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Application and future development of fiber materials in medical devices

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Abstract: *With the continuous progress of science and technology, fiber materials have shown great application potential in the field of medical devices due to their unique physical and chemical properties and good biocompatibility. From the traditional natural fiber to the modern high-performance synthetic fiber, to the emerging carbon-based and liquid metal fiber, fiber materials continue to promote the innovation and development of medical devices. This paper reviews the wide application of fiber materials in the field of medical devices and its future trends. The introduction of different kinds of fiber materials and their application in medical dressings, artificial skin, slow-release drug fibers and medical sutures are discussed. This paper aims to comprehensively comb the application status of fiber materials in medical devices, and discuss their future development trend, so as to provide reference for research and application in related fields.*

Keywords: *fibre materials; medical devices; application; development*

1. Introduction

In the context of the rapid development and continuous innovation of medical technology, the application of material science in the field of medical devices is particularly important. As a class of key performance materials, fiber material is increasingly becoming an important part in the design of medical devices due to its unique physical and chemical characteristics. From traditional surgical sutures to state-of-the-art tissue engineered stents, fiber has shown great potential in improving medical treatment and quality of life[1].

2. Medical natural fiber materials

2.1 Natural regenerated fiber material

2.1.1 Chitin-like fibers

Chitin, also known as chitin, chitysaccharide, the product of acetyl removal is chitosan. Chitin is extremely rich in source, second only to cellulose in nature. It is commonly found in the carstace of shrimp and crab marine arthropods, and is even found in the cell walls of insects, algae and fungi. Chitin fiber and its products, safe and reliable, have been successfully used in protective textiles such as antibacterial socks, underwear, and underwear, and even medical textiles such as bandages, gauze and trauma dressings[2-3].

2.1.2 Collagen fibers

The essence of collagen fibers is collagen, which mainly exists in the internal organs of human body or animals. It is the largest number of three fibers (collagen fibers, elastic fibers and mesh fibers) generated by fibrolasts; tight structure, composed of thinner microfibrils; good toughness, strong resistance to stretch; components similar to human skin, with excellent biocompatibility and complete absorability. With its unique biological properties and structural characteristics, collagen fibers are widely used in the field of regenerative tissue engineering, such as artificial skin, artificial blood vessels, artificial stents and surgical sutures.

2.1.3 and the alginate fiber

Alginate acid is a natural polymer material extracted from brown algae, with a huge molecular

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weight (up to 120,000 ~190,000). It is dissolved into water to form a spinning solution, and then squeezed into the solution containing divalent metal cations through the spray hole, which can form seaweed fiber after solidification. With the development of modern textile forming technology, especially the rise of nonwoven technology, alginate fiber has been widely used in functional medical textiles such as wound dressing, moisturizing mask, hemostatic gauze, disinfectant wipes, microcapsules, and artificial vascular stents, with good absorptive and biocompatibility[4].

2.1.4 Bamboo fiber

The main components of bamboo fiber are cellulose, hemicellulose and lignin, which all belong to the high sugar class, accounting for more than 90% of the total fiber content. The cellulose content in bamboo fiber is very rich, which can be extracted from naturally growing bamboo, and then prepared by physical and chemical methods with good air permeability, water absorption and dyeing. In addition, the unique advantages of bamboo fiber, such as antibacterial, rapid hemostasis, ultraviolet light protection and odor protection, have also attracted much attention in the field of medical textiles.

2.2 Synthetic fiber-based medical textile materials

2.2.1 Polyester-synthesized degradable fibers

(1) Polylactic acid fiber

Polylactic acid (PLA), also known as polypropylene polyester, is a kind of polyester synthetic fiber, belongs to the renewable resource. Lactic acid is mainly extracted from fermentation in plants rich in polysaccharides and starch, such as corn, cassava and sugarcane, and then synthesized by direct polycondensation, ring-opening polymerization and solid polymerization. PLA fiber is formed by PLA as raw material, through extrusion, biaxial stretching, spinning and other ways, with good thermal stability, biodegradability and biocompatibility, the final degradation product is carbon dioxide and water, without any pollution to the environment, is an ideal green resource. PLA fiber is widely used in the medical field[5]. With its good mechanical and degradation properties, it can prepare conventional medical textiles such as artificial bone plates, bone nails, stents, and surgical sutures, and can also be used as high value-added products such as artificial tendon, artificial kidney, hernia mesh and man-made pipelines.

(2) Polyethyl ester fiber

Polyethyl ester (PGA), also known as polyglycolic acid, is prepared by glycolic acid after condensation or ring opening polymerization. It is insoluble in water and almost all organic solvents (except polyhexafluoroisopropyl alcohol). It is a simple linear biodegradable aliphatic high polymer with a glass transition temperature of 35~40°C and a melting point of 225 ~230°C. PGA fibers can be woven by the melting of PGA high polymer slices. They have high strength and high modeling, but they are sensitive to heat and acid and base, and are easy to hydrolysis. Generally, the degradation cycle is 6 months. At present, PGA fibers have been successfully used in high-end medical textiles such as peripheral nerve catheters, artificial blood vessels, surgical sutures and endovascular stents[6].

(3) Polyacetate fiber

Polyethylpropyl ester (PLGA) is an irregular and amorphous copolymer formed by the copolymer of ethyl ester and propyl ester in a certain proportion. By adjusting the content of ethylester (propyl ester), PLGA high polymer with different degradation speed, mechanical properties and characteristic viscosity can be prepared. In 1975, DuPont (DuPont) developed the acetate copolymer surgical suture as the earliest commercialization of PLGA, and then people found that PLGA sutures had better flexibility and longer performance retention time than PGA sutures, and were easy to tie, high strength and easy to use. In addition, PLGA is also widely used in medical surgery anti-adhesion membranes, skin transplantation surgical lines, wound sutures, microcapsules, microspheres, implant agents, as well as high-end medical products such as artificial blood vessels, artificial tendons, cell culture and multi-porous stents[7].

Polyendactone (PCL) is a polymeric polyester that can be composed of cyclic polymerization by the action of catalysts (metal-organic compounds such as tetraphenyl tin) and initiators (dihydroxy or trihydroxyl). PCL fibers can be spun from PCL, insoluble but soluble in organic solvents and characterized by good biocompatibility, biodegradability, high crystallinity and low melting point. It has been widely used in the field of sustained release, such as drug carrier, cell and tissue engineering stents, surgical suture, sanitary wipes and nanofiber stents.

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2.2.2 Poly fiber

Poly-dioxurhexone (PDS) fibers are prepared from PDS monomer by melt spinning or injection molding. It has the advantages of non-toxic, no side effects, no pollution, complete degradation and good mechanical properties, chemical stability and biocompatibility. Therefore, PDS fiber has been widely used in the field of textile and medicine, such as surgical sutures, orthopedic fixation materials (bone nails, bone plate, fixation bolts, fixation anchors, etc.), as well as hemostatic forceps, surgical clamp adhesive and other medical textiles. FIG. 15 is a schematic diagram of the preparation and application flow of PDS fibers.

2.2.3 PolySanya methyl carbonate fiber

Polyanya methyl carbonate (TMC) is made of Sanya methyl carbonate monomer, which is non-toxic, easy to process, high biocompatibility and good degradability. TMC fibers are made of TMC spinning by electrospinning or injection molding, with high elasticity and good mechanical properties. At present, it has been widely used in conventional medical products such as bone plate, bone nails, wound dressing and surgical sutures, as well as high-end medical textiles that can be implanted in vivo, such as hydrogel porous stent, drug sustained-release carrier, vascular stent and artificial kidney.

3. Analysis of the application of fiber materials in medical devices

3.1 Medical dressings

The main function of medical dressing is to isolate the wound from the outside world to ensure that the wound will not be infected due to bacteria or viruses. The fit of the dressing is better to effectively prevent the wound from contact with the outside world. In addition, the air permeability and waterproofing of the medical dressing are also necessary. Medical glass fiber textiles made from glass fiber as the basic material can be made into a medical fiber bandage with good comprehensive performance by coating with modified polyurethane. In addition, the surface area and porosity of the electrospinning made of fiber membrane material are larger than the traditional medical dressing, with good air permeability, which can provide a ventilation and circulation environment for the wound.

3.2 Artificial skin

As the first line of defense of human immunity, the skin can help the human body to prevent a variety of human infections. When people have skin damage such as burns and burns, the human skin can not recover to the initial skin, especially for patients with excessive trauma, and the skin problems can only be solved through skin transplantation.

3.3 Slow-release drug fibers

There are two small molecule drugs for oral and external use, and some drugs need to be in the specified environment and specific location to exert their efficacy. Electrospinning technology is used to simulate tissue and organ cells, which is relatively safe and controllable in slow-release rate.

3.4 Medical sutures

In the middle of the 20th century, the main components of the common medical sutures were nylon and polypropylene, which could not be absorbed by the human body. In the 1960s, people developed the absorbable collagen lines by using the molecular cross-linking regulation process. In the 1990s, the process of chitin-derived fiber synthesis was also increasingly perfect and mature. Since the 21st century, antibacterial sutures that reduce inflammation and are easily absorbed by tissues have been developed. However, whether the absorbable suture or the nonabsorbable suture, its own tensile strength is easy to decline.

In recent years, relevant experts are still carrying out research on medical sutures with functions such as drug carrier, anti-inflammatory and antibacterial resistance. As a core tool of medical activities, medical sutures should have the following functions: ① Biocompatibility. The main function of medical sutures is to close the wounds inside the body and outside the body, which will plant the body and affect the tissues of the body. Therefore, the sutures should first have strong biocompatibility, and will not make the blood and body tissues appear immune rejection and immune response.②

Absorbable and degradability. For procedures such as suture of blood vessels, the removal of medical sutures can cause secondary pain to the patient, and this problem will be effectively avoided without removal. The biodegradability of the medical suture must reach the specified degradation rate to match the healing time of the body tissue, so as to avoid the harm caused to the human body.③ Certain tensile strength and knot-bearing properties. This is because in the process of fixing the wound, the suture needs to maintain the relative stability of the structure to prevent the body or tissue from sinking or cracking, or to be damaged in daily life due to the poor connection. In addition, medical sutures should also maintain their elongation, tensile strength, variable performance and elasticity to ensure that they can withstand tension when working in the body.

4. Future development trend of fiber materials in medical devices

With the integration of materials science, nanotechnology and biotechnology, fiber is undergoing an innovation in medical devices. In the future, smart fiber, with its lightweight, high strength and intelligent characteristics, will be used in the fields of artificial limbs, exoskeleton, surgical tools and biodegradable fibers, such as polylactic acid (PLA) and polyglycolic acid (PGA), will be widely used in fracture fixation and degradability, reducing patient pain and multi-function cost, by combining conductivity, antibacterial and biocompatibility. Together, these trends draw a blueprint for the more accurate, efficient and safe development of fiber materials in medical devices. As shown in table 1.

Table 1: Overview of the future trends of fiber materials in medical devices

Fiber type	key property	application area
Intelligent fiber	Lightweight, high strength, corrosion resistance, intelligent	Prosthetics, exoskeletons, surgical tools, diagnostic devices, and wearable medical devices
Degradable fibers (e. g. PLA, PGA)	Biocompatibility, and degradability	Fracture holder, heart stent, sutures, tissue repair materials
Multifunctional composite fibers	Conductivity, antibacterial properties, biocompatibility, etc	Implants, high-precision diagnostic equipment, and real-time monitoring and feedback system

5. Conclusion

As an important part of the field of medical devices, the continuous optimization and innovative application of fiber materials provide strong support for the progress of medical technology. The medical fibers used in the medical field should usually have good compatibility and degradability. It is urgent to develop medical fiber materials with outstanding comprehensive performance and low price, which helps to create better conditions for the development of China's medical industry and people's healthy and better life.

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