact materials, bone regeneration	[29-30]
Poly-lactic Acid (PLA)	Biocompatible, degradable, thermal stability, favorable mechanical properties	Biomedical devices, food packaging, film synthesis	[2, 31-32]

USAGE OF POLYMERS IN HEALTH

Synthetic polymers were revolutionized the healthcare industry as well as known areas to community such as packaging, construction, textiles, and electronics. Polymer substances were used in tissue regeneration with the first plastic syringe developed. Polymeric materials had contributed to the development of regenerative medicine which envisioned the future of tissue engineering and organ transplants in the light of many years of work on stem cells and 3D printing. It was also available as nanocarrier, scaffold, fibers, lenses, antibacterial dressing materials for biomedical applications [32]. Polymers used in health sector could be divided into two broad categories. Pharmaceutical delivery systems and soluble and insoluble pharmaceuticals were part of the first category of synthetic polymers. Soluble blood plasticizers and insoluble prosthetics were part of the second category of synthetic polymers [35]. The use of synthetic polymers in various health disciplines and their dispersion percentages in polymer matrices [15] were given in Figure 1.

Basic criteria in polymers were processability, reproducibility, adjustability and cost-effectiveness. If material was to be used for therapeutic or regenerative purposes, the properties of the material such as biocompatible, non-immunogenic and non-toxic were considered [29]. One of the most important issues in polymers used in the field of health was the issue of biological compatibility. Since it was in contact with the body for a long time, it could be in harmony with tissues and organs. The material to be used required a small volume of high-quality materials. When the polymer was in contact with the body for an extended period in terms of sutures, vascular grafts, soft tissue replacements and implanted medication delivery, it became extremely important. It was used for the intended interaction between the therapeutic structure and the affected area. In the last 25 years, attempts were made to develop synthetic biomaterials, and many of these efforts were centred on preparing ready-to-use polymers which were biologically inert and steady in biological environments [1, 36]. The stimulus responsiveness, shape memory behaviour, and self-healing ability of polymeric substances were significant features for tissue engineering, medical devices, and cell therapy. Designing these polymeric materials also aided in the development of injectable hydrogels and controlled-release drug delivery systems [37].

Polymers used for therapeutic purposes in drug delivery systems exhibited an innovative and highly attractive approach by acting as a targeted active substance carrier. Polymers played significant role in the pharmaceutical industry because of ability in order to encapsulate or deliver therapeutic agents to several parts of the body. One of the main purposes of using polymers was to slow the rate at which drug molecules were exposed to the aqueous environment around the drug delivery system. For this purpose, stimulus-sensitive hydrogels obtained by cross-linking with greater water holding capacity were synthesized [38]. Polymers protected drugs from several external environments that influence the half-life. It was commonly used in the advancement of immediate or regulated drug delivery system using several mechanisms such as diffusion method, degradation and swelling method. It was adjusted according to its response to radiation, redox potential, pH, and temperature, magnetic and electric fields [39]. In a nano drug delivery system study, better retention of drug-loaded polymeric micelle in the tumour, prolonged circulation time, and reduced extra-site effects were achieved at the cancer site [40]. Models that could precisely forecast the rates at which integrated medicines would release from polymers and their degradation patterns were also necessary. In addition, future injectable systems based on liquid polymers that could be administered intravenously or in the form of injectable particles were the subjects of ongoing studies [41]. Several polymer applications in health [42] were shown in Figure 2.

Many polymer materials have been developed in last years, such as nanodrugs, micelles, vesicles, dendrimers, nanospheres, nanogels polymers and other structures. For example, in a study, single-chain polymer nanoparticles had properties such as multifunctional, heat-sensitive, light-sensitive, and catalytic activity. Polymer nanodrugs were used to arrange with aimed delivery and drug-controlled release functions that responded to stimuli. Conjugation of polymers and drugs could modify the pharmacological characteristics of

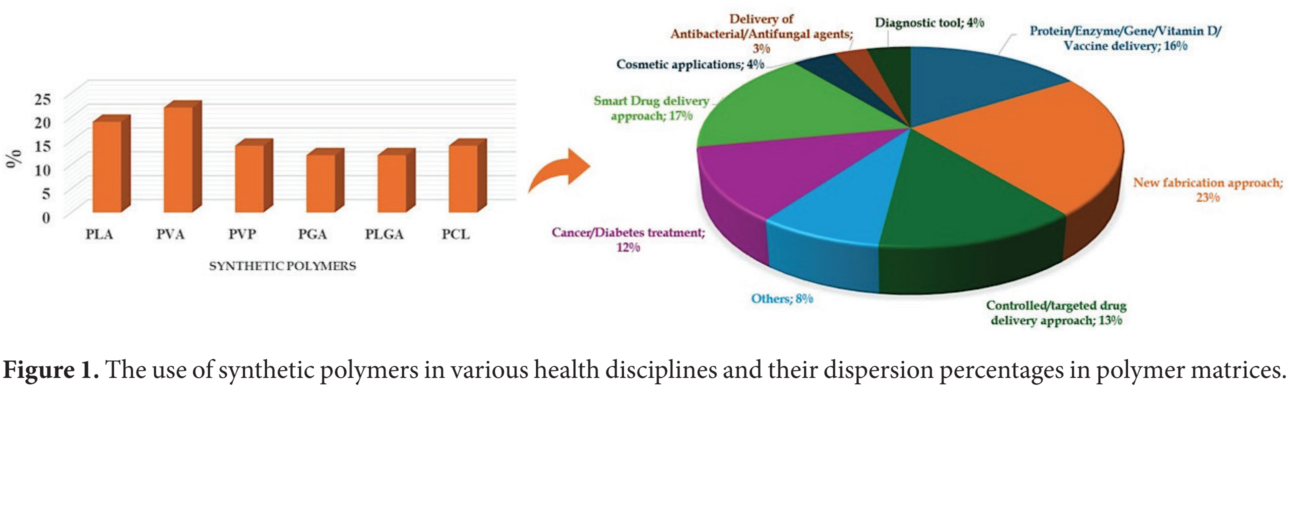

Figure 1. The use of synthetic polymers in various health disciplines and their dispersion percentages in polymer matrices.

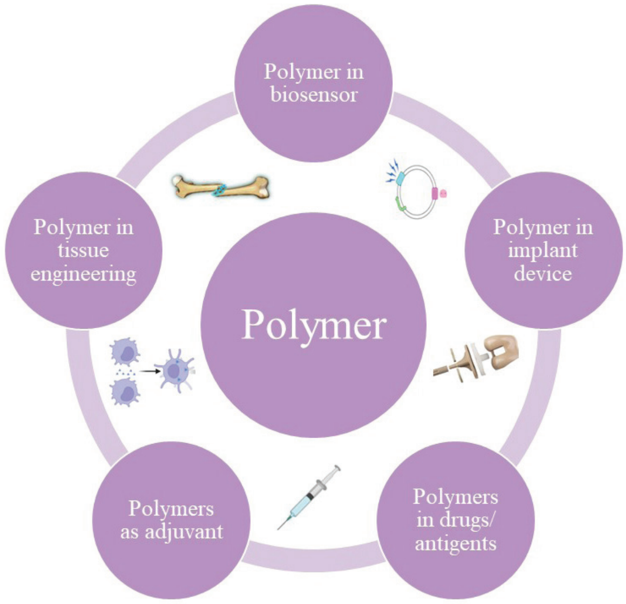

Figure 2. Several polymer applications in health.

drugs by increasing their solubility in drugs. It could improve drug delivery to the target area to be treated. Due to the design flexibility of synthetic polymers, features of polymer nanodrugs including size and porosity could be changed by varying the polymer's length and functionalization. Polymer nanodrugs provided properties such as responsiveness to stimuli, targeting ligands, and biological activity. Thus, it enabled intelligent and predictable transport in pathological areas. Polymer nanodrugs had obtained more attention due to structural diversity and simplicity of functionality. It was simple to functionalize polymer nanodrugs, and functional polymer nanodrugs were produced in a variety of shapes by modifying the structure and physicochemical characteristics of polymerized monomers. Polymeric vesicles among polymer nanodrugs were able to simultaneously load hydrophilic and hydrophobic drugs because of resemblance to liposome vesicles in structure [43]. Various tissue engineering techniques developed using polymer [44] were given in Figure 3.

Tissue engineering field took advantage of the structural and functional properties of polymers such as high surface area, good surface energy, controllable softness on surfaces and ease of manufacture. Studies on various polymer types conducted in tissue engineering to aid or mend cell adhesion, growth, proliferation, and adherence to surfaces. Development of cardiovascular tissue engineering devices was available in areas such as useful and biocompatible polymeric films, surface modification for interface with tough biological tissue. Biodegradable aliphatic polyesters were the synthetic polymers for scaffolds that were most frequently employed. These degradable polyesters were made from caprolactone, lactide, and glycolide. Polyurethanes were one of the most widely used polymers, especially in blood-contact biomedical applications, due to easy synthesis of different forms and the non-coagulating properties of polymer surfaces compared to other polymers. Some of its current applications included catheters, blood bags and artificial heart systems. Polyurethane fibers produced by electric field fiber spinning showed great improvements in the field of wound healing application. The first application of polycaprolactone and polylactic acid polymers was nanofiber scaffolds obtained by electric field fiber spinning in tissue engineering. PCL was very slow to degrade so it was used as a base material for the development of long-term implants due to its semi-crystalline nature and hydrophobicity. It was known that nano mats produced by electric field fiber drawing provided good support during the growth of vascular smooth muscle

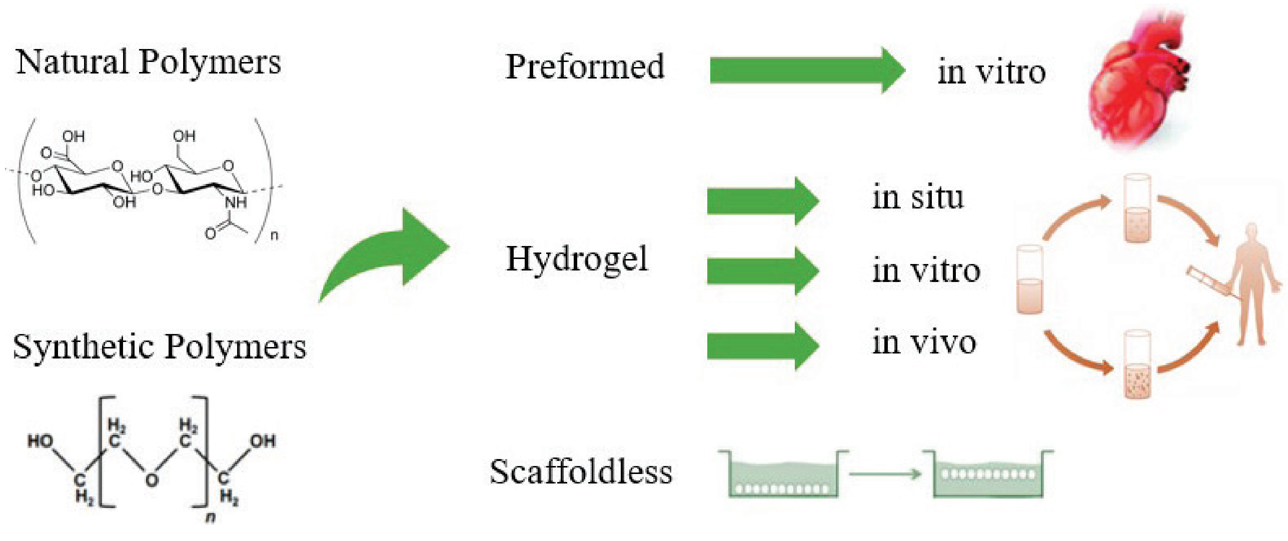

Figure 3. Various tissue engineering techniques developed using polymer.

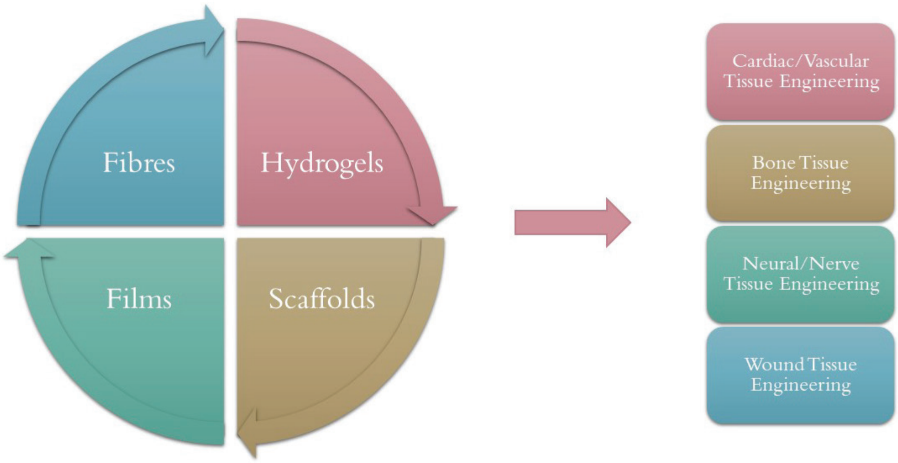

Figure 4. Major conductive polymers and in their tissue engineering usage

cells. The blood could be oxygenated using polymers and used in microporous shapes to function without harming the tissue [45-48]. Major conductive polymers and in tissue engineering usages [49] were shown in Figure 4.

In a research, 3D bioprinting was employed to create scaffolds from chitosan and PVA for liver tissue engineering. It showed higher cell viability in this structure compared to gels crosslinked by other methods [50]. In bone tissue engineering, the use of synthetically synthesized polymers started to replace traditional treatments as alternative techniques. Scaffolds obtained from biomaterials could be used in biomedical applications to extracellular similarities. Especially in this area, studies were continuing different metal or ceramic material combinations that could adapt to the skeleton system and structure to increase durability and improve properties [51]. In a study using PMMA and PEG, it was revealed that they could be used as a biomaterial for orthopedic applications in bone tissue engineering in the presence of gel phase appropriate mechanical and cellular properties [52]. Nanocomposites have emerged as an effective strategy to enhance the structural and functional properties of synthetic polymers in recent years. Studies on the preparation of nanocomposite polymers based on metal or carbon nanostructures in organic and inorganic nanofillers were focused to prepare new biomaterials with advanced properties. The key approach for treating nanocomposite materials was to increase the interfacial adhesion between polymers and nanostructures [53]. Synthetic polymers had received more and more interest as therapeutic agents, due to superior pharmacokinetic profile compared to small molecule medicines. These polymer therapies will probably result in the development of new medications with increased efficacy against a variety of ailments [54, 55]. In various health disciplines, the usage areas of polymers were given in Table 3.

Table 3. The Usage of Polymers in Various Health Disciplines

Health Discipline	Polymer	Usage	References
Pharmaceutical Delivery Systems	Synthetic Polymers	Drug delivery systems, encapsulation, controlled-release drug delivery	[35]
Soluble Pharmaceuticals	Blood Plasticizers	Soluble pharmaceutical applications	[35]
Insoluble Pharmaceuticals	Prosthetics	Insoluble pharmaceutical applications	[35]
Therapeutic/Regenerative	Biocompatible Polymers	Sutures, vascular grafts, soft tissue replacements, implanted medication delivery	[29]
Drug Delivery	Stimulus-sensitive Hydrogels	Targeted active substance carriers, immediate/ controlled drug delivery systems	[38]
Cancer Treatment	Polymeric Micelles	Drug-loaded polymeric micelles, prolonged circulation time, reduced extra-site effects	[40]
Injectable Systems	Liquid Polymers	Injectable hydrogels, injectable particles	[41]
Nanodrugs	Various Nanopolymers	Stimuli-responsive drug delivery, increased drug solubility, targeted drug delivery	[43]
Tissue Engineering	Polyurethane, PCL, PLA	Scaffold development, vascular smooth muscle cell growth, wound healing	[45-48]

Table 4. Applications and Advancements in Healthcare

Application	Advancements	References
Regenerative Medicine	Contributed to tissue engineering and organ transplants; stem cells and 3D printing	[32]
Stimulus Responsiveness	Significant for tissue engineering, medical devices, cell therapy; led to development of injectable hydrogels and controlled-release drug delivery systems	[37]
Nano Drug Delivery	Achieved better retention of drug-loaded polymeric micelles in tumors; prolonged circulation time; reduced extra-site effects; injectable systems	[40, 41]
Polymer Nanodrugs	Multifunctional, heat-sensitive, light-sensitive, catalytic activity; targeted delivery, drug-controlled release, increased solubility, improved drug delivery	[43]
Cardiovascular Devices	Development of polymeric films, surface modification for tough biological tissue; aliphatic polyesters like caprolactone, lactide, glycolide	[44, 45-48]
Wound Healing	Polyurethane fibers produced by electric field fiber spinning; used in catheters, blood bags, artificial heart systems	[45-48]
Bone Tissue Engineering	Use of biomaterial scaffolds for extracellular similarities; metal/ceramic combinations for skeleton adaptation	[50, 51]
Orthopedic Applications	PMMA and PEG as biomaterials with appropriate mechanical and cellular properties	[52]
Nanocomposites	Enhanced properties of synthetic polymers using metal/carbon nanostructures to increase interfacial adhesion between polymers and nanostructures	[53]

RESULTS AND DISCUSSION

In summary, synthetic polymers entered lives rapidly in 20th century with the latest technological developments and many types of polymers were used in almost all areas of health. In this study, it was aimed to give an idea about synthetic polymers and usage in the field. Although problems such as toxicity were encountered in synthetic polymers, it could be controlled with new synthesis techniques. Since the purification of natural polymers was difficult and costly, their commercial production and use was also limited. Synthetic polymers were needed to meet the biochemical and biomechanical requirements of emerging technologies such as tissue engineering, medical regeneration, gene therapy, new drug delivery systems and implantable devices. Currently, research areas were developing where nanoparticles, nano drugs, imaging in the biological environment, and the synthesis of biomedically applicable polymers were combined to facilitate targeted delivery of agents. Especially in the treatment of cancer and chronic diseases with polymeric encapsulation techniques, the best methods and techniques will be developed by reacting and interacting with the host cells, tissues, and organs. Studies continue for the development of smart polymer materials focused on the cell or tissue that were desired to be directly improved and repaired. In near future, more benefits will be provided in the field of health from these polymers developed in line with the needs (Table 4).

CONCLUSION

The advancements facilitated the development of polymers with enhanced biocompatibility and functionality for a wide range of medical applications. The studies into nanocarriers, nanodrugs, and other innovative polymer-based systems highlighted the potential for further advancements in targeted drug delivery and therapeutic interventions. The integration of smart polymers and polymeric encapsulation techniques offered promising areas for improving treatment efficacy, particularly in the management of cancer and chronic diseases. Future research and development would likely continue to focus on optimizing polymer properties for specific medical applications, enhancing the precision and effectiveness of treatment modalities. Considering technological advancements and clinical needs, synthetic polymers would play an increasingly significant role in advancing healthcare solutions and addressing complex medical challenges. As a result, it was expected that this research study on synthetic polymers would shed light on future studies and research in the field of health.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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