IOCB 2024 Conference

The 1st International Online Conference on Biomimetics

15–17 May 2024 | Online

Recent advances in the application of smart fibrous scaffolds as biomimetic constructs for wound healing

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INTRODUCTION & AIM

Regenerative medicine focuses on reconstructing damaged tissues through tissue engineering. Nanofibers, particularly those created through electrospinning, are a valuable tool in this field. These nanofibers can mimic the natural extracellular matrix (ECM) and enhance tissue efficiency. Electrospinning enables the production of bioactive dressings that imitate the ECM's structure, aiding in wound healing. This technology has the potential to develop effective wound care products and dressings. Complex fibrous materials made from natural and synthetic polymers, combined with medicinal and biological agents, are used to create these dressings. As innovation progresses, more sophisticated systems are being developed in a controlled manner.

METHOD

The electrospinning technique is an excellent method for creating 3D structures using electrostatic forces. This process produces filaments with dimensions ranging from nanometers to micrometers, with higher surface areas compared to filaments made using conventional spinning methods. More than 200 organic and synthetic materials, such as gelatin, collagen, silk fibroin, chitosan, polycaprolactone (PCL), poly-lactic acid (PLLA), polyvinyl alcohol (PVA), polyvinylpyrrolidone (PVP), and others have been used for electrospinning. As this process can replicate the extracellular matrix and provide optimal substrates for cell growth and tissue development, the use of nanofibers has increased in various fields over the years. As the technology has advanced, more complex systems have been developed in a controlled way. Various nanofiber manufacturing technologies have been developed for biomedical applications. Coaxial electrospinning is used to produce core-shell nanofibers with complex microstructures. Hollow nanofiber tubes, a new design, can carry different bioactive agents and promote drug dissolution. Multi-layered nanofibers are created using triaxial electrospinning to overcome the loading capacity limitations of conventional nanofibers (Fig. 1) (Del Bakhshayesh, Babaie et al. 2022). Triaxial and quadriaxial electrospinning, with three or four concentric needles respectively, have also been developed. Additionally, a new generation of polymer nanofibers with a porous structure has been developed to enhance drug delivery and tissue engineering efficiency. These modified nanofibers have a high specific surface area due to their porosity and interwoven pores, making them effective for tissue engineering, wound healing, and drug delivery applications (Fig. 2) (Rahmani Del Bakhshayesh, Saghebasl et al. 2023). On the other hand, modifying the surface of nanofibers can enhance their effectiveness by enabling the continuous release of various factors for drug delivery and promoting cellular response in tissue engineering. Ligands are used for cell recognition and detecting active molecules. Plasma treatment, wet chemical methods, surface graft polymerization, and co-electrospinning of bioactive agents and polymers are employed to modify the surface of non-natural polymeric nanofibers for drug delivery and tissue engineering (Fig. 3) (Del Bakhshayesh, Babaie et al. 2022).

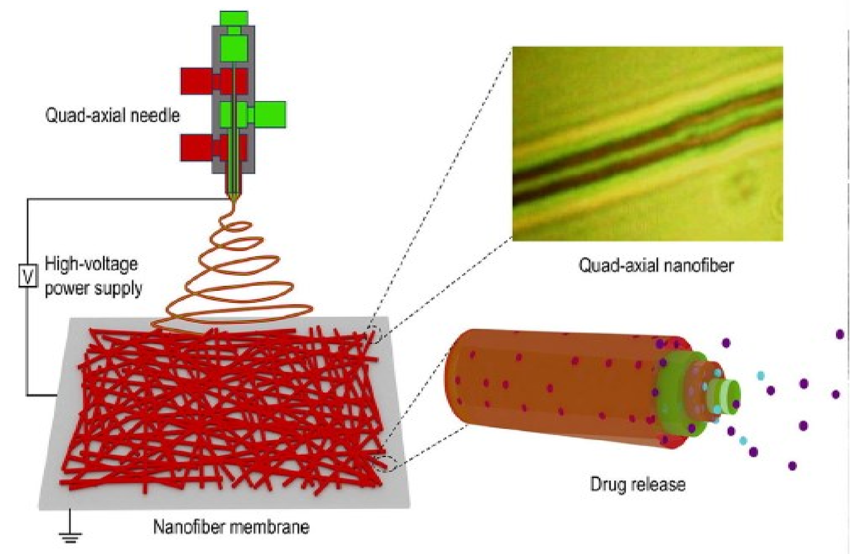

Figure 1. Schematic illustration of quadriaxial electrospinning (Zhang, Chi et al. 2021).

Figure 2. Schematic illustration of the formation of porous membrane (Lu, Wang et al. 2020).

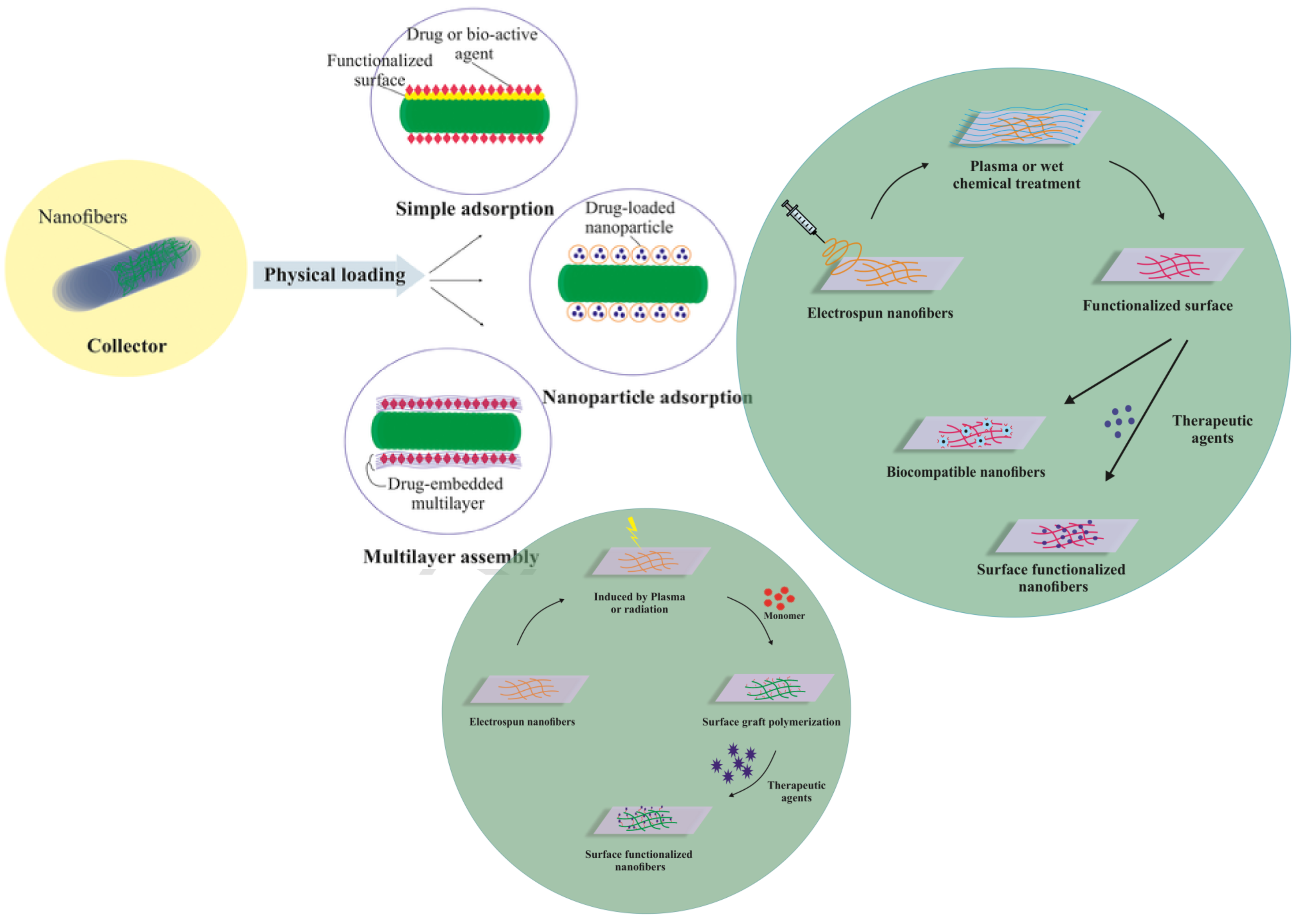

Figure 3. Different methods of surface modification of electrospun nanofibers (Del Bakhshayesh, Babaie et al. 2022).

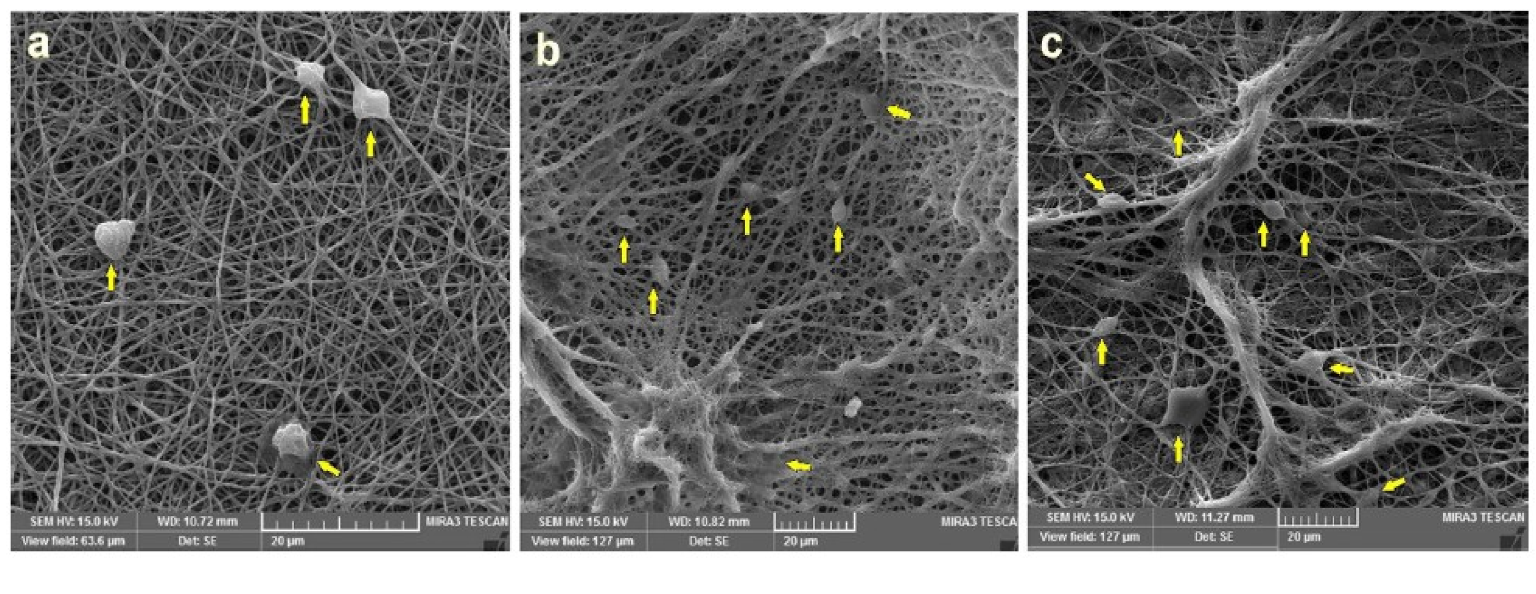

Figure 4. SEM images shows the NIH-3T3 fibroblast cells attachment on the a PU/PCL, b PU/PCL/soybean oil, and c PU/PCL/soybean oil/gold nanoparticles nanocomposite fibers at 3rd day after seeding (Asadi, Del Bakhshayesh et al. 2023).

RESULTS & DISCUSSION

Our research team conducted a study to create a nanocomposite electrospun scaffold that is highly efficient and biomimetic. The scaffold needed to have suitable biological properties and physicochemical performance, for which we used a mixture of polycaprolactone and polyurethane (PCL/PU). To improve its properties, we added gold nanoparticles (GNPs) and soybean oil (SO) to the mixture. The desired nanofibers were created by electrospinning the PCL/PU mixed solution with GNPs and SO (Asadi, Del Bakhshayesh et al. 2023). It was observed that the addition of soybean oil (SO) and Gold nanoparticles (GNPs) increased the electrical conductivity of the fibrous mats. Biocompatibility evaluations were carried out by measuring cell viability and adherence of cells to the scaffold's surfaces. The results showed that the inclusion of SO and GNPs supports fibroblasts. Therefore, the nanocomposite fibrous mats containing SO and GNPs have the potential to be used in various regenerative medicine and wound healing applications (Fig. 4) (Asadi, Del Bakhshayesh et al. 2023).

CONCLUSION

Electrospun nanofibers have biomimetic and physicochemical properties, making them suitable for different regenerative medicine applications, specifically for wound healing. These nanofibers can be structurally modified and combined with various functional additives to create more sophisticated systems in a controlled manner.

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