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# NANOFIBER-BASED DRUG DELIVERY SYSTEMS FOR CANCER THERAPY: RECENT ADVANCES AND FUTURE PERSPECTIVES: REVIEW

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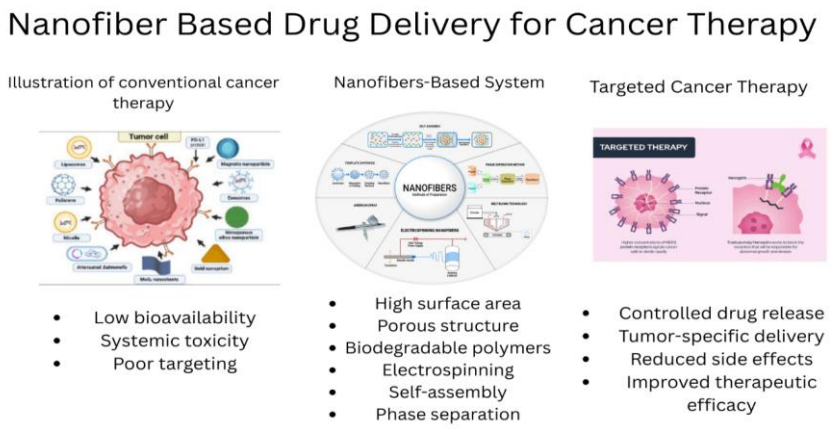
## ABSTRACT

**Background:** Cancer treatment often faces problems such as poor drug targeting, low bioavailability, and severe side effects. To overcome these limitations, nanofibers-based drug delivery systems have gained attention in recent years. Because of their high surface area, porous structure, and nanoscale size, nanofibers can carry drugs efficiently and release them in a controlled manner, making them useful for cancer therapy. **Methods:** Nanofibers are prepared using methods such as electrospinning, self-assembly, and phase separation, which allow control over fiber size and composition. Both natural and synthetic polymers that are biocompatible and biodegradable are commonly used to reduce toxicity. These nanofibers can load different anticancer agents, including chemotherapeutic drugs, proteins, genes, and immunotherapeutics. To improve targeting, nanofibers can be surface-modified with ligands, and stimuli-responsive systems are designed to release drugs in response to pH, temperature, or enzymes present in the tumor environment. **Evaluation:** Several preclinical studies have reported improved anticancer activity using nanofibers-based systems. These systems show better tumor suppression, reduced drug resistance, and fewer systemic side effects compared to conventional drug delivery. Encapsulation within nanofibers also helps protect drugs from degradation and improves their stability. **Conclusion:** Nanofibers-based drug delivery systems offer a promising and flexible approach for cancer treatment. However, challenges such as large-scale production, long-term safety, and regulatory approval still need further research before clinical application.

**KEYWORDS**: Biocompatible, Immunotherapeutics, Nanofibers.

**Graphical Abstract**




## INTRODUCTION

Conventional drug delivery systems often suffer from poor bioavailability, rapid drug clearance, and lack of site specificity, which significantly limit therapeutic efficacy, particularly in cancer treatment. These limitations have driven the development of advanced delivery platforms capable of achieving localized and sustained drug action. Among these, nanofiber-based systems have emerged as a promising approach due to their structural versatility and ability to minimize systemic toxicity (Alves D et.,al 2023)

Nanofibers exhibit unique properties such as a high surface-area-to-volume ratio, interconnected porous architecture, and structural resemblance to the extracellular matrix, making them suitable for efficient drug encapsulation and enhanced interaction with biological tissues. Early investigations demonstrated that electrospun nanofibers could successfully incorporate chemotherapeutic agents and biomolecules, resulting in controlled drug release and improved anticancer efficacy (YanE et.,al 2023)

With progress in fabrication techniques, nanofiber-based drug delivery systems evolved toward specialized architectures such as core–shell and implantable nanofibrous meshes. These systems enabled improved control over release kinetics and showed strong potential in localized chemotherapy and prevention of tumor recurrence following surgical intervention (Kaplan JA et.,al 2016) However, differences in fiber architecture significantly influence drug distribution and release behavior, highlighting the need for rational design strategies tailored to specific therapeutic requirements.

More recent studies have focused on multifunctional and stimuli-responsive nanofibers capable of responding to tumor microenvironment conditions or external triggers such as light. These advanced systems allow precise spatiotemporal control of drug release and support combination therapeutic strategies, further strengthening the role of nanofibers in next-generation cancer therapy (Agiba AM et.,al 2024). Despite these advances, challenges related to scalable manufacturing, long-term safety, and clinical translation of nanofiber-based drug delivery systems remain insufficiently addressed.

Although nanofibers have been explored across various therapeutic applications, the present review primarily focuses on their role in anticancer drug delivery systems.

**Method of Preparation of Nanofibers for Anticancer Drug Delivery**

This section provides a descriptive overview of the commonly reported methods used for the preparation of nanofibers for anticancer drug delivery, with emphasis on polymer selection and electrospinning-based fabrication techniques described in the literature.

**Selection of Polymer and Therapeutic Agent**

The selection of an appropriate polymer and anticancer drug represents a critical initial consideration in the development of nanofiber-based drug delivery systems, as it influences fibre formation, drug encapsulation efficiency, release kinetics, mechanical stability, and biocompatibility. Biodegradable and biocompatible polymers such as polycaprolactone (PCL), poly(lactic-co-glycolic acid) (PLGA), polyvinyl alcohol (PVA), alginate, gelatin, and cellulose derivatives have been widely reported due to their favourable mechanical properties, controlled degradation behaviour, and established biomedical acceptance (Alves D et al., 2023).

Anticancer agents including cisplatin, curcumin, paclitaxel, docetaxel, daunorubicin, and 5-fluorouracil have been extensively incorporated into nanofibrous matrices because of their proven therapeutic efficacy and compatibility with polymeric systems (Yan E et al., 2023). Reported studies indicate that polymer selection is governed by factors such as drug solubility, drug–polymer miscibility, polymer degradation rate, and the intended duration of therapy, all of which collectively influence drug release behaviour and therapeutic performance.

**Preparation of Polymer–Drug Solutions**

In reported fabrication approaches, a homogeneous polymer–drug solution is typically prepared to ensure uniform fibre formation and consistent drug distribution within nanofibers. The selected polymer is dissolved in a suitable solvent or solvent system to obtain a solution with appropriate viscosity, conductivity, and surface tension for electrospinning.

The anticancer drug is subsequently incorporated under controlled stirring conditions to promote uniform dispersion and minimize phase separation. In some formulations, surfactants or stabilizing agents have been employed to improve drug–polymer compatibility and enhance encapsulation efficiency, particularly for poorly soluble or hydrophilic drugs (Absar S et al., 2015).

**Electrospinning Techniques**

Electrospinning is the most frequently reported technique for the fabrication of drug-loaded nanofibers due to its versatility, simplicity, and ability to generate fibers with nanoscale diameters. Based on the desired fiber architecture and drug release characteristics, electrospinning techniques reported in the literature can be broadly categorized into conventional electrospinning, coaxial electrospinning, and emulsion electrospinning.

*Conventional electrospinning* involves the use of a single polymer–drug solution to produce uniform nanofibers and has been widely described for sustained drug delivery applications (Yuan Y et al., YEAR). However, studies have indicated that this approach may offer limited control over initial burst release, particularly for hydrophilic or surface-associated drugs.

*Coaxial electrospinning* employs a dual-fluid system to generate core–shell structured nanofibers, allowing physical separation of the drug from the external environment. This technique has been reported to provide enhanced control

over drug release kinetics and is particularly advantageous for the delivery of sensitive biomolecules, combination therapies, and drugs requiring prolonged or staged release (Yan E et al., 2023).

*Emulsion electrospinning* utilizes a single emulsion system to produce fibers with core–shell-like architectures without the need for complex spinneret configurations. Literature reports suggest that this method is effective for incorporating hydrophilic drugs into hydrophobic polymer matrices while maintaining controlled drug distribution and release behavior (Absar S et al., 2015).

**Influence of Processing Parameters**

Published studies have demonstrated that electrospinning outcomes are strongly influenced by processing parameters such as applied voltage, solution flow rate, needle-to-collector distance, and ambient environmental conditions. Variations in these parameters have been reported to significantly affect fiber diameter, morphology, and drug distribution within the nanofibrous matrix, highlighting the importance of controlled processing conditions during nanofiber fabrication (Yuan Y et al., YEAR).

**Post-Fabrication Processing and Translational Considerations**

Following electrospinning, nanofibrous mats reported in the literature are typically subjected to drying processes to remove residual solvents and are subsequently characterized for morphological features, drug encapsulation efficiency, and in vitro drug release behavior (Chen K et al., 2021). Depending on the intended therapeutic application, nanofibers have been further processed into implantable meshes, localized delivery scaffolds, or other dosage form configurations suitable for cancer therapy.

Despite encouraging preclinical findings, several studies have highlighted challenges related to batch-to-batch reproducibility, large-scale manufacturing, and regulatory approval, which continue to limit the clinical translation of nanofiber-based drug delivery systems. Addressing these challenges through process standardization, scalable fabrication strategies, and comprehensive safety evaluation has been identified as essential for the successful therapeutic adoption of nanofiber-mediated anticancer drug delivery.

**Nanofibers for Localized Chemotherapy Delivery**

Localized chemotherapy systems are among the earliest applications of nanofibers and aim to maintain sustained therapeutic levels at the tumour site. These studies show strong evidence for reduced recurrence and enhanced tumour suppression as seen in table 1

**Table -1**

| Sl. No | Year | Title | Conclusion | Research gap | Reference No |
|---|---|---|---|---|---|
| **1** | **2014** | Biocompatible core shell electrospun nanofibers as protein application for chemotherapy against ovarian cancer | The study showed that PVA/chitosan core–shell nanofibers can be made reliably and are fully biocompatible, with the chitosan shell helping control drug release. When loaded with doxorubicin, these fibers delivered the drug into ovarian cancer cells and effectively slowed | While drug release was controllable, the materials still dissolve rapidly under physiological conditions, indicating a need for refining the fiber composition or crosslinking strategies to improve sustained release in realistic | Yan E et.,al 2014 |

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| | | | their growth in vitro, suggesting real promise for more controlled chemotherapy scaffolds. | therapeutic environments. | |
| **2** | **2014** | Curcumin loaded poly (lactic-co-glycolic) acid nanofiber for the treatment of carcinoma | Curcumin-loaded PLGA nanofibers were successfully fabricated with smooth, uniform morphology using optimized electrospinning conditions. The nanofibers showed suitable physicochemical properties, supporting their potential as an effective carrier system for curcumin delivery. | The study did not assess in-vivo efficacy, physiological release behavior, or long-term biocompatibility, which are essential to evaluate the clinical relevance of this delivery system. | Sampath M et.,al 2014 |
| **3** | **2015** | Preparation and therapeutic application of docetaxel-loaded poly(d,l-lactide) nanofibers in preventing breast cancer recurrence | Docetaxel-loaded PDLLA nanofibers provided sustained local drug release and effectively reduced breast cancer recurrence after tumor resection. Their good biocompatibility and strong in-vivo performance highlight their potential as a localized therapy to prevent tumor relapse. | The study lacks detailed pharmacokinetic, biodistribution, long-term safety, and comparative systemic therapy data, which are necessary to evaluate clinical translation. | Ding Q et.,al 2016 |
| **4** | **2015** | PLGA nanofibers improves the antitumoral effect of daunorubicin | Daunorubicin-loaded PLGA nanofibers were successfully fabricated and showed sustained drug release with enhanced antitumoral and anti-angiogenic effects compared to free drug. The formulation demonstrated good biocompatibility, supporting its potential as a localized cancer therapy. | The study lacks pharmacokinetic data, long-term toxicity evaluation, mechanistic insights, and direct comparison with systemic daunorubicin therapy, limiting clinical translation. | Guimareas et.,al 2015 |
| **5** | **2015** | Enhanced Bioavailability and Anticancer Effect of Curcumin-loaded electrospun nano fibers : In Vitro and In Vivo Studies | curcumin-loaded PVP nanofibers were successfully made by electrospinning and showed smooth morphology with the drug in an amorphous state. These fibers dissolved quickly, dramatically increased curcumin's bioavailability in vivo, and significantly slowed tumor growth in mice, suggesting a promising way to improve oral delivery of poorly soluble anticancer agents. | The study didn't explore long-term stability or how to sustain curcumin release beyond rapid dissolution, leaving room for work on controlled release kinetics and formulation robustness for clinical translation. | Wang C et.,al 2015 |
| **6** | **2016** | Prevention of lung cancer recurrence using Cisplatin-loaded superhydrophobic | Cisplatin-loaded superhydrophobic nanofiber meshes provided | Despite encouraging results, long-term release behavior under | Kalpan JA et.,al 2016 |

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| | | nanofiber meshes | sustained local drug release and significantly reduced post-surgical tumor recurrence in lung cancer models. Compared to systemic cisplatin, this localized approach improved recurrence-free survival while minimizing toxicity, highlighting its strong potential as a post-resection therapeutic strategy. | physiological conditions and in-vivo aspects such as drug stability, biodistribution, targeting, and safety remain insufficiently explored, limiting clinical translation. | |
| **7** | **2017** | Preparation and characterization of Fe3O4-Ag2O quantum dots decorated cellulose nanofibers as a carrier of anticancer drugs for skin cancer | $Fe_3O_4$–$Ag_2O$ quantum dot–decorated cellulose nanofibers successfully carried etoposide and methotrexate with sustained release and enhanced anticancer activity. Their magnetic behavior and improved drug performance suggest strong potential as advanced carriers for skin cancer therapy. | The study lacks in-vivo validation, long-term toxicity and pharmacokinetic data, and mechanistic insight into tumor–nanocarrier interactions, which limits clinical translation. | Fakhri A et.,al 2017 |
| **8** | **2017** | Development and characterization of the Cisplatin-loaded nanofibers for the treatment of cervical cancer | Cisplatin-loaded PCL/chitosan nanofibers showed strong mucous adhesion, sustained drug release, and effective localized tumor reduction in cervical cancer models. This biodegradable vaginal delivery system improved therapeutic efficacy while potentially reducing systemic toxicity, highlighting its promise for cervical cancer treatment. | The study does not address systemic pharmacokinetics, long-term mucosal safety, or detailed tumor response mechanisms, and lacks direct comparison with standard systemic cisplatin therapy, limiting translational assessment. | Aggarwal Umet.,al 2018 |
| **9** | **2019** | Poly(d,l-lactide)/polyethylene glycol micro/nanofiber mats as paclitaxel-eluting carriers: preparation and characterization of fibers, in vitro drug release, antiangiogenic activity and tumor recurrence prevention | Paclitaxel-loaded PDLLA/PEG micro- and nanofiber mats were successfully fabricated and showed sustained drug release with strong anti-angiogenic activity. When applied locally, the fibers effectively reduced tumor recurrence, highlighting their potential as post-surgical anticancer delivery systems. | The study did not explore detailed pharmacokinetics, long-term biodegradation and safety, or direct comparison with systemic paclitaxel therapy, limiting assessment of clinical translation. | Hobzovz R et.,al 2019 |
| **10** | **2020** | Electrospun PVA-Dacarbazine nanofibers as a novel nano brain-implant for treatment of glioblastoma: *in silico* and *in vitro* | PVA-based electro spun nanofibers incorporating dacarbazine provide a promising localized treatment strategy for glioblastoma. The nano-implant approach ensures | Despite promising in vitro results, dacarbazine-loaded electrospun nanofiber implants lack in vivo evaluation, leaving their long-term safety, | Steffens L et.,al 2020 |

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| | | | sustained drug release directly at the tumor site, improving therapeutic efficacy while reducing systemic toxicity. In silico and in vitro findings collectively support the potential of this system as an advanced alternative to systemic chemotherapy for brain tumors. | brain compatibility, and clinical translational potential unclear. | |
| 11 | 2021 | Alginate/gelatin sponge combined with curcumin-loaded electrospun fibers for postoperative rapid hemostasis and prevention of tumor recurrence. | The integration of curcumin-loaded electrospun fibers within an alginate–gelatin sponge offers a multifunctional postoperative platform. This system achieves rapid hemostasis while delivering sustained anticancer therapy, effectively reducing the risk of tumor recurrence. The dual functionality highlights its potential to improve postoperative recovery and long-term cancer management. | Although the formulation showed effective sustained drug release and anticancer activity, the study did not include systemic pharmacokinetic or biodistribution analysis, long-term mucosal and reproductive toxicity evaluation, mechanistic tumor response investigations, or comparison with conventional cisplatin therapy, limiting its translational assessment. | Chen K et.,al 2021 |
| 12 | 2024 | Development of 5-fluorouracil/etoposide co-loaded electrospun nanofibrous scaffold for localized anti-melanoma therapy | The co-loaded PVA/chitosan nanofibrous scaffold enabled sustained release of 5-FU and etoposide and showed enhanced cytotoxic and apoptotic effects against melanoma cells. This dual-drug system highlights strong potential for localized anti-melanoma therapy with reduced systemic toxicity. | In-vivo efficacy, biodegradation, long-term safety, and interactions with normal tissues were not assessed, limiting evaluation of clinical translation. | Alves D et.,al 2023 |
| 13 | 2025 | Electrospun Coaxial Polycaprolactone/ Polyvinylpyrrolidone Fibers Containing Cisplatin: A Potential Local Chemotherapy Delivery System for Cervical Cancer Treatment | Coaxial electro spun PCL/PVP nanofibers successfully encapsulated cisplatin and enabled controlled, sustained drug release. The fibers showed promising anticancer activity against cervical cancer cells, supporting their potential as a localized chemotherapy delivery system. | The study lacks in-vivo validation, long-term safety evaluation, and comparative analysis with conventional cisplatin therapy, which are necessary for clinical translation. | Silva-Lopez et.,al 2025 |

**Theme Introduction (Table-2)**

Managing poorly soluble drugs and combining multiple therapeutic agents remains a key challenge in cancer therapy. Nanofibers offer versatile platforms to improve solubility, stability, and combination delivery efficiency are seen in table 2.

**Table 2: Nanofibers for Poor Solubility and Combination Therapy.**

| Sl No | Year | Topic | Conclusion | Research Gap | Reference |
|---|---|---|---|---|---|
| 1 | 2015 | Investigation of synthesis and processing of cellulose, cellu-lose acetate and poly(ethylene oxide) nanofibers incorporating anti-cancer/tumour drug cis-diammineplatinum (II) dichloride using electrospinning techniques | Cisplatin was successfully incorporated into cellulose, cellulose acetate, and PEO nanofibers using single-nozzle and coaxial electrospinning, producing diverse and well-defined fiber morphologies. The study highlights electrospinning as a versatile technique for fabricating polymeric nanofibers capable of carrying anticancer drugs. | Drug release behaviour, cytotoxic efficacy, and in vivo performance were not evaluated, limiting understanding of the system's therapeutic potential. | Absars et.,al 2015 |
| 2 | 2017 | Sequel of MgO nanoparticles in PLACL nanofibers for anti-cancer therapy in synergy with curcumin/β-cyclodextrin | Cisplatin was successfully incorporated into electrospun cellulose, cellulose acetate, and PEO fibers, producing diverse morphologies and showing that electrospinning can tailor polymeric carriers for drug delivery. | Drug release behaviour, cytotoxicity, and biological performance in relevant environments were not evaluated, limiting potential for controlled delivery evaluation. | SudakaranS V et';al 2017 |
| 3 | 2018 | Early-stage release control of an anticancer drug by drug–polymer miscibility in a hydrophobic fiber-based drug delivery system. | . Drug–polymer miscibility is a critical determinant of early-stage drug release behavior in hydrophobic fiber-based delivery systems. Enhanced miscibility ensures uniform drug distribution, minimizes burst release, and enables predictable release kinetics. Optimizing drug–polymer interactions is therefore essential for improving treatment safety, efficacy, and consistency in fiber-based anticancer therapies. | Despite promising sustained release and anticancer efficacy, the study lacks systemic pharmacokinetic and biodistribution data, long-term mucosal and reproductive safety evaluation, mechanistic tumor response analysis, and comparison with standard systemic cisplatin therapy, limiting its translational relevance. | Yuan y et.,al 2018 |
| 4 | 2019 | Electro spun oral formulations for combined photo-chemotherapy of colon cancer | Coaxially electrospun fibers carrying carmofur and rose bengal showed controlled, colon-targeted release with minimal stomach leakage and enhanced selective toxicity against colon cancer cells under light, suggesting strong potential for combined photo-chemotherapy. | However, more work is needed in vivo to confirm therapeutic benefit, optimize light activation parameters, and evaluate long-term safety and colon specificity beyond cell models. | Li H et.,al 2019 |
| 5 | 2019 | Loading of quinoxaline derivatives in poly(L-lactic) acid/Pluronic® F-127 nanofibers enhances anticancer efficiency. | Electrospun PLLA nanofibers loaded with quinoxaline derivatives represent an effective polymeric drug delivery platform for cancer therapy. The nanofiber matrix enhances drug stability, enables controlled and sustained release, and significantly improves the therapeutic index. Activation of p53- and p21-mediated apoptotic | Despite demonstrating effective formulation performance and anticancer efficacy, the study lacks systemic pharmacokinetic and biodistribution evaluation, long-term safety assessment, detailed mechanistic insights into tumor response, and | El-Aasar et.,al 2019 |

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| | | | pathways further confirms the superior anticancer potential of this system over conventional formulations. | comparison with standard cisplatin therapy, limiting its translational significance. | |
| 6 | 2021 | Improved bioavailability of oxcarbazepine, a BCS class II drug by centrifugal melt spinning: In-vitro and in-vivo implications | Centrifugal melt-spun oxcarbazepine microfibers dramatically enhanced dissolution rate and improved oral bioavailability, showing faster systemic absorption and better pharmacokinetics than the pure drug. | Still, clinical relevance is limited without deeper investigation into long-term stability, safety across populations, and comparison with existing bioavailability-enhancing strategies. | Nasirs et.,al 2021 |
| 7 | 2022 | Emulsion-electrospun polyvinyl alcohol nanofibers as a solid dispersion system to improve solubility and control the release of probucol, a poorly water-soluble drug | Probucol was successfully incorporated into emulsion-electrospun PVA nanofibers, resulting in improved drug solubility and a more controlled release profile compared to the pure drug. The nanofibers demonstrated the potential of emulsion electrospinning as an effective solid-dispersion strategy for poorly water-soluble drugs. | The study did not evaluate in vivo performance, long-term stability, or pharmacokinetic behaviour, which are essential for assessing clinical applicability. | Shibatat et.,al 2022 |
| 8 | 2022 | PVA/κ-carrageenan/Au/camptothecin/pegylated-polyurethane/paclitaxel nanofibers against lung cancer treatment | The review highlights the growing role of nanofibers in biomedical and drug delivery applications. Their structural properties, such as high surface area and tunable porosity, make them suitable for carrying and releasing therapeutic agents in a controlled manner. | However, the majority of studies remain at the laboratory level. Additional work is required to assess toxicity, long-term stability, and scalability of production before these materials can be widely applied in healthcare settings | Irani M et.,al 2022 |
| 9 | 2023 | Localized therapeutic approaches based on micro/nanofibers for cancer treatment. Molecules. | This study emphasizes the advantages of localized drug delivery using micro- and nanofibers for cancer treatment. By delivering therapeutic agents directly to the affected site, these systems help reduce systemic side effects while improving treatment effectiveness. | Most of the reported outcomes are limited to preclinical studies. The lack of clinical trials and long-term safety evaluation presents a major gap that must be addressed to support further clinical translation. | Alves D et.,al 2023 |
| 10 | 2024 | An overview of nanofibers and microfibers for improved oral delivery of medicines: Challenges and advances | The review highlights that nano- and microfibers offer significant advantages for oral drug delivery, particularly for improving solubility, dissolution, and bioavailability of poorly water-soluble drugs. Advances in spinning techniques and polymer design show strong potential for next-generation oral formulations. | Despite promising progress, challenges related to large-scale manufacturing, long-term stability, in vivo performance, and regulatory translation remain insufficiently addressed. | Ghasemiye hP et.,al 2021 |
| 11 | 2025 | Fabrication of Gemcitabine and Mitoxantrone Loaded PLG/Mesoporous Silica Nanofibers: Investigation of In Vitro Drug Release and Anticancer Activity in Pancreatic Cancer Cells | Dual-drug PLG/mesoporous silica nanofibers successfully co-encapsulated and released both gemcitabine and mitoxantrone, showing enhanced inhibition of pancreatic cancer cell growth in vitro compared to single-drug systems. | In vivo efficacy, pharmacokinetics, and long-term safety were not examined, limiting insight into translational potential. | WuH et.,al 2025 |

**Theme Introduction (Table-3)**

Advanced and smart nanofiber drug delivery systems can be seen as tiny drug carriers designed to work in harmony with the body. Instead of releasing medicine all at once, these fine fibers quietly hold and release drugs in a controlled manner, responding to the body's needs. This approach aims to make treatments more effective while reducing unwanted side effects are seen in table 3

**Table 3: Advanced and Smart Nanofiber Drug Delivery Systems.**

| Sl No | Year | Topic | Conclusion | Research Gap | Reference |
|---|---|---|---|---|---|
| 1 | 2018 | Improved anticancer properties of stem cells derived exosomes by prolonged release from PCL nanofibrous structure | PCL nanofibrous scaffolds enabled sustained release of stem cell–derived exosomes, enhancing their anticancer activity compared to free exosomes. | Long-term in vivo safety, biodistribution, and mechanistic understanding of exosome–tumor interactions were not investigated. | Rezaie et.,al 2018 |
| 2 | 2020 | pH-sensitive core-shell electrospun nanofibers based on polyvinyl alcohol/polycaprolactone as a potential drug delivery system for chemotherapy against cervical cancer | Core–shell PVA/PCL nanofibers showed pH-dependent drug release and enhanced cytotoxicity against cervical cancer cells, indicating potential for targeted chemotherapy. | Long-term safety, pharmacokinetics, and in vivo anticancer efficacy remain unexplored. | Yan E et.,al2020 |
| 3 | 2021 | Multifunctional cellulosic nanofiber film with enhanced antimicrobial and anticancer properties by incorporation of ethanolic extract of *Garcinia mangostana* peel | Incorporation of mangosteen peel extract into cellulosic nanofibers improved both antimicrobial and anticancer activity while maintaining good material properties. | The study lacked vivo validation and detailed mechanistic insight into anticancer action, limiting translational relevance. | TaokaewS et.,al 2021 |
| 4 | 2023 | pH-responsive nanofiber membranes for superior controlled release of poorly water-soluble drug and its release mechanism study | pH-responsive nanofiber membranes enabled controlled release of poorly water-soluble drugs, with release behavior strongly influenced by environmental pH. | In vivo validation and long-term biocompatibility of the pH-responsive system remain unaddressed. | WuC et.,al 2023 |
| 5 | 2024 | Advances in Light-Responsive Smart Multifunctional Nanofibers: Implications for Targeted Drug Delivery and Cancer Therapy | The review discusses how light-responsive and dual-stimuli nanofibers enable controlled drug release and better tumor targeting compared to conventional delivery systems. By responding to more than one external stimulus, these nanofibers offer improved control over therapeutic action in cancer treatment | Despite their potential, several practical challenges remain. Issues related to large-scale fabrication, long-term biocompatibility, and detailed in-vivo validation need to be addressed before these systems can be considered suitable for clinical use. | AgibaAM et.,al 2024 |
| 6 | 2025 | Electro spun Nanofiber Platforms for Photodynamic Therapy: Role and Efficacy in | This work shows that electro spun nanofibers loaded with photosensitizers can be | improve light-delivery techniques and to evaluate the performance of these systems under | Eldem et.,al 2025 |

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| | | Cancer, Antimicrobial, and Wound Healing Applications | effectively used for localized photodynamic therapy. The approach improves treatment accuracy while reducing unwanted damage to nearby healthy tissues. In addition to cancer therapy, the study also highlights their usefulness in antimicrobial applications and wound healing, mainly due to controlled reactive oxygen species generation. | in-vivo and clinical conditions. | |

**Future Perspectives**

Nanofiber-based drug delivery systems hold significant promise for advancing next-generation therapeutics; however, their future development must focus on bridging the gap between laboratory research and clinical application. Greater emphasis is required on scalable and reproducible manufacturing strategies, including the transition from conventional laboratory electrospinning to industrial-scale techniques capable of producing uniform nanofibers with consistent drug loading and release characteristics.

Future research is expected to move toward precision-engineered nanofibers, where polymer composition, fiber architecture, and drug distribution are rationally designed based on disease-specific requirements. The integration of smart and multifunctional features—such as stimuli-responsive behavior, combination drug loading, and theragnostic capabilities—will further enhance therapeutic efficacy and allow personalized treatment approaches. Additionally, expanding investigations into non-cancer therapeutic areas, including wound healing, infectious diseases, and neurological disorders, may broaden the clinical relevance of nanofiber-based systems.

Importantly, long-term biocompatibility, toxicity, and degradation studies must be prioritized to ensure safety and regulatory acceptance. Collaboration between material scientists, pharmaceutical researchers, clinicians, and regulatory agencies will be crucial for translating promising nanofiber technologies into approved clinical products. With continued interdisciplinary efforts and technological advancements, nanofibers are poised to play a transformative role in the future of novel drug delivery systems.

## CONCLUSION

Nanofibres represent a highly promising platform for cancer therapy due to their ability to enhance targeted drug delivery, improve therapeutic efficacy, and reduce systemic toxicity. Their high surface area, tunable structure, and compatibility with a wide range of anticancer agents enable controlled and sustained drug release tailored to tumor-specific conditions. Advances in fabrication techniques and surface functionalization have further strengthened their role in precision oncology by improving tumor targeting and minimizing off-target effects. Although challenges such as large-scale manufacturing, long-term biocompatibility, and regulatory considerations remain, ongoing research continues to address these limitations. Overall, nanofibres-based systems hold significant potential to transform cancer treatment and contribute to more effective and patient-friendly therapeutic strategies.

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**Abbreviations**

| | |
|---|---|
| PLGA | Poly(lactic-co-glycolic acid) |
| PVA | Polyvinyl alcohol |
| 5-FU | 5-fluorouracil |
| PDLLA | Poly(d,l-lactide) |
| PEG | Polyethylene glycol |
| PVP | Polyvinylpyrrolidone |
| PEO | Poly(ethylene oxide) |
| PLLA | Poly(L-lactic) acid |
| BCS | Biopharmaceutical Classification System |
| PLG | Poly(lactide-co-glycolide) |
| pH | Potential of Hydrogen. |
| PLGA | Poly(lactic-co-glycolic acid) |
| PCL | Polycaprolactone |

**CONFLICT OF INTEREST**

The authors declare that there is no conflict of interest related to the publication of this review article.

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**Author contribution:** All authors contributed equally to the literature survey, manuscript drafting, critical revision, and final approval of the manuscript.

**Summary:** Nanofibers-based drug delivery systems offer a promising solution to the limitations of conventional cancer therapy, including poor targeting, low bioavailability, and systemic toxicity. Their high surface area and porous structure allow efficient drug loading and controlled release. Nanofibers fabricated using techniques such as electrospinning and self-assembly can deliver various anticancer agents and improve their stability. Targeted and stimuli-responsive nanofibers enhance tumor-specific drug release and reduce side effects. Although challenges related to large-scale production and safety remain, nanofibers-based systems show strong potential to improve the effectiveness of cancer therapy.

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