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A Brief Review of Electrospun Nanofibers as Drug Carriers, Discussing Loaded Drugs and the Biopolymers Used as Supporting Matrices.

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Abstract: *Electrospinning is recognized as an innovative and advantageous technique for polymer nano fiber fabrication. Its combination of operational simplicity and economic efficiency makes it a vital tool for both industrial scaling and academic exploration. The process yields non-woven membranes characterized by remarkable surface-to-volume ratios and high porosity. These scaffolds are further defined by their mechanical robustness, structural stability, and the ease with which they can be chemically functionalized for specialized applications. The adaptability of nanofiber synthesis allows for the precise tailoring of materials to address challenges across multiple disciplines, ranging from sustainable energy and biotechnology to clinical healthcare and environmental remediation. The recent progress and significant role of electro spinning in the biomedical field particularly in tissue regeneration, therapeutic release, and wound management are thoroughly evaluated here. In addition to identifying procedural limitations and ongoing scientific challenges, this work provides strategic insights into the trajectory of this fabrication technology for future medical applications.*

Keywords: Biopolymers, electrospinning, nanofibers, drug release, fast release, controlled release

1. Introduction

The integration of nanotechnology into pharmaceutical sciences has revolutionized drug delivery by enhancing treatment effectiveness, reducing adverse reactions, and allowing for the precise, regulated release of medications [1, 2]. As a leading technique for polymer fabrication, electrospinning offers a simple yet effective way to produce continuous nanofiber films. These fibers, ranging from micro to nanoscale in diameter, possess unique physical characteristics specifically engineered through the electrospinning process [3,4]. Electrospun nanofibers are excellent candidates in filtration, drug delivery systems, in separation membranes, as reinforcement in composite materials and medical devices, as well as in biomaterials for wound

dressings and scaffolds for tissue engineering [5]. By utilizing a shared solvent system, the electrospinning process can produce fibers from a variety of hydrophilic and hydrophobic polymer combinations. The synergy between synthetic and biological polymers yields nanofibers with superior surface area, opening new possibilities for targeted drug delivery**,** wound healing, and tissue engineering [6]. A primary objective in drug delivery involves the controlled release of essential biomolecules through the rapid dissolution of biodegradable polymers. This method is advantageous as it enhances both the solubility and bioavailability of the drug while allowing for precise control over delivery rates and locations. While traditional enteral (tablets, capsules) and parenteral (intravenous, subcutaneous) systems are common, they often suffer from drawbacks such as first-pass metabolism and patient discomfort [7].The versatility of synthetic and biological hybrid nanofibers makes them ideal for modern medicine. Their high surface-area-to-volume ratio

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improves drug encapsulation, while their tunable structure provides a reliable method for controlling the timing and rate of medication release [8-18].

1.1. Electrospinning Process

Fiber fabrication typically involves passing a polymer solution (wet spinning) or a melt (dry spinning) through a spinneret, where it is mechanically elongated and deposited onto a substrate. During this procedure, solvents are eliminated via evaporation, post-processing, or precipitation in a specialized bath. While various forces can drive the stretching of the polymer, electrospinning specifically utilizes electrostatic tension generated by a high-voltage source as its primary driving mechanism [19].The application of electrical voltage initiates the movement of free charges, which acts as the driving force for the polymer solution's flow. The successful creation of electrospun nanofibers is primarily governed by the solution's surface tension, viscoelasticity, and charge density. While the final morphology and diameter of the fibers are determined by both processing and solution variables, high-viscosity polymeric solutions are preferred to ensure fiber continuity through molecular interactions. Although jet instability can lead to the formation of beaded fibers, this can be corrected by increasing viscosity or refining other parameters to produce smooth, bead-free strands. Additionally, the process allows for the integration of various additives to create functionalized nanofibers [20-22].

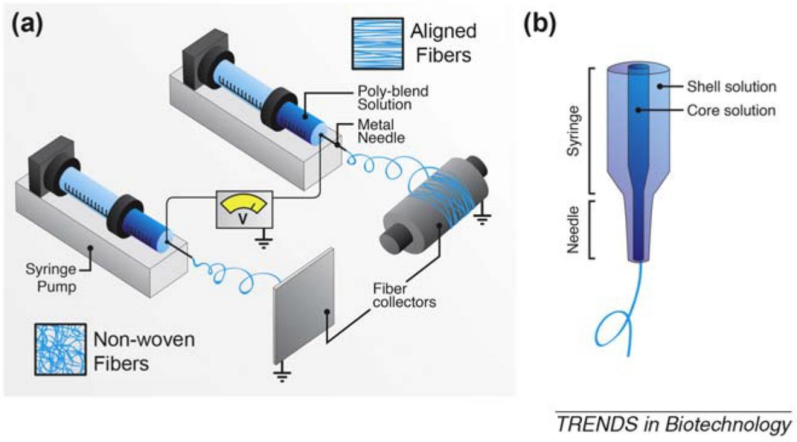

Figure 1. Electrospinning apparatus: (a) Collection Methods and Fiber Alignment Nonwoven Mats: polymer fibers are collected on a stationary flat surface, Aligned Fibers: By using a rotating spindle (drum)(b) Coaxial Electrospinning for Core-Shell Structures [17].

II. BIOMEDICAL APPLICATIONS OF DRUG LOADED NANOFIBERS

By mimicking the biological function of the extracellular matrix (ECM), electrospun nanofibers provide a superior platform for wound care. Their skin-like tensile strength and flexibility make them ideal for clinical use, as they foster a microenvironment where cells can effectively attach, grow, and specialize [23-28].Fiber architecture is essential for tailoring nanofibers to specific manufacturing needs. By optimizing electrospinning setups, including solvent types and electrical potential, researchers can control fiber morphology. This optimization is crucial for biomedical success, as the resulting structure dictates how well cells attach and proliferate, as well as the polymer's antimicrobial properties[29].The medical field has shown growing interest in nanofibers made from biocompatible polymers due to their unique structural advantages and flexibility as drug carriers. By utilizing diverse electrospinning techniques, researchers have developed both Natural and synthetic polymer systems that provide precise controlled-release functionality [30].

Electrospun nanofibers support biological functions by allowing for the diffusion of oxygen and nutrients and the disposal of metabolic waste, alongside the delivery of biofactors like proteins and genes. Their morphology ranging from hollow

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fibers to 3D scaffolds can be precisely tuned during the fabrication process. Consequently, these materials are ideal for tissue engineering and advanced pharmaceutical delivery [31].

2.1. Wound Dressing

The advantages of nanofibrous wound dressings over traditional solid films stem from the unique structural properties of electrospun NFs. By manipulating the fabrication parameters, researchers can achieve a high surface-area-to-volume ratio and enhanced porosity, which are critical for effective healing [32-34].Wound healing is a sophisticated and dynamic biological process characterized by four distinct yet highly integrated phases. Although these stages—hemostasis, inflammation, proliferation, and remodelingare often described as a linear sequence, they frequently overlap in a coordinated effort to restore tissue integrity [35,36].

2.1.1. The Four Phases of Repair

Hemostasis (Immediate): The body's primary objective is to stop bleeding. This involves rapid vasoconstriction and the formation of a fibrin clot, which serves as a temporary protective "plug" and a foundation for incoming repair cells [37].
Inflammation (Days 1–4): Once the bleeding is controlled, the body focuses on cleaning the wound site. Neutrophils and macrophages migrate to the area to neutralize bacteria and remove cellular debris, preparing the environment for new growth.Proliferation (Days 4–21): During this "rebuilding" phase, the wound is filled with new tissue. Key activities include angiogenesis(forming new blood vessels), granulation (depositing collagen), and epithelialization (skin cells migrating across the wound surface) [38,39].
Remodeling (Months to Years): The final maturation stage involves the reorganization of collagen fibers. The initial, disorganized tissue is replaced by a more structured matrix, increasing the wound's tensile strength and gradually fading the appearance of the scar [40,41].

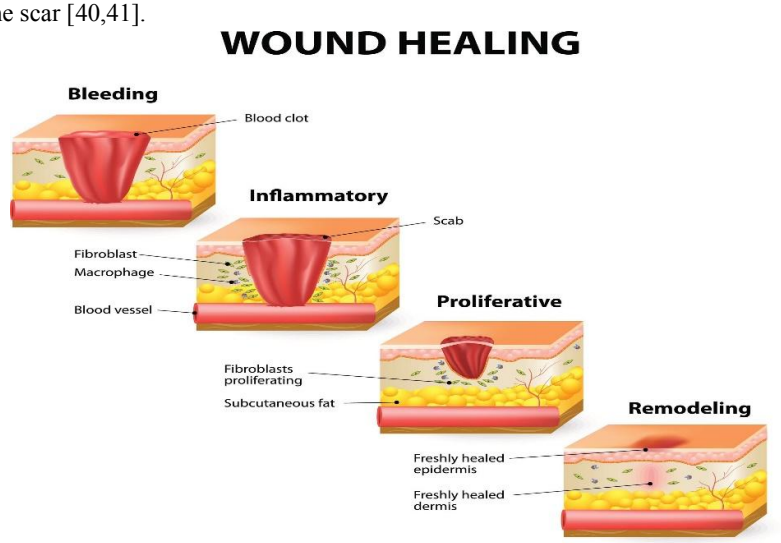

Fig.2 Stages of wound healing [40,41]

2.2. Diabetes and Obesity

Using polymeric microneedles (MNs) represents a highly effective and innovative strategy for administering treatments for diabetes and obesity. A primary benefit of using polymers is their biocompatibility (BC) and biodegradability (BD), which allow the needles to dissolve safely within the skin while releasing the medication.Obesity stems from an accumulation of white adipose tissue (WAT), but converting this into energy-burning brown fat can effectively reduce it [42]. Because traditional drug delivery methods often fail to treat obesity efficiently, researchers like Than et al. developed transdermal (TD) patches featuring detachable, dissolving microneedles (MNs) These microneedles were created using PDMS (poly(dimethylsiloxane)) molds and a combination of PLGA and Hyaluronic Acid (HA) polymers.

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The needles were loaded with the drug CL316243 and a tracking agent called Cyanine5. When tested on obese mice, this system successfully delivered the medication through the skin, triggering the conversion of white fat to brown fat and proving to be a highly effective treatment met [43,44].

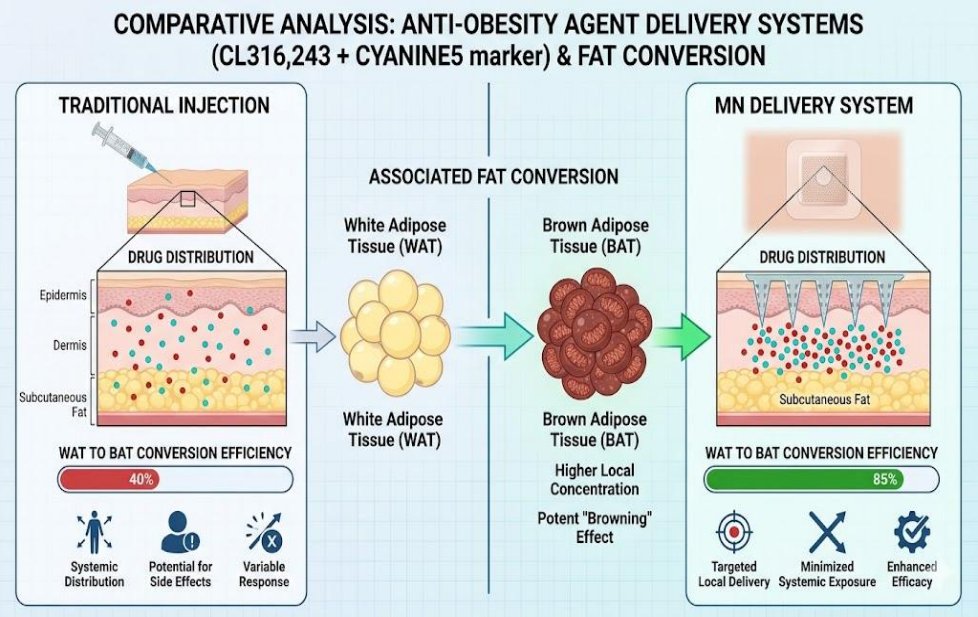

Fig.3. The comparison between traditional injections and Microneedle (MN) systems for delivering anti-obesity agents (CL316,243 and Cyanine 5) highlights significant differences in therapeutic efficiency and fat conversion [43,44].

2.3. Drug delivery

The use of electrospun fibers for drug delivery has gained significant attention due to their unique physical properties. When these fibers are produced using a single-nozzle setup, the resulting structure has an exceptionally high surface area-to-volume ratio. This high surface area means that a large portion of the medication remains at or near the fiber's exterior. Consequently, when the fibers come into contact with a solvent or bodily fluid, they often undergo a burst releasea phase where a massive amount of the drug is discharged almost instantly at the start of the delivery process [45]

Core Mechanisms of Single-Nozzle Fibers

Surface Concentration: Because the drug and polymer are mixed and spun from a single source, the drug is distributed throughout the thin fiber. Since the fiber is so thin, "throughout" effectively means "near the surface."

Rapid Dissolution: The increased surface area allows the surrounding fluid to access and dissolve the surface-level medication immediately.

Initial Spike: This "burst" is characterized by a rapid spike in drug concentration, which can be useful for treatments requiring an immediate loading dose, though it can be a challenge for those needing a steady, long-term release [46].

2.4. Protein, DNA, RNA, and Growth Factors

As electrospinning technology has matured, it has become increasingly capable of incorporating a diverse range of bioactive compounds. Beyond simple drugs, researchers are now successfully integrating complex biological molecules such as proteins, DNA, RNA, and growth factors directly into these nanofiber structures. One of the primary obstacles in advanced electrospinning is maintaining the biological integrity and therapeutic potency of the incorporated drugs or

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biomolecules. Because the electrospinning environment is often harsh, ensuring that medications especially sensitive ones like proteins or genetic material remain functional after the fiber is formed is a significant technical challenge. By strategically selecting appropriate biomaterials and fine-tuning the processing parameters, it is feasible to achieve high encapsulation efficiency while preserving the functional integrity of therapeutic agents [47]. Success in advanced drug delivery depends on balancing the physical chemistry of the fiber with the delicate nature of the cargo. To integrate bioactive compounds into nanofibers, researchers typically use either coaxial or blend (mixed) electrospinning. However, the choice of method significantly impacts how effective the medication remains once the fiber is formed [48].

The Challenge of Blend Electrospinning

In blend electrospinning, the therapeutic agents are mixed directly into the polymer solution before spinning. While this is a simpler, one-step process, it often leads to a reduction in bioactivity.

Exposure to Solvents: Sensitive biomolecules (like proteins or DNA) are forced into direct contact with potentially harsh organic solvents used to dissolve the carrier polymer.

Structural Damage: The mixing process can denature delicate proteins, causing them to lose their functional 3D shape.

Surface Migration: During the spinning process, the drug often migrates to the outer surface of the fiber, leading to a "burst release" rather than a controlled, steady delivery.

In a study by Chew et al., researchers successfully encapsulated human nerve growth factor (HNGF) within specialized nanofibers. To stabilize and protect the growth factor, they used Bovine Serum Albumin (BSA) as a carrier protein.

The nanofibers themselves were synthesized from a sophisticated copolymer known as PCLEEP, which is a combination of PCL (polycaprolactone) and poly(ethyl ethylene phosphate).

2.5 Tissue Engineering

Polymeric electrospun nanofibers have become a cornerstone of tissue engineering because they can be engineered to mimic the extracellular matrix (ECM)the natural "scaffolding" that surrounds cells in the human body. By adjusting the polymer type and spinning parameters, researchers create environments that encourage cells to attach, grow, and specialize into specific tissues [49,50]. The development of 3-D scaffolds is a breakthrough in tissue engineering because these structures provide the physical environment necessary for cells to move (migration), multiply (proliferation), and securely attach (adhesion).To achieve these "bio-functional" properties, researchers are increasingly focusing on hybrid composite nanofibers. These systems are considered more promising because they combine the structural strength of synthetic polymers with the biological advantages of natural materials [51-60].

Key Applications by Tissue Type

Tissue Type	How Nanofibers Help	Common Polymers Used
Skin / Wound Healing	Provide a breathable barrier that prevents bacterial infection while allowing oxygen exchange and cell migration.	Collagen, Chitosan, PVA
Bone Regeneration	Fibers are often loaded with hydroxyapatite or growth factors to encourage "mineralization" and bone cell (osteoblast) growth.	PCL, PLA, Silk Fibroin
Nerve Repair	Aligned nanofibers act as physical "tracks" or guides that help regenerating axons grow in the correct direction across a gap.	PCLEEP, PCL, PLGA
Vascular (Blood Vessel)	Creating small-diameter tubes that mimic the elasticity and strength of natural veins and arteries.	Polyurethanes, Elastin

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III. CONCLUSION

Electrospinning is a highly adaptable and efficient method for producing nano- and micro-scale fibers, and it has undergone substantial development since it was first introduced. By precisely adjusting solution characteristics, operational parameters, and environmental factors, it is possible to customize fiber structure, size, and properties according to specific application needs. Owing to its exceptional flexibility, electrospinning has been widely adopted across various disciplines. However, despite its many benefits, achieving large-scale production while preserving uniform fiber quality and consistency remains a significant challenge.

V. CONSTRAINTS

Electrospinning is a highly versatile and effective technique for producing nano- and micro-scale fibers, and it has advanced considerably since its introduction. By carefully adjusting solution properties, processing parameters, and environmental conditions, researchers can control fiber morphology, diameter, and functionality to suit specific applications. Its exceptional adaptability has enabled its use across a wide range of fields. Despite its many advantages, certain **limitations** still exist in scaling up electrospinning for large-scale production while maintaining precise control over fiber characteristics.

The ability to successfully electrospin nanofibers is highly influenced by the viscosity and electrical conductivity of the polymer solution, which differ depending on the material used. Achieving consistent fiber diameter, minimizing defects, enabling continuous collection of single fibers, and effectively processing polymers with difficult properties continue to be significant challenges. Material-related limitations involve selecting appropriate polymer–solvent combinations, managing solutions with high viscosity or sensitivity to temperature, and advancing the development of innovative polymer blends, nanocomposites, environmentally friendly solvents, and bio-based polymers.

ensuring stable encapsulation and achieving well-regulated release behavior remains essential. From a processing perspective, advancements are required in nozzle and equipment design to minimize clogging, improve the efficiency of needleless and multi-jet techniques, promote better fiber alignment and orientation, and achieve accurate deposition using patterned collectors, auxiliary electric fields, and near-field electrospinning. Incorporating in-situ crosslinking, melt electrospinning, and solvent recovery approaches can further improve the stability and sustainability of the fibers. In addition, the use of non-destructive characterization techniques, along with machine learning for process optimization and automated quality control systems, will play a key role in maintaining consistency and enabling large-scale production of high-performance electrospun materials across diverse applications.

VI. FUTURE PERSPECTIVE

This review explores the evolving landscape of biomedical science, with a particular focus on the significant advantages offered by electrospun nanofibers. By shifting away from traditional, less effective fiber production methods, electrospinning has emerged as a distinct and essential fabrication technique for modern medical needs. The limitations of traditional fiber production methods have created a significant demand for more advanced and specialized fabrication techniques. Electrospinning technology has emerged as a transformative solution, offering unique capabilities that are essential for the next generation of biomedical applications. A primary advantage of electrospinning is the seamless integration of therapeutic agents directly into the nanofiber matrix. However, this ease of incorporation brings specific technical hurdles that researchers must overcome to ensure clinical success. The release kinetics of a drug can be finely tuned by adjusting the physical dimensions of the nanofibers, specifically their wall thickness. In the realm of tissue engineering, this structural control allows for the creation of sophisticated 3-D porous scaffolds using polymers that the body can naturally absorb. The physical structure, or morphology, of electrospun nanofibers is specifically engineered to enhance the body's natural healing mechanisms. By providing an expansive network of "docking sites," these scaffolds facilitate the attachment and expansion of new tissue. In summary, electrospun nanofibers are highly regarded as transformative materials for biomedical engineering because they offer a rare combination of functional versatility and

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industrial scalability. Their ability to be "programmed" with specific medical properties, paired with their high continuous production rates, makes them ideal candidates for widespread clinical use.

REFERENCES

1. Wang, W., Lu, K.J., Yu, C.H., Huang, Q.L. and Du, Y.Z., 2019. Nano-drug delivery systems in wound treatment and skin regeneration. *Journal of nanobiotechnology*, *17*(1), p.82.
2. Vinatier, C., Gauthier, O., Fatimi, A., Merceron, C., Masson, M., Moreau, A., Moreau, F., Fellah, B., Weiss, P. and Guicheux, J., 2009. An injectable cellulose□based hydrogel for the transfer of autologous nasal chondrocytes in articular cartilage defects. *Biotechnology and bioengineering*, *102*(4), pp.1259-1267.
3. Habeeb, S., Rajabi, L. and Dabirian, F., 2019. Comparing two electrospinning methods in producing polyacrylonitrile nanofibrous tubular structures with enhanced properties. *Iranian journal of chemistry and chemical engineering*, *38*(3), pp.23-42.
4. Okutan, N., Terzi, P. and Altay, F., 2014. Affecting parameters on electrospinning process and characterization of electrospun gelatin nanofibers. *Food Hydrocolloids*, *39*, pp.19-26.
5. Yang, Q., Li, Z., Hong, Y., Zhao, Y., Qiu, S., Wang, C.E. and Wei, Y., 2004. Influence of solvents on the formation of ultrathin uniform poly (vinyl pyrrolidone) nanofibers with electrospinning. *Journal of Polymer Science Part B: Polymer Physics*, *42*(20), pp.3721-3726.
6. Khil, M.S., Cha, D.I., Kim, H.Y., Kim, I.S. and Bhattarai, N., 2003. Electrospun nanofibrous polyurethane membrane as wound dressing. *Journal of Biomedical Materials Research part B: applied biomaterials: an official journal of the society for biomaterials, the Japanese society for biomaterials, and the Australian society for biomaterials and the Korean society for biomaterials*, *67*(2), pp.675-679.
7. Huang, Z.M., Zhang, Y.Z., Kotaki, M. and Ramakrishna, S., 2003. A review on polymer nanofibers by electrospinning and their applications in nanocomposites. *Composites science and technology*, *63*(15), pp.2223-2253.
8. Zeng, J., Xu, X., Chen, X., Liang, Q., Bian, X., Yang, L. and Jing, X., 2003. Biodegradable electrospun fibers for drug delivery. *Journal of controlled release*, *92*(3), pp.227-231.
9. Sill, T.J. and Von Recum, H.A., 2008. Electrospinning: applications in drug delivery and tissue engineering. *Biomaterials*, *29*(13), pp.1989-2006.
10. Yoo, H.S., Kim, T.G. and Park, T.G., 2009. Surface-functionalized electrospun nanofibers for tissue engineering and drug delivery. *Advanced drug delivery reviews*, *61*(12), pp.1033-1042.
11. Kenawy, E.R., Bowlin, G.L., Mansfield, K., Layman, J., Simpson, D.G., Sanders, E.H. and Wnek, G.E., 2002. Release of tetracycline hydrochloride from electrospun poly (ethylene-co-vinylacetate), poly (lactic acid), and a blend. *Journal of controlled release*, *81*(1-2), pp.57-64.
12. Zeng, J., Yang, L., Liang, Q., Zhang, X., Guan, H., Xu, X., Chen, X. and Jing, X., 2005. Influence of the drug compatibility with polymer solution on the release kinetics of electrospun fiber formulation. *Journal of controlled release*, *105*(1-2), pp.43-51.
13. Katti, D.S., Robinson, K.W., Ko, F.K. and Laurencin, C.T., 2004. Bioresorbable nanofiber□based systems for wound healing and drug delivery: Optimization of fabrication parameters. *Journal of Biomedical Materials Research Part B: Applied Biomaterials: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials*, *70*(2), pp.286-296.
14. Cui, W., Zhou, Y. and Chang, J., 2010. Electrospun nanofibrous materials for tissue engineering and drug delivery. *Science and technology of advanced materials*, *11*(1), p.014108.
15. Yu, D.G., Shen, X.X., Branford-White, C., White, K., Zhu, L.M. and Annie Bligh, S.W., 2009. Oral fast-dissolving drug delivery membranes prepared from electrospun polyvinylpyrrolidone ultrafine fibers. *Nanotechnology*, *20*(5), p.055104.

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International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 7, April 2026 Impact Factor: 8.2

16. Bognitzki, M., Czado, W., Frese, T., Schaper, A., Hellwig, M., Steinhart, M., Greiner, A. and Wendorff, J.H., 2001. Nanostructured fibers via electrospinning. *Advanced materials*, *13*(1), pp.70-72.
17. He, C.L., Huang, Z.M., Han, X.J., Liu, L., Zhang, H.S. and Chen, L.S., 2006. Coaxial electrospun poly (L□ lactic acid) ultrafine fibers for sustained drug delivery. *Journal of Macromolecular Science, Part B*, *45*(4), pp.515-524.
18. Uyar, T. and Kny, E. eds., 2017. *Electrospun materials for tissue engineering and biomedical applications: research, design and commercialization*. Woodhead Publishing.
19. Reneker, D.H. and Yarin, A.L., 2008. Electrospinning jets and polymer nanofibers. *Polymer*, *49*(10), pp.2387-2425.
20. Fong, H., Chun, I. and Reneker, D.H., 1999. Beaded nanofibers formed during electrospinning. *Polymer*, *40*(16), pp.4585-4592.
21. Lee, K.H., Kim, H.Y., Bang, H.J., Jung, Y.H. and Lee, S.G., 2003. The change of bead morphology formed on electrospun polystyrene fibers. *Polymer*, *44*(14), pp.4029-4034.
22. Uyar, T. and Besenbacher, F., 2008. Electrospinning of uniform polystyrene fibers: The effect of solvent conductivity. *Polymer*, *49*(24), pp.5336-5343.
23. Farhaj, S., Conway, B.R. and Ghori, M.U., 2023. Nanofibres in drug delivery applications. *Fibers*, *11*(2), p.21.
24. Rostamitabar, M., Abdelgawad, A.M., Jockenhoevel, S. and Ghazanfari, S., 2021. Drug□eluting medical textiles: From fiber production and textile fabrication to drug loading and delivery. *Macromolecular Bioscience*, *21*(7), p.2100021.
25. Jiffrin, R., Razak, S.I.A., Jamaludin, M.I., Hamzah, A.S.A., Mazian, M.A., Jaya, M.A.T., Nasrullah, M.Z., Majrashi, M., Theyab, A., Aldarmahi, A.A. and Awan, Z., 2022. Electrospun nanofiber composites for drug delivery: a review on current progresses. *Polymers*, *14*(18), p.3725.
26. Liu, L., Xu, W., Ding, Y., Agarwal, S., Greiner, A. and Duan, G., 2020. A review of smart electrospun fibers toward textiles. *Composites Communications*, *22*, p.100506.
27. Miguel, S.P., Figueira, D.R., Simões, D., Ribeiro, M.P., Coutinho, P., Ferreira, P. and Correia, I.J., 2018. Electrospun polymeric nanofibres as wound dressings: A review. *Colloids and surfaces B: Biointerfaces*, *169*, pp.60-71.
28. Wang, Y., Yu, D.G., Liu, Y. and Liu, Y.N., 2022. Progress of electrospun nanofibrous carriers for modifications to drug release profiles. *Journal of Functional Biomaterials*, *13*(4), p.289.
29. Gómez-Tejedor, J.A., Van Overberghe, N., Rico, P. and Ribelles, J.L.G., 2011. Assessment of the parameters influencing the fiber characteristics of electrospun poly (ethyl methacrylate) membranes. *European Polymer Journal*, *47*(2), pp.119-129.
30. Mele, E., 2016. Electrospinning of natural polymers for advanced wound care: towards responsive and adaptive dressings. *Journal of Materials Chemistry B*, *4*(28), pp.4801-4812.
31. Khil, M.S., Cha, D.I., Kim, H.Y., Kim, I.S. and Bhattarai, N., 2003. Electrospun nanofibrous polyurethane membrane as wound dressing. *Journal of Biomedical Materials Research part B: applied biomaterials: an official journal of the society for biomaterials, the Japanese society for biomaterials, and the Australian society for biomaterials and the Korean society for biomaterials*, *67*(2), pp.675-679.
32. Ladd, M.R., Hill, T.K., Yoo, J.J. and Lee, S.J., 2011. Electrospun nanofibers in tissue engineering. *Nanofibers-production, properties and functional applications*, pp.347-373.
33. Yang, Y., Zhu, X., Cui, W., Li, X. and Jin, Y., 2009. Electrospun composite mats of poly [(D, L□lactide)□co□ glycolide] and collagen with high porosity as potential scaffolds for skin tissue engineering. *Macromolecular Materials and Engineering*, *294*(9), pp.611-619.
34. Kumbar, S.G., Nukavarapu, S.P., James, R., Nair, L.S. and Laurencin, C.T., 2008. Electrospun poly (lactic acid-co-glycolic acid) scaffolds for skin tissue engineering. *Biomaterials*, *29*(30), pp.4100-4107.

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ISSN: 2581-9429 Volume 6, Issue 7, April 2026 Impact Factor: 8.2

35. Gonzalez, A.C.D.O., Costa, T.F., Andrade, Z.D.A. and Medrado, A.R.A.P., 2016. Wound healing-A literature review. *Anais brasileiros de dermatologia*, *91*, pp.614-620.
36. Ambekar, R.S. and Kandasubramanian, B., 2019. Advancements in nanofibers for wound dressing: A review. *European Polymer Journal*, *117*, pp.304-336.
37. Gauglitz, G.G., Korting, H.C., Pavicic, T., Ruzicka, T. and Jeschke, M.G., 2011. Hypertrophic scarring and keloids: pathomechanisms and current and emerging treatment strategies. *Molecular medicine*, *17*(1-2), pp.113-125.
38. Mohanty, C. and Pradhan, J., 2020. A human epidermal growth factor-curcumin bandage bioconjugate loaded with mesenchymal stem cell for in vivo diabetic wound healing. *Materials Science and Engineering: C*, *111*, p.110751.
39. Augustine, R., Hasan, A., Dalvi, Y.B., Rehman, S.R.U., Varghese, R., Unni, R.N., Yalcin, H.C., Alfkey, R., Thomas, S. and Al Moustafa, A.E., 2021. Growth factor loaded in situ photocrosslinkable poly (3-hydroxybutyrate-co-3-hydroxyvalerate)/gelatin methacryloyl hybrid patch for diabetic wound healing. *Materials Science and Engineering: C*, *118*, p.111519.
40. Wang, P., Huang, S., Hu, Z., Yang, W., Lan, Y., Zhu, J., Hancharou, A., Guo, R. and Tang, B., 2019. In situ formed anti-inflammatory hydrogel loading plasmid DNA encoding VEGF for burn wound healing. *Actabiomaterialia*, *100*, pp.191-201.
41. zadehGharaboghaz, M.N., Farahpour, M.R. and Saghaie, S., 2020. Topical co-administration of Teucriumpoliumhydroethanolic extract and Aloe vera gel triggered wound healing by accelerating cell proliferation in diabetic mouse model. *Biomedicine & Pharmacotherapy*, *127*, p.110189.
42. Berman, B., Maderal, A. and Raphael, B., 2017. Keloids and hypertrophic scars: pathophysiology, classification, and treatment. *Dermatologic surgery*, *43*, pp.S3-S18.
43. Kaplani, K., Koutsi, S., Armenis, V., Skondra, F.G., Karantzelis, N., Tsaniras, S.C. and Taraviras, S., 2018. Wound healing related agents: Ongoing research and perspectives. *Advanced Drug Delivery Reviews*, *129*, pp.242-253.
44. Ambekar, R.S. and Kandasubramanian, B., 2019. Advancements in nanofibers for wound dressing: A review. *European Polymer Journal*, *117*, pp.304-336.
45. Municoy, S., Alvarez Echazu, M.I., Antezana, P.E., Galdopórpora, J.M., Olivetti, C., Mebert, A.M., Foglia, M.L., Tuttolomondo, M.V., Alvarez, G.S., Hardy, J.G. and Desimone, M.F., 2020. Stimuli-responsive materials for tissue engineering and drug delivery. *International Journal of Molecular Sciences*, *21*(13), p.4724.
46. Mehnath, S., Chitra, K., Karthikeyan, K. and Jeyaraj, M., 2020. Localized delivery of active targeting micelles from nanofibers patch for effective breast cancer therapy. *International Journal of Pharmaceutics*, *584*, p.119412.
47. Bhattarai, R.S., Bachu, R.D., Boddu, S.H. and Bhaduri, S., 2018. Biomedical applications of electrospun nanofibers: Drug and nanoparticle delivery. *Pharmaceutics*, *11*(1), p.5.
48. Baek, J., Lee, E., Lotz, M.K. and D D'Lima, D., 2020. Bioactive proteins delivery through core-shell nanofibers for meniscal tissue regeneration. *Nanomedicine: Nanotechnology, Biology and Medicine*, *23*, p.102090.
49. Ranjbar-Mohammadi, M. and Bahrami, S.H., 2016. Electrospun curcumin loaded poly (ε-caprolactone)/gum tragacanth nanofibers for biomedical application. *International journal of biological macromolecules*, *84*, pp.448-456.
50. Tetteh, G., Khan, A.S., Delaine-Smith, R.M., Reilly, G.C. and Rehman, I.U., 2014. Electrospun polyurethane/hydroxyapatite bioactive Scaffolds for bone tissue engineering: The role of solvent and hydroxyapatite particles. *Journal of the mechanical behavior of biomedical materials*, *39*, pp.95-110.
51. Wang, H., Li, Y., Zuo, Y., Li, J., Ma, S. and Cheng, L., 2007. Biocompatibility and osteogenesis of biomimetic nano-hydroxyapatite/polyamide composite scaffolds for bone tissue engineering. *Biomaterials*, *28*(22), pp.3338-3348.

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52. Sell, S.A., Wolfe, P.S., Garg, K., McCool, J.M., Rodriguez, I.A. and Bowlin, G.L., 2010. The use of natural polymers in tissue engineering: a focus on electrospun extracellular matrix analogues. *Polymers*, *2*(4), pp.522-553.
53. Ehrmann, A., 2021. Non-toxic crosslinking of electrospun gelatin nanofibers for tissue engineering and biomedicine—a review. *Polymers*, *13*(12), p.1973.
54. Tortora, G.J. and Derrickson, B.H., 2018. *Principles of anatomy and physiology*. John wiley& sons.
55. Cao, H., Liu, T. and Chew, S.Y., 2009. The application of nanofibrous scaffolds in neural tissue engineering. *Advanced drug delivery reviews*, *61*(12), pp.1055-1064.
56. Jain, A., Kim, Y.T., McKeon, R.J. and Bellamkonda, R.V., 2006. In situ gelling hydrogels for conformal repair of spinal cord defects, and local delivery of BDNF after spinal cord injury. *Biomaterials*, *27*(3), pp.497-504.
57. Khorshidi, S., Solouk, A., Mirzadeh, H., Mazinani, S., Lagaron, J.M., Sharifi, S. and Ramakrishna, S., 2016. A review of key challenges of electrospun scaffolds for tissue□engineering applications. *Journal of tissue engineering and regenerative medicine*, *10*(9), pp.715-738.
58. Alvarez-Perez, M.A., Guarino, V., Cirillo, V. and Ambrosio, L., 2010. Influence of gelatin cues in PCL electrospun membranes on nerve outgrowth. *Biomacromolecules*, *11*(9), pp.2238-2246.
59. Binan, L., Tendey, C., De Crescenzo, G., El Ayoubi, R., Ajji, A. and Jolicoeur, M., 2014. Differentiation of neuronal stem cells into motor neurons using electrospun poly-L-lactic acid/gelatin scaffold. *Biomaterials*, *35*(2), pp.664-674.
60. Sophia Fox, A.J., Bedi, A. and Rodeo, S.A., 2009. The basic science of articular cartilage: structure, composition, and function. *Sports health*, *1*(6), pp.461-468