# Development of Silk Fibroin Dressings and Advances in Their Application in Wound Healing

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**Abstract.** Wound healing is a complex process involving hemostasis, inflammation, proliferation, and remodeling phases. Medical wound dressings are commonly employed to promote wound healing, alleviate patient discomfort, and prevent further tissue inflammation or expedite wound closure. Among various wound dressings, silk fibroin dressings have garnered widespread attention due to their outstanding anti-inflammatory and hemostatic properties, as well as excellent biocompatibility. Therefore, this paper introduces the biological characteristics of silk fibroin, elucidates the current research status of silk fibroin-based wound dressings in various forms such as nanofibers, hydrogels, films, foams, and ointments, and discusses the challenges and future research directions in the field of silk fibroin-based dressings for wound repair, providing insights for further development and application of silk fibroin dressings.

**Keywords:** Silk Fibroin; Biological activity; Wound dressing; Wound repair; Skin.

## 1. Introduction

The skin serves as the body's primary barrier against external injuries, with functions including sensation, secretion, absorption, respiration, and temperature regulation [1, 2]. However, once the integrity of the skin is compromised, it can lose some of its functions, leading to wound infections, tissue damage, or even life-threatening situations. Therefore, promoting wound healing and skin repair is crucial. An ideal dressing should possess flexibility, strength, breathability, non-immunogenicity, resistance to microbial invasion, and maintain a gently moist environment at the wound interface. Compared to traditional medical gauze or bandages, newly developed wound dressings in recent years, such as nanofiber dressings and hydrogel dressings, have gained widespread attention due to their diverse functions.

Silk primarily contains 25% silk sericin and 75% silk fibroin, comprising mulberry silk and non-mulberry silk. The difference lies in the amino acid composition, with mulberry silk fibroin containing a high proportion of serine and a low proportion of alanine, while non-mulberry silk fibroin is rich in glycine and serine, along with alanine, forming the tripeptide sequence Arg-Gly-Asp (RGD) [3-5]. This sequence serves as a crucial site for cell adhesion recognition and holds significant importance in the field of tissue engineering [6].

Fibroin, a globular protein derived from silk, consists of eighteen amino acids and boasts a wide range of applications. It exhibits outstanding mechanical properties, breathability, high oxygen permeability, excellent biocompatibility, controllable degradability, and ease of processing. In recent years, silk fibroin has garnered researchers' attention in the field of wound repair, making it a favorable biomaterial choice for developing wound dressings. This paper provides an overview of the biological characteristics of silk fibroin as wound repair dressings and focuses on elucidating the research status and advancements of various fibroin-based dressings in wound repair.

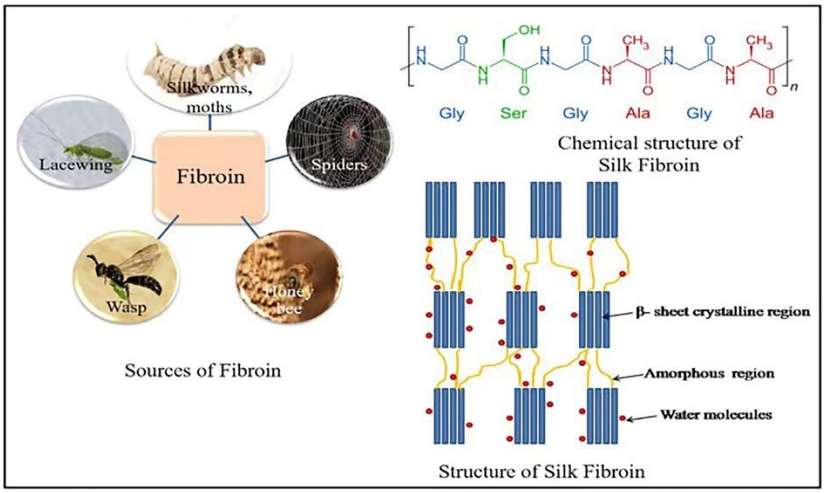


**Figure 1.** Source and Structure of Silk Fibroin [7].

## 2. Biological characteristics of silk fibroin

### 2.1. Hemostatic Properties

The hemostatic stage marks the first phase of wound healing, as prompt hemostasis prevents excessive blood loss and potential fatality. In recent years, numerous studies have demonstrated the hemostatic properties of silk fibroin. There are two main reasons underlying its hemostatic mechanism. Firstly, through physical blockage, silk fibroin adheres to and physically seals the wound by dissolution or swelling, thus achieving hemostasis. Wei et al. [8] prepared a sericin-PEG sponge by mixing silk fibroin with polyethylene glycol (PEG, 1500 Da) and freeze-drying the mixture. The sericin-PEG sponge, dissolved and converted into a gel form by blood, induced rapid gelation of silk fibroin, physically blocking bleeding sites in a rabbit liver injury model. Results showed superior hemostatic performance of silk fibroin compared to gelatin sponge in terms of hemostasis time (136.17±62.27s and 249.83±29.18s) and blood loss (2.16±1.27g vs 4.97±1.44g). Secondly, silk fibroin influences the blood coagulation process directly by activating clotting factors or platelets, thereby initiating the coagulation cascade, promoting platelet adhesion and aggregation, and facilitating the interaction between platelets and fibrinogen [4]. Kundu et al. [9] found that silk fibroin significantly shortened the coagulation time and, through in-depth analysis comparing platelet-free plasma (PFP) and platelet-rich plasma (PRP), demonstrated silk fibroin's activation of platelet-mediated clotting cascade, achieving approximately 50% reduction compared to gelatin. Additionally, Dahlke et al. [3] observed thrombus formation upon sericin sutures implantation, indicating silk fibroin's ability to bind with fibrinogen and platelets, thus promoting coagulation cascade and achieving hemostasis.

### 2.2. Anti-inflammatory Properties

Silk fibroin exhibits excellent anti-inflammatory characteristics, as it not only alleviates inflammation at the wound site upon implantation but also generates minimal inflammatory reactions, which are conducive to disrupting pathogens present at the injury site, promoting the release of growth factors, and aiding in wound repair [10]. This is mainly attributed to two factors: Firstly, silk fibroin can inhibit the production of pro-inflammatory cytokines in the inflammatory response, downregulating the expression of various inflammatory factors in inflamed tissues, including COX-2, IL-6, IL-1β, and TNF-α [11]. Secondly, the abundance of amino acids in silk fibroin can activate the JNK-STAT signaling pathway in macrophages, mediating M2 polarization behavior of macrophages [6], thereby reducing the inflammatory response at the implantation site. Rnjak Kovacin et al. [12] prepared fibroin scaffolds and implanted them into rats. The experimental results showed that compared to implants for two weeks, the number of infiltrating immune cells within the porous

fibroin scaffold after four weeks of implantation significantly decreased, indicating a significant inhibition of the inflammatory response. Olivier Etienne et al. [13] implanted silk fibroin hydrogel into mice. Within two weeks, signs of inflammation were observed in the silk gel and surrounding tissues, with abundant macrophages and neutrophils. However, after one month of implantation, these immune cells decreased rapidly and completely disappeared after three months. This result indicates that fibroin implantation into wounds may induce a certain degree of inflammation, leading to an increase in macrophages. However, with the passage of time, macrophages polarize, thereby reducing the inflammatory response at the implantation site.

### 2.3. Angiogenesis

Angiogenesis is a crucial aspect of the proliferation phase during wound healing, where new capillaries sprout in the new tissue to provide nutrient supply and facilitate wound closure. Silk fibroin plays a key role in aiding wound vascularization, involving multiple aspects such as promoting endothelial cell proliferation and migration, regulating extracellular matrix synthesis and degradation, and participating in endothelial cell differentiation [6]. In essence, silk fibroin promotes vascular regeneration and accelerates wound healing by modulating cell signaling pathways and interacting with other cellular factors and molecules. Chouhan et al. [14] utilized fibroin hydrogel for burn wounds and found that, compared to untreated wounds, the wound sites treated with fibroin hydrogel exhibited a tenfold increase in vascular density, indicating silk fibroin's ability to recruit cells to form capillaries at the wound site and accelerate new tissue formation. Stoppato et al. [15] incorporated silk fibroin fibers into polylactic acid-soaked sponge scaffolds and observed that this composite scaffold not only promoted the growth of endothelial cells in vivo but also facilitated the vascularization process in vivo. This was mainly attributed to macrophages and multinucleated giant cells secreting angiogenic factors. Wang et al. [10] found that silk fibroin mixed with silk sericin (SS) and prepared into SF-SS fiber membranes by electrospinning could activate macrophages, particularly enhancing the proportion of M2 macrophages to promote angiogenesis. Therefore, as a biomaterial, silk fibroin possesses angiogenic properties, which are beneficial for its application in wound healing.

### 2.4. Re-epithelialization

Re-epithelialization is a crucial stage in wound healing, and research has confirmed that silk fibroin can promote the expression of fibronectin and vascular endothelial growth factor, activate the NF-κB signaling pathway, and facilitate wound re-epithelialization, thereby inducing wound healing [4, 16]. Chouhan et al. [17] mixed a 13% PVA solution (w/v) with a 3% (w/v) SF solution in a ratio of 4:1 and used electrospinning technology to manufacture fibroin nanofiber mats, which were then applied to diabetic wounds in rabbits. Results showed that on the 14$^{th}$ day, wounds treated with this material exhibited growth and new formation of tongue epithelium, indicating early re-epithelialization, whereas wounds treated with pure PVA nanofiber mats did not. By the 21$^{st}$ day, the healed wounds also displayed a well-structured matrix of epidermis and dermis, as well as budding hair follicles and sebaceous glands, which were not observed in wounds treated with pure PVA nanofiber mats. Additionally, SF can be used for corneal wound healing. Abdel et al. [18] treated rabbit corneal epithelial injuries with eye drops containing soluble silk fibroin. The study results demonstrated that eye drops containing silk fibroin significantly increased epithelial cell proliferation, promoted corneal epithelial regeneration, and accelerated the healing of corneal epithelial injuries. Therefore, the excellent biological properties of silk fibroin provide a favorable microenvironment for cells, aiding in the migration of keratinocytes, promoting early re-epithelialization of wounds, and reducing wound healing time.

### 2.5. Biodegradability

The degradation characteristics of biomaterials directly impact the speed and quality of wound repair [5]. Specifically, in the early stages of implantation, biomaterials should be stable to provide

mechanical support for cells and tissues. Subsequently, the biomaterials need to gradually degrade to accommodate the growth of new tissue. It is well known that fibroin exhibits very slow biodegradability, taking months or even years [4]. The high stability of SF is attributed to the repetitive hydrophobic domains (GAGA) n present in the fibroin heavy chain, which are resistant to degradation. Bucknall et al. [19] examined the stability of silk fibers by measuring the tensile strength of fibers implanted subcutaneously in animal models after 70 days. Results showed that the tensile strength significantly decreased only after 70 days of implantation. Generally, with increasing degradation rate, the tensile strength of fibers may decrease, indicating that the slow degradation rate of SF may be beneficial for manufacturing wound dressing substrates or temporary graft applications, providing long-term stability and sufficient mechanical strength. Wang et al. [20] implanted silk scaffolds into immunocompromised rats and found that the silk scaffolds remained intact with a significantly slow degradation rate. Signs of degradation and loss of structural integrity were observed in the periphery where macrophages could approach the scaffold, while the scaffold remained essentially intact in areas without macrophages. This indicates that silk fibroin is highly stable in vivo and degrades slowly due to the phagocytic activity of macrophages.

Additionally, as a protein material, SF is composed of peptide chains and exhibits biodegradability under protein hydrolysis conditions. Most proteinases tend to degrade the amorphous SF [21]. This indicates that by altering the content of crystalline structures, SF biomaterials with controlled degradation can be prepared. For instance, Huang et al. [22] introduced a matrix metalloproteinase-2-sensitive sequence into SF to prepare a novel transgenic SF, which exhibited a significantly higher degradation rate compared to regular SF, meeting specific usage requirements under certain conditions.

## 3. Silk fibroin wound dressings

### 3.1. Silk fibroin nanofiber dressings

In recent years, nanofibers have attracted widespread attention in the field of wound repair due to their large specific surface area, high porosity, and excellent breathability [23]. Currently, most silk-based nanofiber wound dressings are prepared using silk fibroin as the matrix through electrospinning technology. However, single silk-based dressings alone cannot meet the demands of wound healing. Therefore, researchers have further compounded natural extracts or polymeric materials with silk-based dressings as carriers to prepare multifunctional wound dressings. Additionally, there are studies utilizing silk fibroin nanofiber dressings as drug delivery vehicles to promote the functionalization of wound dressings, providing specific treatments for specific wounds [24].

#### 3.1.1. Silk fibroin nanofiber dressings compounded with natural extracts

Biological extracts obtained from animals and plants, such as essential oils, enzymes, and honey, possess advantages such as safety, affordability, and eco-friendliness. Additionally, these biological extracts typically exhibit inherent antibacterial, antiviral, anti-inflammatory, and antioxidant properties. Therefore, incorporating these biological extracts into silk-based wound dressings will impart the dressings with superior anti-inflammatory and wound healing-promoting functionalities.

Oregano essential oil (OEO) is a promising natural compound with excellent antibacterial, antioxidant, and anti-inflammatory activities [25]. Khan et al. [26] encapsulated OEO in poly (L-lactide-co-caprolactone) (PLCL)/silk fibroin (SF) nanofiber membranes (NF), overcoming the drawbacks of OEO's instability and volatility, achieving an encapsulation efficiency as high as 59.14 ± 0.58 (%). Furthermore, the potential for in vivo wound healing of the nanofiber membrane was evaluated. Results confirmed that nanofiber membranes prepared with 5% OEO concentration could completely inhibit bacterial growth, with inhibition rates reaching 100 ± 0.61 for Staphylococcus aureus and 98.02 ± 0.34 for Escherichia coli, while also accelerating wound healing, making it a potential candidate for wound dressings.

Fenugreek is a natural antioxidant. Selvaraj S et al. [27] combined fenugreek with silk fibroin using electrospinning to prepare fenugreek-silk fibroin nanofiber dressings and applied them to rat wounds. The results showed that silk fibroin fenugreek nanofibers could achieve re-epithelialization, enhance collagen deposition, and accelerate wound healing. Additionally, the antioxidant properties of the nanofiber pads were studied through DPPH assay. DPPH is a stable free radical that exhibits maximum absorption at 517 nm. DPPH radicals are neutralized by accepting electrons or hydrogen atoms. As the concentration of fenugreek increased, the DPPH clearance efficiency also increased. Silk fibroin nanofibers exhibited 5.6% antioxidant properties, while when mixed with fenugreek at a ratio of 1:1, they exhibited 49.3% antioxidant properties. This indicates that combining fenugreek with silk fibroin nanofibers can enhance the antioxidant properties of silk protein nanofiber dressings, facilitating better wound repair.

Basal, G et al. [28] incorporated polyphenols extracted from olive leaf extract (OLE) into nanofibers made of a mixture of hyaluronic acid and cellulose, and prepared a silk protein nanofiber mesh using co-axial electrospinning. OLE imparts potent antibacterial, antifungal, and antiviral properties as well as excellent antioxidant activity to the nanofiber. SF provides it with certain mechanical properties and biodegradability, making it an efficient wound dressing.

### 3.1.2. Silk fibroin nanofiber dressings compounded with polymeric materials

Compared to natural extracts, people can regulate the different components of polymeric materials to impart various properties to silk-based nanofiber dressings, including antibacterial, anti-inflammatory properties, and drug release.

XU et al. [29] prepared a novel biodegradable multifunctional nanofiber membrane using SF, PLCL, and CPL via electrospinning. The results showed that the SP/CPL nanofiber membrane exhibited good hydrophilicity and degradation properties. Additionally, the appropriate addition of CPL significantly enhanced its mechanical properties in wet conditions and promoted NIH-3T3 cell compatibility. Moreover, the SP/CPL nanofiber membrane effectively promoted the growth of fibroblast cells, and its inhibitory effects on Escherichia coli and Staphylococcus aureus increased with the concentration of CPL. Importantly, in vivo studies demonstrated that the SP/CPL-1.5 nanofiber membrane played a significant role in wound healing in diabetic mice, particularly by enhancing the TGF-β signaling pathway and promoting the formation of myofibroblasts in diabetic mouse wounds. Furthermore, the SP/CPL composite nanofiber membrane reduced wound inflammation, downregulated the expression of IL-1β and TNF-α inflammatory genes, and promoted wound healing.

MK et al. [30] utilized electrospinning technology to fabricate silk fibroin/polyvinyl alcohol (PVA)/reduced graphene oxide (RGO)/ZnO NPs nanofibers, demonstrating that the synthesized material could inhibit the growth of Staphylococcus aureus and Escherichia coli, exhibit good biocompatibility, and promote the proliferation and migration of NIH 3T3 fibroblast cells. Moreover, treating rats with these silk fibroin nanofibers showed significant wound healing activity and tissue regeneration. Therefore, this study suggests that SF/PVA/RGO/ZnO NPs nanofibers hold promise as wound dressings for preventing bacterial growth and promoting wound repair.

### 3.1.3. Functionalized silk fibroin nanofiber dressings as drug carriers

Peng Y et al. [31] utilized electrospinning to fabricate PLGA/SF/ART (artemisinin) fiber membranes, leveraging PLGA for robust mechanical properties and SF for enhanced biocompatibility and drug release capabilities. With SF's aid, ART, an anti-inflammatory agent, was loaded onto the membrane, ensuring sustained drug release, with cumulative ART release reaching 69% after three weeks. In vitro evaluations demonstrated that the PLGA/SF/ART membrane exhibited excellent anti-inflammatory properties and cell compatibility. Khan et al. [32] incorporated silver into SF nanofibers to confer antimicrobial properties and enhance their applicability. Compared to the original nanofibers, the addition of Ag increased the charge density in the polymer solution, resulting in finer fibers. Furthermore, Ag addition inhibited the growth of microorganisms, providing the necessary antimicrobial activity for SF nanofibers in tissue engineering.

### 3.2. Silk fibroin hydrogel dressings

Hydrogels are a class of hydrophilic polymer materials with a three-dimensional network structure, typically formed by chemical or physical crosslinking of polymers, exhibiting properties similar to the extracellular matrix. Hydrogels can provide a moist healing environment for wounds, as well as advantages such as breathability, absorption of tissue exudates, and self-dissolving wound cleansing [33]. Crosslinking methods for hydrogels include physical and chemical crosslinking. Physical crosslinking methods include temperature and pH-mediated self-assembly, ultrasound, and electric fields. Chemical crosslinking methods include chemical crosslinking agents, photopolymerization, γ irradiation, and enzyme crosslinking [34]. Silk fibroin (SF) possesses cell adhesion and proliferation capabilities, along with excellent hydrophilicity, cell compatibility, and biodegradability, making it widely used in wound repair and other fields. However, pure SF hydrogels have limited functionality and may not effectively promote wound healing. Nowadays, most SF hydrogel dressings used for wound care are composite hydrogels. SF composite hydrogels are composed of SF and natural or synthetic polymers, which can impart anti-inflammatory, antimicrobial, and other properties to silk-based hydrogels, thereby preventing wound infections and promoting better wound healing.

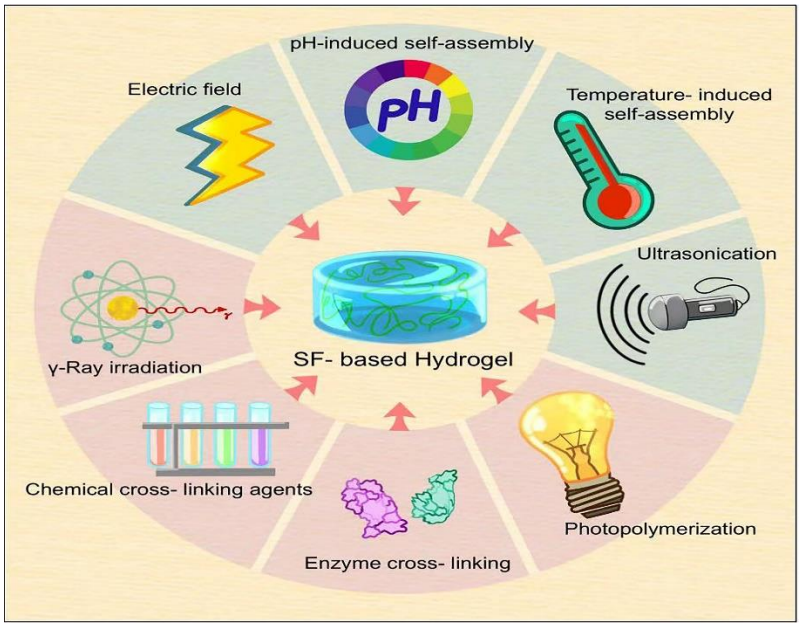


**Figure 2.** Preparation methods of silk fibroin hydrogel [34].

#### 3.2.1. Silk fibroin hydrogel with anti-inflammatory effects

Zahoor,S et al. [35] combined silk fibroin hydrogel with extracts rich in fig and onion, and topically applied it to diabetic wounds. The results showed that compared to untreated diabetic controls, all hydrogel-treated groups had significantly higher wound contraction rates from day 3 to day 11 ($P < 0.001$). Serum levels of anti-inflammatory cytokine interleukin-10 and tissue inhibitor of metalloproteinases (TIMP) were significantly higher ($P < 0.001$). This indicates that silk-based hydrogel enriched with fig and onion extracts can serve as an effective treatment for diabetic wounds, with anti-inflammatory effects.

Y U et al. [36] developed an injectable hydrogel based on host-guest interactions and hydrophobic beta-sheet double crosslinking using silk fibroin, acryloyl-β-cyclodextrin, and hydroxyethyl acrylate. This SF based hydrogel was confirmed to be dually cross linked by host-guest interaction and hydrophobic beta-sheet conformation, and demonstrated improved mechanical properties, long-term stability, rapid self-healing behavior, injectability, and good biocompatibility, benefiting its application as wound dressing. By utilizing the inclusion complexation of β-cyclodextrin, curcumin with antioxidant and anti-inflammatory activities can be loaded into it. Curcumin is not prone to burst release initially, exhibiting prolonged and sustained drug release behavior, thereby increasing granulation tissue thickness, collagen disposition, upregulating vascular endothelial growth factor

(VEGF), and reducing inflammation response in full-thickness skin defect models. Meanwhile, the good mechanical properties and biocompatibility of silk fibroin ensure the long-term stability of the hydrogel in vivo, thereby enhancing wound healing outcomes.

YIN et al. [37] introduced Rhein, which has anti-inflammatory functions, into silk fibroin hydrogel through chemical crosslinking, resulting in a silk/Rhein composite hydrogel. The SF/Rhein hydrogels showed fibrous network nanostructure, high water content (~90%), high water adsorption ability (>2 folds of its own weight), acceptable mechanical strength, biocompatibility and antibacterial properties, suitable as dressings for the treatment of bacterial infected wounds. This composite hydrogel can enhance the stability and structural integrity of Rhein, thus significantly reducing wound inflammation and effectively rebuilding neovascularization and epidermis in wound repair experiments.

Hyung Woo Ju et al. [38] simply mixed calcium alginate, carboxymethyl cellulose, and SF to prepare a novel silk fibroin-based hydrogel for burn-induced wounds. The results showed that SF-based hydrogels are excellent materials for treating second-degree burns, mitigating the inflammatory response in most wounds. In another study [39], when chitosan-based hydrogels were loaded with SF and L-Proline, they improved cell adhesion and proliferation. The prepared hydrogels outperformed other polymers and could potentially serve as alternative wound dressings for chronic diabetic or burn wounds.

#### 3.2.2. Silk fibroin hydrogel with antibacterial properties

Zahra et al. [40] prepared a novel hydrogel dressing for inhibiting bacterial infection in wounds by combining silk fibroin with sodium alginate loaded with antibacterial curcumin nanoparticles (Cur-NP). In vitro tests demonstrated that the hydrogel effectively inhibited the growth of Escherichia coli and Staphylococcus aureus, while exhibiting high biocompatibility and promoting cell growth and proliferation. Chen et al. [41] physically cross-linked silk fibroin with carboxymethyl chitosan (CMCS) via hydrogen bonds to form SF-CMCS hydrogel. CMCS, a chitosan derivative, possesses antibacterial, moisturizing, and antioxidant properties. In vitro, the hydrogel exhibited water retention, stability, and antibacterial characteristics. In vivo, it promoted the formation of granulation tissue and wound closure in full-thickness skin lesions in mice. Mazurek et al. [42] incorporated silver nanoparticles with potent antibacterial properties into silk fibroin hydrogel dressings and applied them to wounds in male rats to study the effectiveness of nano-silver-loaded silk fibroin (NSF) gel in promoting wound healing. The results showed that compared to pure SF gel, NSF gel exhibited excellent antibacterial properties and superior wound healing capabilities.

### 3.3. Other silk fibroin wound dressings

In addition to nanofiber and hydrogel types, other silk fibroin wound dressings include membrane, sponge, and ointment types.

#### 3.3.1. Membrane-type silk fibroin dressings

Membrane-type silk fibroin dressings can be prepared by casting method, generally with good transparency but relatively poor breathability. For instance, BAI et al. [43] prepared a transparent composite membrane by casting silk fibroin and polyvinyl alcohol. By adding sodium chloride as a template, the porosity and breathability of the composite membrane can be effectively controlled. Studies have found that this composite membrane has certain antibacterial and anti-inflammatory functions. When an appropriate amount of tea tree oil is added, the composite membrane can more significantly inhibit lipopolysaccharide-induced macrophage production of NO, and the antibacterial proportion is significantly increased.

#### 3.3.2. Sponge-type silk fibroin dressings

Sponge-type silk fibroin dressings have a porous structure, resulting in excellent water absorption and breathability. They can absorb a large amount of exudate, keep the wound dry, and facilitate oxygen entering the wound, promoting healing and tissue regeneration. However, due to their low

strength and high production costs, they have not been widely used. SF sponges can be produced from SF solutions through freeze-drying, direct foaming, templating, and electrospinning deposition methods. Kang et al. [44] developed a SF-alginate mixed sponge and evaluated its effects on wound healing in a rat model. The results showed that compared to other treatments including SF or alginate alone, SF/alginate mixed sponges could better induce wound healing. Due to faster proliferation of epithelial cells and enhanced deposition of collagen, increased fibroblast proliferation may contribute to better epithelialization. It may have clinical implications for skin wound treatment.

### 3.3.3. Foam-type silk fibroin dressings

Foam-type silk fibroin dressings are typically prepared by freeze-drying. Their advantages lie in their porous structure, which allows for the absorption of a large amount of tissue exudate and good breathability; additionally, they can inhibit microbial invasion. Bai et al. [45] mixed degummed silk solution with a certain amount of Gastrodia elata extract and ethanol, then freeze-dried it to obtain silk-based foam dressings with a porosity ranging from 40% to 80%. This foam dressing exhibits combined anti-inflammatory effects of Gastrodia elata and silk, and its ability to promote diabetic wound healing is comparable to that of commercial neomycin ointment.

## 4. Conclusion

Wound healing is a complex process involving interactions among many cells and matrices. Silk fibroin possesses hemostatic, anti-inflammatory, angiogenic, and epithelialization properties, accelerating the wound repair process. Currently, the application of silk fibroin as a biomaterial in wound repair has been extensively researched.

While acknowledging the value of silk fibroin-based wound dressings, existing issues and future directions also warrant serious consideration. (1) Wound healing is a complex dynamic process, influenced not only by inflammation but also by issues such as bacterial infection and exudate management. Therefore, incorporating antimicrobial and exudate management functionalities into silk fibroin-based dressings will better meet practical application needs. (2) In the treatment of some specific wounds, the efficacy and safety of silk fibroin have not been clinically proven, and functionalized treatment has not been fully realized. For example, in the treatment of pressure injuries, the pressure resistance, breathability, and efficacy of silk fibroin-based dressings have not been demonstrated. Pressure injuries are common hospital-acquired injuries, especially in patients who are bedridden or have limited mobility. Prolonged pressure can damage the skin and tissues, leading to necrosis in severe cases. Therefore, further improvement is needed in the treatment of some specific wounds using silk fibroin-based dressings to meet the diverse needs of wounds and achieve complete wound repair functionality. (3) In recent years, with the development of smart materials, there is increasing attention to the development of intelligent biological dressings to achieve timely treatment. For example, when the level of destructive cytokines in the wound environment rises, smart biological dressings need to be able to deliver bioactive compounds to the wound site and actively interact with the wound environment. Additionally, smart biological dressings can monitor wounds and surrounding environments by analyzing physiological signals from wound exudates in real-time. However, in clinical practice, these functional dressings still face many challenges. Future research could combine bioactive silk fibroin dressings with smart dressings to further achieve intelligence on the basis of functionalization, namely dynamic interaction with the wound environment and real-time visualization monitoring of wounds. This approach holds promise for providing a novel solution for clinical repair treatment of trauma wounds.

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