Nanotechnological Based Efficient Wound Dressing Silk Fibrous Proteins

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Compared to other often used wound dressing materials like films and sponges, nanofibers are one-dimensional (1-D) nanomaterials that have a bigger surface area, are more porous, and have superior gas permeability. As a result, they are important for wound care and management. Because of these characteristics, the nanofibers can speed up wound healing by encouraging skin regeneration, retaining moisture, and eliminating exudates from wounds. Many different materials, such as synthetic and natural polymers, can be used to create nanofibers. Fibrous proteins such as collagen and silk fibroin are important components of natural polymers used in skin tissue engineering. Fibrous proteins are distinct biomaterials mostly due to their highly repeated amino acid sequence, which allows them to carry out the majority of mechanical and architectural tasks seen in nature. The creation of nanofibers from fibrous proteins is the main goal of this endeavour.

Keywords: public health, Nano technology, Nano fibers.

1. Introduction

The skin is the largest organ system in the human body, making up 15% of an adult's total weight and consisting of three primary layers. Skin is often subjected to several traumas from the external environment because of its defensive nature. Damage to the skin's natural anatomical structure and function is referred to as a wound. Skin wounds can be as minor as a crack in the epithelium or as severe as a wound that extends to the subcutaneous tissue and damages surrounding structures such as muscles, tendons, and bone [1]. When an acute or chronic injury causes skin damage, a series of events known as wound healing is set off, leading to the contraction and closure of the wound as well as the restoration of the skin's barrier function. The remarkable physical and chemical characteristics of nanomaterials, which include 1-D (nanofibers, nanowires, nanorods, and nanotubes), 2-D (nanosheets), and Zero Dimensional (0-D) (nanoparticles, quantum dots) nanomaterials, make them fascinating. Because of their special qualities, one-dimensional nanostructures, or 1-D nanostructures, find use in a wide range of industries [9]. One-dimensional nanomaterials called nanofibers have exceptional qualities over all other known forms of material, including a very high surface to volume ratio, flexibility in surface functions, and excellent mechanical properties (stiffness and tensile strength). Figure 1 displays an image captured by a scanning electron microscope (SEM) of polyvinyl alcohol (PVA) nanofibers.

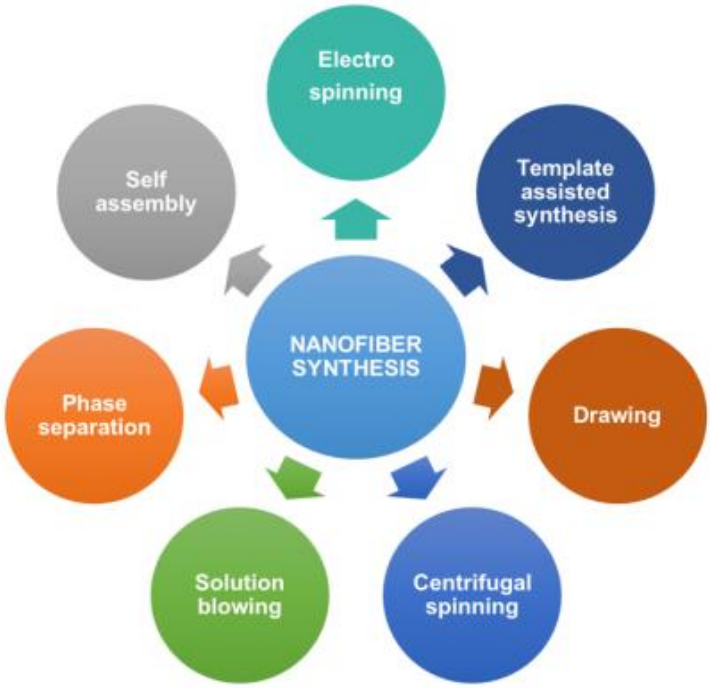

Figure 1 Different strategies used for the preparation of nanofibers

Nanofibers can be generated using a variety of techniques, such as centrifugal spinning, electrospinning, phase separation, drawing, self-assembly, and template-assisted synthesis [10]. The most well-known and widely used of them is electrospinning since it is straightforward, continuous, flexible enough to use a wide range of polymers (both synthetic and natural), and offers excellent control over the shape and orientation of nanofibers [2].

In this instance, section 1 of the article examines the introduction, while section 2 examines the application of nanofibers. The purpose of the nano structured material is explained in Sections 3, and the project is concluded in Section 4.

2. Applications of Nanofibers

Numerous materials, such as carbon-based nanomaterials, synthetic and natural polymers, semiconducting and composite nanomaterials, and carbon-based nanomaterials, are used to make nanofibers [12]. They are extensively employed in three key fields: energy generation and storage (solar cells, batteries and fuel cells, piezoelectricity, super capacitors, hydrogen storage and generation), water treatment and environmental remediation (chemical and gas sensing, photocatalysis, water treatment and ultrafiltration), and healthcare (tissue engineering and regenerative medicine, wound dressing, drug and therapeutic agent delivery, biological sensing) [3][5]. Due to their special qualities, including a high surface to volume ratio, more surface available for drug loading, an Extracellular Matrix (ECM) that mimics nature, and the ability to promote the adhesion of different cell types, they are superior candidates in biomedical applications such as wound care, burn care, medical implants, drug delivery vehicles, biomimetic actuators, enzyme immobilisation scaffolds, and organ repair [4]. Preparing the nanofibers for use in biomedical applications requires the use of biocompatible and biodegradable polymers.

Nanofibers' extracellular matrix-mimicking nature makes them one of the most promising options for wound treatments. The numerous phases of the wound healing process are aided by the high surface to volume ratio, high porosity, and mechanical strength of the nanofibers. Because of the nanofibers' high porosity, which permits gas exchange, wound dehydration is prevented. A large surface area makes it easier to absorb wound exudate effectively [11]. Because of their large surface area, the nanofibers can also be combined with bioactive substances such as growth factors, angiogenic factors, antioxidant, antimicrobial, and anti-inflammatory compounds. These substances can then interact with the surface of the wound to promote tissue regeneration and improved cellular behaviour. Figure 2 below describes the characteristics of nanofibers that make them good candidates.

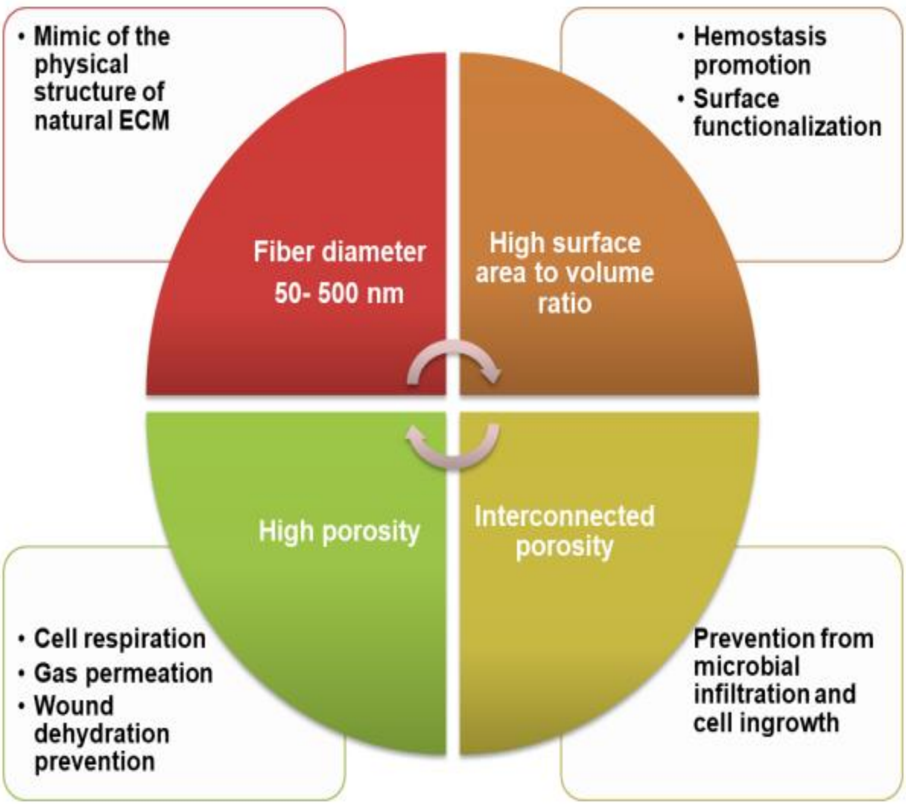

Figure 2 Advantages of nanofibers as wound dressings

High levels of biocompatibility and biodegradability are exhibited by natural biopolymers such proteins and polysaccharides. They have inherent bioactivity and come from natural resources. Biopolymer-prepared nanofibers have a surface topography and structure similar to that of the ECM. This facilitates the restoration of tissue function more quickly. While keratin and silk fibroin have biomolecule binding domains and cell recognition sites, proteins like collagen and gelatin provide support for extracellular matrix (ECM). Chitosan and alginates are examples of natural polysaccharides with antibacterial and anti-inflammatory properties.

3. Significance of Silk Fibrous Proteins

Generally speaking, fibrous proteins have a lengthy, drawn-out structure. They are made up of extremely repeated sequences of amino acids, which significantly contribute to the secondary structure's homogeneity. In nature, globular proteins mostly perform catalytic and molecular recognition tasks, whereas fibrous proteins primarily perform mechanical and architectural tasks [6]. Fibrous proteins are perfect for biomedical applications because of their superior mechanical qualities, stability, and biocompatibility. In globular proteins, single folded chains can perform desired activities like catalysis and recognition, but in fibrous proteins, inter- and intra-chain interactions are necessary to accomplish the desired structure-function.

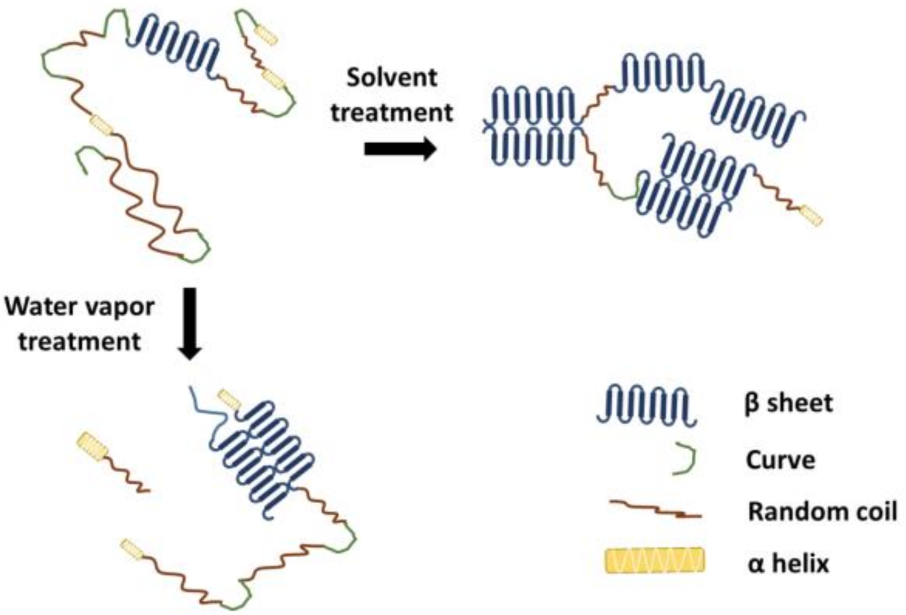

Figure 3 Schematic representation depicting structural changes induced by methanol vapor or water vapor

The morphology of silk fibres is core-shell, with the glue-like protein sericin forming the outer layer and fibroin making up the inner layer. The sericin shell is between 0.5 and 2 μm thick, and the fibroin core is made up of two triangular-shaped filaments. Silk fibroin is superior to other natural polymers in that it has readily accessible chemical groups that allow for functional changes, high mechanical qualities, outstanding biocompatibility, water-based manufacturing, and biodegradability. Silk has a ten-fold better strength-to-density ratio than steel and is stronger than Kevlar, the strongest synthetic fibre. The XIV protease enzyme is responsible for the degradation of silk, and the resulting byproducts are readily metabolised by humans [7].

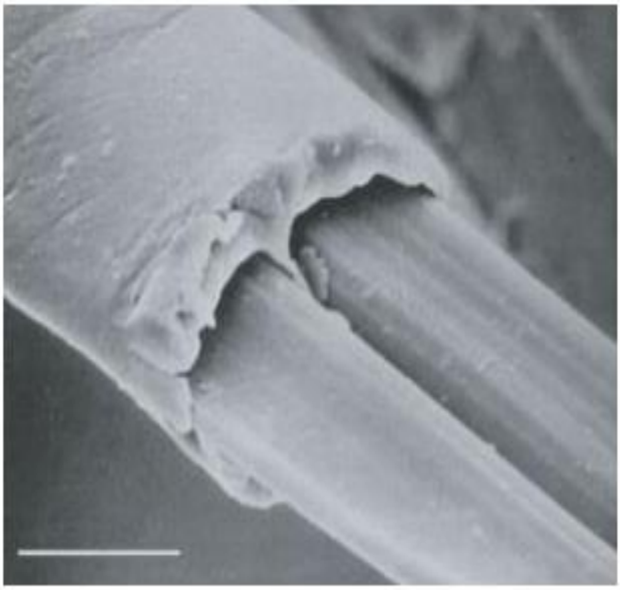

Figure 4 SEM image of silk fiber before degumming

It is possible to adjust the rate of degradation by modifying the processing methods. The composition of the β-sheet determines the pace of degradation. Aqueous solutions can be used to treat silk, allowing for the fabrication of films and sponges, among other materials [8–10]. When exposed to alcohols, silk becomes insoluble; however, it is possible to genetically modify silk to achieve the correct molecular weight, crystallinity, and solubility. Silk fibroin enhances the adhesion, proliferation, and development of several cell types, demonstrating good compatibility with biological systems.

4. Conclusion

The length of time it takes for wounds to heal in wound treatment depends on the type of wounds and how well the dressing is applied. Because plant-based compounds have a wide range of active ingredients, including phenolic compounds, essential oils, fatty acids, and flavonoids, as well as being readily available, inexpensive, bioavailable, and having few side effects, they can be helpful in increasing the effectiveness of wound dressings. Promising properties such as antioxidant, anti-inflammatory, antibacterial, and anti-cancerous properties are demonstrated by the active components in plant extracts. These active ingredients have the potential to be therapies that improve the effectiveness of wound healing when used in wound dressings. By combining them into nanostructures or shrinking them to the nano range, their effectiveness can be further enhanced.

References

1. Kumar, Vinay, Amit Kumar, Narendra Singh Chauhan, Govind Yadav, Mayank Goswami, and Gopinath Packirisamy. "Design and fabrication of a dual protein-based trilayered nanofibrous scaffold for efficient wound healing." ACS Applied Bio Materials 5, no. 6 (2022): 2726-2740
2. Bhattacharya, Debalina, Biva Ghosh, and Mainak Mukhopadhyay. "Development of nanotechnology for advancement and application in wound healing: a review." IET nanobiotechnology 13, no. 8 (2019): 778-785.
3. Lehmann, Tanner, Alyssa E. Vaughn, Sudipta Seal, Kenneth W. Liechty, and Carlos Zgheib. "Silk fibroin-based therapeutics for impaired wound healing. Pharmaceutics 14, no. 3 (2022): 651.
4. Yang, J. (2013). The Theory of Planned Behavior and Prediction of Entrepreneurial Intention Among Chinese Undergraduates. Social Behavior and Personality: An International Journal, 41(3), 367–376. https://doi.org/10.2224/sbp.2013.41.3.367.
5. Ataide, Janaína A., Beatriz Zanchetta, Érica M. Santos, Ana Laura M. Fava, Thais FR Alves, Letícia C. Cefali, Marco V. Chaud, Laura Oliveira-Nascimento, Eliana B. Souto, and Priscila G. Mazzola. "Nanotechnology-based dressings for wound management." Pharmaceuticals 15, no. 10 (2022): 1286.
6. Alamer, L., Alqahtani, I. M., & Shadadi, E. (2023). Intelligent Health Risk and Disease Prediction Using Optimized Naive Bayes Classifier. Journal of Internet Services and Information Security, 13(1), 01-10.
7. Zarrintaj, Payam, Abolfazl Salehi Moghaddam, Saeed Manouchehri, Zhaleh Atoufi, Anahita Amiri, Mohammad Amir Amirkhani, Mohammad Ali Nilforoushzadeh, Mohammad Reza Saeb, Michael R. Hamblin, and Masoud Mozafari. "Can regenerative medicine and nanotechnology combine to heal wounds? The search for the ideal wound dressing." Nanomedicine 12, no. 19 (2017): 2403-2422.
8. Zhang, Shuangshuang, Syed Atta-ul-Mubeen Shah, Kanta Basharat, Sarmad Ahmad Qamar, Ali Raza, Abdullah Mohamed, Muhammad Bilal, and Hafiz MN Iqbal. "Silk-based nano-hydrogels for futuristic biomedical applications." Journal of drug delivery science and technology 72 (2022): 103385.
9. Agarwal, Anushka, Gyaneshwar K. Rao, Sudip Majumder, Manish Shandilya, Varun Rawat, Roli Purwar, Monu Verma, and Chandra Mohan Srivastava. "Natural protein-based electrospun nanofibers for advanced healthcare applications: progress and challenges." 3 Biotech 12, no. 4 (2022): 92.
10. Ozyilmaz, A. T., & Bayram, E. I. (2023). Glucose-Sensitive Biosensor Design by Zinc Ferrite (ZnFe2O4) Nanoparticle-Modified Poly (o-toluidine) Film. Natural and Engineering Sciences, 8(3), 202-213.
11. Patil, Priyanka P., Michaela R. Reagan, and Raghvendra A. Bohara. "Silk fibroin and silk-based biomaterial derivatives for ideal wound dressings." International journal of biological macromolecules 164 (2020): 4613-4627.
12. Farokhi, Mehdi, Fatemeh Mottaghitalab, Yousef Fatahi, Ali Khademhosseini, and David L. Kaplan. "Overview of silk fibroin use in wound dressings." Trends in biotechnology 36, no.

9 (2018): 907-922.

13. Zhang, Dongdong, Linpeng Fan, Linlin Ma, Junqiu Liu, Kai Zhou, Xinran Song, Meiqi Sun et al. "Helicobacter pylori ribosomal protein-A2 peptide/silk fibroin nanofibrous composites as potential wound dressing." Journal of biomedical nanotechnology 15, no. 3 (2019): 507-517.