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RECENT ADVANCES IN POLYMER-BASED DRUG DELIVERY SYSTEMS FOR SKIN CANCER DIAGNOSIS AND TREATMENT: A REVIEW STUDY

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Abstract

Skin cancer is still a major world health issue, and the death and incidence rates are rising. While standard therapies like chemotherapy, radiotherapy, and surgery are available, they often have problems like drug resistance, systemic toxicity, and not being able to target the right area. Polymer-based drug delivery systems (DDSs) have become a potential alternative in recent years. They make drugs more bioavailable, less toxic to the body as a whole, and easier to control and target. This review talks about the latest progress made in polymer-based DDSs for skin cancer and shows how they can be used to diagnose and treat the disease. A lot of research has been done on biocompatibility, stability, and effectiveness of key kinds of polymers, such as natural, synthetic, and copolymers. A total of 33 studies were looked at, with a focus on new polymer systems designed for skin cancer treatment, such as hydrogels, micelles, nanoparticles, nanofibers, and dendrimers. Aside from that, the study also talks about different ways to diagnose problems using polymer carriers and imaging agents. The literature was gathered by searching databases in a planned way and then choosing what to include based on its scientific value and usefulness. Problems like harm, expense, instability, and government restrictions were named, and suggestions for the future were made, such as personalized treatment and hybrid systems. Overall, polymer-based DDSs are going to change the way skin cancer is treated by making it more effective, safer, and more focused.

Keywords: Polymer, Drug Delivery system, Skin Cancer.

1. INTRODUCTION

General Background

Skin cancer is one of the most common types of cancer in the world. It happens when skin cells grow in a way that isn't normal, usually because of UV rays. Conventional treatments, like surgery, radiation therapy, and chemotherapy, often have bad side effects and aren't very good at what they're supposed to do.

Significance of Polymer-Based DDSs

The development of polymer-based DDSs opens up new ways to make drugs more stable, control how quickly they are released, improve their ability to penetrate through skin layers, and target cancerous cells specifically. People are interested in natural and

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man-made polymers like chitosan, PEG, PLGA, and PCL because their biocompatibility and ability to change their physicochemical features have made them popular.

Scope of the Review

This review puts together a summary of the latest progress in polymer-based DDSs that are used to find and treat skin cancer. It talks about the different kinds of polymers, how they are delivered, their uses in medicine and diagnostics, problems they can cause, and where they think future study should go.

2. METHODOLOGY

This study used a method called "systematic review." Keywords like "skin cancer," "nanoparticles," "biodegradable polymers," and "polymer drug delivery" were used to search databases like PubMed, Scopus, Web of Science, and Google Scholar. Research on polymer-based DDSs for skin cancer that was published in a peer-reviewed magazine within the last ten years was required to be included. Studies that didn't have anything to do with polymer delivery methods or that only looked at other types of cancer were ruled out. The final choice was made up of 33 study papers. The following workflow diagram illustrates the methodology used for this literature review:

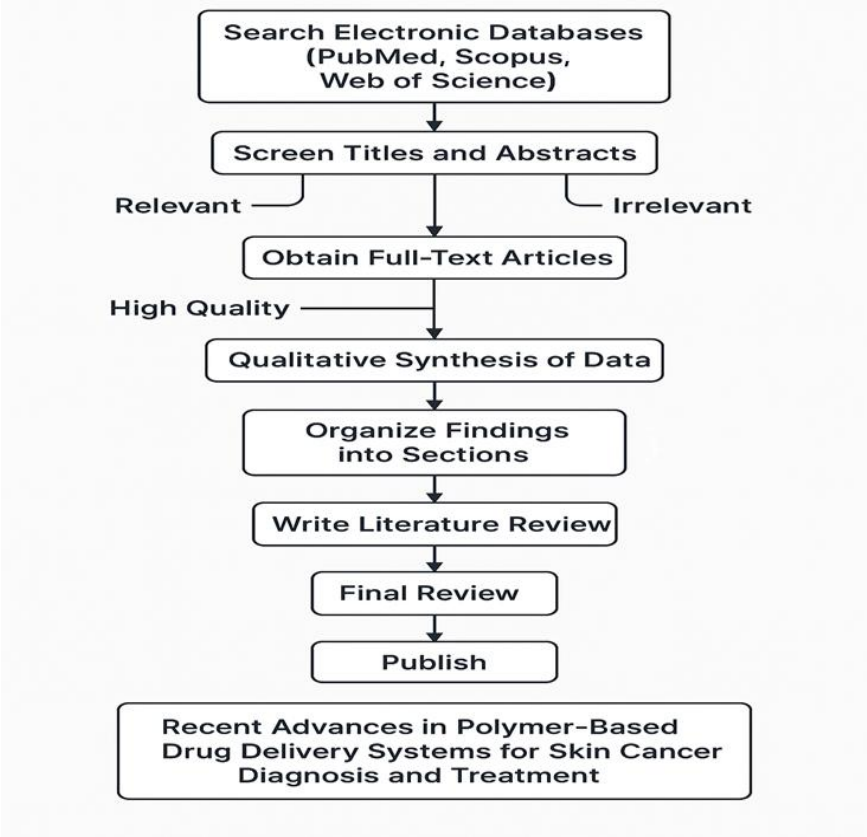

Fig 1: Workflow diagram illustrates the methodology

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3. LITERATURE REVIEW

The following table (Table 1) summarizes the key findings from the reviewed research papers, focusing on major outcomes and the associated research challenges. It provides a consolidated view of advancements and gaps in polymer-based drug delivery systems for skin cancer diagnosis and treatment.

Table 1: Summary of literature review as table

Ref.No	Research Paper Title	Major Outcome of Study	Research Gap/Challenge
1	Advancements in nanoparticle-based treatment approaches for skin cancer therapy	Demonstrated multifunctional nanoparticles improving targeted delivery and reduced toxicity.	Requires more clinical validation and long-term toxicity studies.
2	Gene Regulations upon Hydrogel-Mediated Drug Delivery Systems in Skin Cancers	Showed regulation of gene expression via hydrogel DDS.	Need for in vivo studies and toxicity analysis.
3	Magnetic Gels in Skin Cancer Treatment	Magnetic gels enhance diagnostics and drug targeting.	Clinical testing and cost-effectiveness remain unexplored.
4	Exploring Nanocarriers as Treatment Modalities for Skin Cancer	Nanocarriers improve penetration and efficacy in therapy.	Scalability and regulatory approvals are lacking.
5	Recent Advances of Nanotechnology in the Treatment of Skin Cancer	Nanotech enables better delivery, monitoring, and control.	Translation to clinical practice is slow.
6	Intelligent hydrogels for treating malignant melanoma	Smart hydrogels offer responsive and controlled release.	Complexity in design and biocompatibility testing needed.
7	Polymer-Based Drug Delivery Systems for Cancer Therapeutics	Polymers provide versatility in cancer drug delivery.	Requires personalization for diverse tumor profiles.
8	Chitosan and Derivatives in Cancer	Chitosan shows good biocompatibility and drug loading.	Instability in some biological conditions limits use.
9	Polymer Drug Conjugated Systems	Demonstrates site-specific drug delivery potential.	Risk of premature drug release not fully resolved.
10	Polymer-Based Hydrogels Applied in Drug Delivery	Hydrogels allow sustained and localized delivery.	Lacks clinical translation and immune response analysis.
11	Polymeric Nanoparticles for Targeted Skin Drug Delivery	Effective penetration and local drug retention.	Manufacturing challenges for scale-up.
12	PLGA Nanoparticles in Nanomedicine	Versatile PLGA systems offer targeted cancer therapy.	Risk of burst release and degradation needs control.
13	Microsponges Based DDS	Microsponges offer high payload with sustained release.	Limited studies on skin permeability and safety.
14	Hybrid Systems Using Nanoemulgels	Nanoemulgels show synergy in topical cancer therapy.	Regulatory and formulation consistency issues.

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15	Smart Photodynamic Therapy with Chitosan	Enables on-demand drug activation in cancer tissues.	Control over light exposure and tissue depth required.
16	Gene Therapy for Wound Healing	Enhances angiogenesis using polymer DDS.	Safety concerns over gene transfer still exist.
17	Stimuli-responsive Alginate Nanogels	Responsive systems ensure site-specific delivery.	Trigger accuracy and reproducibility are issues.
18	Sorafenib-Based DDS	Shows prolonged and site-specific drug release.	Resistance development and toxicity monitoring needed.
19	pH-responsive Polymers for DDS	Effective in tumor microenvironment targeting.	Ensuring stability before reaching target site is a gap.
20	PEG-based Hydrogels for Drug Delivery	Hydrogels reduce systemic toxicity and prolong action.	Mechanical strength and retention issues.
21	PEI Co-Delivery System for Breast Cancer	Improved transfection efficiency in therapy.	Cytotoxicity of PEI remains a concern.
22	Nano-Gels for Skin Cancer	Effective topical treatment via nano-sized gels.	Long-term dermal toxicity and inflammation unknown.
23	Smart Nanoparticles for Cancer Therapy	Responsive NPs enhance precision and effectiveness.	Tumor heterogeneity challenges universal application.
24	Electrospinning Nanofiber Scaffolds	Improved dermal drug absorption using nanofibers.	Standardization in production and clinical use needed.
25	Lipid-Polymer Hybrid NPs for Topical DDS	Hybrid carriers provide better retention and control.	Complex formulation process limits reproducibility.
26	Nanofibers for Topical Therapeutics	Nanofibers improve stability and skin absorption.	Cost and large-scale synthesis challenges.
27	Lipid Polymer Hybrid NPs in Cancer	Combines benefits of both systems for synergy.	Inconsistent particle size and stability are concerns.
28	Nanomedicine in Breast Cancer	Targets delivery, enhances bioavailability.	Clinical studies are insufficient and expensive.
29	Doxorubicin Loaded Nanogel	Penetrates skin effectively for breast cancer therapy.	Lacks long-term patient safety evaluation.
30	Methacrylate Nanofilms for Skin Cancer	Offers sustained release of anticancer drugs.	Risk of skin irritation and environmental impact.
31	Polymer Microneedles for Transdermal Delivery	Painless and efficient delivery across skin barrier.	Risk of skin infection and cost of production.
32	Smart Nanostructured DDS	Promotes targeted release triggered by environment.	Potential for off-target effects and systemic toxicity.
33	Localized Cancer Combination Therapy	Multi-drug delivery through localized systems.	Complexity in synchronizing drug actions and dosages.

4. MAJOR INSIGHTS FOUND

A thorough look at 33 new studies (Table-1) on drug delivery systems (DDSs) based on polymers for skin cancer shows important findings. Most study shows that polymer-based nanocarriers are very good at targeting cancer cells while also lowering their effects on

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the body as a whole. Natural and manufactured polymers can be used in many ways, such as to control drug release, make them biodegradable, or change their surface to help drugs penetrate better. A number of studies also look into the possibilities of diagnostic imaging and delivery that is responsive to stimuli. However, there are still problems with clinical translation, long-term biocompatibility assessments, and manufacturing methods that can be used on a large scale.

5. CASE STUDIES

Case studies show that polymeric DDSs like PLGA, chitosan, and PEGylated nanoparticles can effectively target both melanoma and non-melanoma skin cancers in both in vitro and in vivo settings. Some versions got better permeation and tumor-specific accumulation with few side effects. For example, PLGA nanocarriers with 5-fluorouracil and PEGylated doxorubicin showed a lot of tumour shrinkage in mouse models. These examples show that personalized DDSs might be able to meet the specific therapeutic needs of each patient.

6. CHALLENGES AND FUTURE DIRECTIONS

Even though there has been success that is encouraging, polymer-based DDSs for skin cancer still have problems. Some of these are inconsistent clinical results, the possibility that nanomaterials are harmful, the development of immune responses, and a lack of clarity in regulations. In the future, researchers need to focus on long-term safety profiles, watching drugs in real time, and personalized medicine methods. Using AI to drive design and high-throughput screens together could speed up DDS optimization. Closing the gap between how well something works in the lab and how well it works in the clinic will require collaborations between different fields and help from regulators.

7. DISCUSSION AND CONCLUSION

This review emphasises that polymer-based drug delivery methods are a new and exciting way to diagnose and treat skin cancer. There have been big improvements in polymer flexibility, tumor-targeting effectiveness, and co-delivery methods, according to the research. But before these systems can be used in hospitals, more study needs to be done to fix the problems and issues with regulations that have already been mentioned. Polymeric DDSs have the potential to completely change the way skin cancer is treated if new ideas are kept coming up and translated into practice.

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