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# Research on Silk Fibroin Biomaterials for Wound Dressing

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**Abstract:** With the development of the times, biology and textile technology industry has been greatly promoted. Domestic and foreign research focus on silk fibroin gradually shifted from the traditional textile field to the biomedical textiles field .the research on silk fibroin wound dressing is gradually developed, which has a great impact on accelerating wound repair. Studies have shown that the effect of wound repair is closely related to the physical and chemical properties of the raw materials. These characteristics also show that silk can be designed flexibly according to the requirements of dressing. Similarly, the production process of silk fibroin dressings and the association between adhesion and drug delivery also have a great impact. This article will elaborate the performance characteristics, advantages and problems in the research process of silk fibroin dressings, including silk fibroin membrane, silk fibroin hydrogel, silk fibroin scaffold, nanofiber membrane and other materials, as well as some new silk fibroin wound dressings currently under research, and clarify the development direction and outlook of silk fibroin in the future.

**Keywords:** Silk fibroin, Wound dressing, Wound repair, Tissue engineering, Hydrogel, Nanofiber.

## 1. Introduction

With the rapid development of textile material science, clinical medicine and other disciplines, as well as inter-disciplinary exchanges and cooperation, the progress of biomedical textiles has won the attention of global scientific research and product development. Due to their excellent biological properties, biomedical textiles play an important role in diagnosis and treatment of living organisms, repairing or replacing their diseased organs and helping tissue growth.

According to historical records, silk fibroin was widely used in biomedical textiles as a wound suture a hundred years ago, and its good biocompatibility can be seen. Silk, also known as "natural silk", is a long, continuous fibre made from the secretion of silk fluid by mature silkworms when they make cocoons. The natural fibroin fibre formed by silkworm larvae through the synthesis of silk fibroins in the silk glands. With the in-depth study of the structure and properties of silk, the application of silk and silk fibroins has taken a new direction.

Silk not only has good mechanical properties, but also has good air permeability, oxygen permeability, biocompatibility and controlled biodegradability. And its excellent characteristics make it as a wound dressing which has also been well used.

## 2. Study of Basic Sericin Fibroin Wound Dressing

In addition to meeting the microenvironmental requirements of keeping the traumatised area of the skin moist and comfortable, an ideal trauma dressing should also be antibacterial, breathable, adsorbent, and less susceptible to skin damage.

At present, the traditional medicine load the life active substances into various forms of carriers such as silk fibroin film through the delivery system dressing to heal the skin trauma, which is currently the most useful skin healing and repair bio-active dressings.

### 2.1. Silk fibroin film

The preparation process of silk fibroin film is simple, and the performance parameters such as film size, thickness and pore size can be easily adjusted, which can create favourable conditions for the flexible design of dressing to meet the requirements of trauma repair. Medical silk fibroin membrane is usually formulated as a polymer material consisting of 75% natural fibroin and 25% colloidal fibroin. When the drug-carrying silk fibroin covers the damaged surface, it can protect the trauma surface and at the same time promote the skin regeneration through the drug, which greatly improves the efficiency and safety of trauma healing.

Since the use of silk fibroin will be in direct contact with the cells in the human body, especially blood cell. In order to prevent the appearance of the effect of foreign bodies, before used in the human body, we must consider the cytocompatibility of the silk fibroin membrane, to ensure biosafety, which is precisely the necessity of clinical trials. Silk fibroins are secreted and synthesised by endothelial cells on the inner wall of silk glands, which are natural fibroins with high molecular purity. This also means that silk fibroins can be degraded into products which can be absorbed by the body and have no adverse effects on the human body. Silk fibroins have good mechanical properties of natural fibres and can be processed into the form of moulded scaffolds. However, there are relatively few research results on the biocompatibility of skin regeneration membranes with silk fibroin membranes, and the safety of skin regeneration membranes for clinical use is still debated.

Silk fibroin membrane has excellent skin biocompatibility, and can rapidly become a good raw material for the preparation of skin tissue regeneration fibroin membrane materials, which puts forward the ideas and methods for the independent research and development, and use of skin tissue

engineering materials in China.

### 2.2. Silk fibroin scaffold

The Silk fibroin scaffold presents a three-dimensional network structure with a porous structure. Through the porous structure, gas-liquid exchange can be achieved, providing growth environment and nutrients for cell growth. Compared with the silk fibroin membrane, the production process of silk fibroin scaffolds is also more convenient and simple. Most of the silk fibroin scaffolds can be obtained directly by freeze-drying, and the pore size can be adjusted by adding the size of the salt particles and other methods. According to the fact that the main component of collagen is elastin, the silk fibroin and elastin were crosslinked by natural biological crosslinking agent, Genipin. After freeze-drying, the porous scaffolds with small pore size, low swelling rate, low release rate and degradation rate can be obtained.

Studies have shown that silk fibroin composite porous sponge has good hemostatic ability, can promote the body's endogenous coagulation. Because of its porous structure, silk fibroin three-dimensional scaffolds can maintain a good and stable environment for cell proliferation and growth which means the porous network structure can effectively induce bacterial adhesion.

### 2.3. Silk fibroin hydrogel

A gel is a form between a solid and a liquid. Hydrogel is an elastic gel formed from a macromolecule solution. It has the properties of a polymer electrolyte and a three-dimensional structure. Hydrogel uses water as a dispersion medium to absorb and retain large amounts of water, and has a cross-linked network structure.

The main configuration of silk fibroin is composed of SilkI, SilkII and SILKIII. Silk fibroin has alternating hydrophilic and hydrophobic chains. Although silk fibroin has a low viscosity, it has good physical properties and degradability, which maens so many kinds of silk fibroin hydrogels can be formed by various gelation processes. Then silk fibroin hydrogels imitate human organ cells and build an organizational system. The regenerated silk fibroin can be gelatinized under certain conditions because of its hydrophobicity. The regenerated silk fibroin solution is a colloidal dispersion system.

In addition, the silk fibroin-based hydrogels can be modified by changing the chemical sequence. The same effect can be achieved by changing the length of block and adjusting the crystallinity. At present, the research is in the stage of physical mixing of silk fibroin hydrogel with different materials, the aim is to improve its function and performance through experimental tests, and make it a good choice for biomedical applications, which is also the development prospect of silk fibroin hydrogels in the future.

## 3. New Silk Fibroin Wound Dressings

### 3.1. Silk fibroin nanofibers

Silk fibroin nanofibers, which were originally used in biomedical textiles, have been found to be further developed in medicine in recent years. In recent years, silk fibroin nanofibers have even been used in the fields of optical components and wastewater treatment because of their excellent properties.

Silk fibroin nanofiber is a kind of silk fibroin structure, which like silk fibroin itself, has good mechanical properties and hygroscopicity, as well as excellent Biocompatibility and biodegradable properties. It can be used as a new functional material.Silk fibroin nanofibers are widely used in modern medical textiles because of their good Biocompatibility and ability to degrade into harmless substances, such as wound dressing, slow-release drug and tissue reconstruction, etc. . Due to the lack of function, the pure silk fibroin nanofibers have some defects, such as hard and brittle under certain drying conditions, and difficult to control the degradation rate, etc.These reasons limit its application conditions and fields.

In order to improve the spinnability of silk fibroin nanofibers and improve their properties and capabilities, more and more scientific research focuses on silk fibroin blended with other materials, a series of SF/CS nanofibers were prepared by electrospinning with water as solvent. The blend spinning of silk fibroin and other materials increases the functionality of silk fibroin composites. This can effectively avoid the defects of silk fibroin itself cause a certain impact on the final product.

Electrospun silk fibroin nanofiber dressings are based on silk fibroin, using formic acid as solvent, the regenerated silk fibroin nanofiber membranes were prepared by electrospinning. Electrospun silk fibroin nanofiber dressings are silk fibroin nanofiber membranes prepared under improved process conditions. After treatment, the poor water absorption properties of the original silk fibroin are changed, can withstand a more humid environment, ensuring a better moisture permeability. Because of these excellent characteristics, silk fibroin nanofiber dressings have the conditions for treating deep burn wounds, but there are still some problems and difficulties to be overcome.

### 3.2. Double-layer silk fibroin composite film dressings

New wound dressings with improved properties are being developed, and silk fibroin-coated bilayers have attracted increasing attention because of their ability to mimic the two-layer structure of the epidermis and dermis. It aims at the problems of poor water absorption and mechanical properties of silk fibroin. Using silk fibroin as substrate, adding glycerol to silk fibroin could reduce the dissolution rate of silk fibroin film in water, and improve the water resistance and flexibility of silk fibroin. The moisture permeability and air permeability of silk fibroin film can meet the requirements of medical materials better than other materials.

The research on release characteristics of silk fibroin film showed that silk fibroin composite double-layer film reached the required effect earlier than single-layer film in the release solution. The silk fibroin complex bilayer membrane observed by naked eye, the membrane itself was colorless and transparent. It was found that the flexibility of double-layer film was better than that of single-layer film. The drug release time can be controlled by the composite thickness of the membrane, which is more in line with the requirements of drug sustained release preparations.

### 3.3. Silk fibroin fiber-gel composite dressings

The results show that the elasticity of silk fibroin material can hardly meet the requirement of practical wound dressing. In this paper, the preparation of composite poly hydrogels PNIPPAm based on silk fibroin fibers by free radical polymerization was studied, the viscoelastic properties,

swelling properties and repeated swelling-shrinkage properties of the composite hydrogels were investigated.

The experimental results show that the silk fibroin fiber-gel can improve the properties of silk fibroin. There is a gap between the silk fibroin fiber on the surface and the hydrogel, which can be used as a good water delivery channel and is beneficial to water molecules entering and leaving. The properties of silk fibroin fiber-gel composite dressings are not only related to the experimental temperature, but also may affect the properties of the dressings, and silk fibroin fiber and hydrogel content has a great relationship. Therefore, the new bioactive dressings have a good prospect in promoting wound healing.

### 3.4. Silk fibroin microspheres-scaffold composite dressings

Chronic wound healing is a difficult problem in tissue engineering and regenerative medicine. The drug itself and whether the wound activity can be maintained for a long time is the key to wound healing, so we need silk fibroin bioactive wound dressings to promote wound healing. The growth factors for wound healing were embedded in silk fibroin spheres, and silk fibroin spheres and scaffolds were connected by certain methods to synthesize silk fibroin microspheres-scaffolds composite dressings. When wound dressing is applied, silk fibroin microspheres degrade gradually, and the dissolution of skeleton can effectively delay the release of growth factors, thus realizing the long-term treatment of chronic wound. Combining biologically active insulin-silk fibroin microspheres with silk fibroin scaffolds is advantageous for the treatment of chronic wounds.

## 4. Conclusion

Studies have shown that research on silk fibroin dressings for wound repair has yielded rich results. Whether it is the conventional silk fibroin membrane, silk fibroin scaffold or silk fibroin hydrogel, or the new silk fibroin bilayer membrane, etc., all of them have gained a great deal of attention and support from the academic and medical fields. The biocompatibility and high plasticity of silk fibroin have laid a good material foundation for subsequent research.

While affirming the medical value of silk fibroin wound dressing, we should also clearly recognize that there are still many difficulties and problems waiting to be overcome, including how to design flexible silk fibroin dressing for different physiological characteristics of the wound repair process. This requires further understanding of the physiological processes such as cell division, migration, and proliferation of biological cells for different silk fibroin dressings. These mechanisms are also important directions for our future research.

Wound repair is a complex process that requires not only the unilateral action of the dressing, but also the cooperation of human organs and tissue cells within the organism. In order to safely and efficiently explore the potential ability of silk fibroin, to more flexibly utilize the biological properties of silk fibroin, and to synthesize new silk fibroin wound dressings using new technologies and new methods, future research can focus on the classification of different types of wounds, and the design of different dressings for different wounds to utilize different physicochemical properties. The development of wound dressings that are highly effective in repairing and removing scar residues will provide theoretical and material support for the clinical application of wound repair in the medical field.

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