Advancements in nanoparticles for transdermal drug delivery systems.

Bohong Zu*

School of Pharmacy, Guangdong Pharmaceutical University, Guangzhou, China

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Description

Transdermal drug delivery systems have gained significant attention in recent years due to their non-invasive nature and ability to provide controlled drug release. Nanoparticles, with their unique properties and versatility, have emerged as promising carriers for enhancing drug delivery through the skin. Nanoparticles offer several advantages when incorporated into transdermal drug delivery systems. Firstly, their small size allows for deeper penetration into the skin, facilitating efficient drug uptake. Additionally, nanoparticles can encapsulate a wide range of drug molecules, including hydrophobic and hydrophilic compounds, thereby expanding the therapeutic options for transdermal delivery. Moreover, nanoparticles can protect drugs from degradation, improving their stability and prolonging their release. This controlled release feature ensures a sustained therapeutic effect, reducing the frequency of drug administration. Furthermore, nanoparticles can be modified to target specific skin layers or cells, enhancing drug accumulation at the desired site while minimizing systemic exposure and side effects.

Despite their potential, nanoparticles face certain challenges when incorporated into transdermal patches. The selection of suitable nanoparticle materials is important to ensure biocompatibility, stability, and controlled drug release. Additionally, issues related to nanoparticle size distribution, aggregation, and skin permeation need to be carefully addressed. Skin barrier properties, such as the stratum corneum, can hinder nanoparticle penetration, requiring innovative strategies to enhance skin permeability. Moreover, the scalability and cost-effectiveness of nanoparticle production methods need to be considered for their successful translation into commercial transdermal patches.

Recent advancements have contributed to the progress of nanoparticle-based transdermal drug delivery systems. One approach involves the use of lipid-based nanoparticles, such as Solid Lipid Nanoparticles (SLNs) and Nanostructured Lipid Carriers (NLCs). These lipid-based systems offer improved drug loading, enhanced stability, and controlled release properties. Additionally, the use of polymeric nanoparticles, including Poly (Lactic-co-Glycolic Acid) (PLGA) nanoparticles, has gained attention. These nanoparticles can be tailored to achieve desired release profiles and exhibit excellent biocompatibility. Various surface modifications and functionalizations have been explored to enhance nanoparticle penetration and target specific skin layers or cells. For instance, surface modification with penetration enhancers, such as oleic acid or surfactants, has shown improved skin permeation. Moreover, active targeting strategies involving ligands or antibodies on the nanoparticle surface have been investigated to achieve specific interactions with receptors or cells in the skin.

Incorporating stimuli-responsive nanoparticles into transdermal patches is another exciting development. These nanoparticles can respond to external stimuli, such as temperature, pH, or light, triggering drug release at the desired site or in response to specific conditions. This approach allows for spatiotemporal control over drug release, enhancing therapeutic efficacy.

Nanoparticles have opened new avenues in transdermal drug delivery, offering numerous advantages for controlled and targeted delivery through the skin. Their small size, versatility, and ability to encapsulate various drug molecules make them promising candidates for transdermal patches. However, several challenges related to skin permeation, nanoparticle stability, and scalability need to be overcome for successful translation into clinical applications. Recent advancements in lipid-based nanoparticles, polymeric nanoparticles, surface modifications, and stimuli-responsive systems have shown promise in addressing these challenges and improving transdermal drug delivery. Further research and development in this field will likely lead to the design of more effective and patient-friendly transdermal patches, expanding the therapeutic options for various diseases and improving patient outcomes.

*Correspondence to:

Bohong Zu,

School of Pharmacy,

Guangdong Pharmaceutical University,

Guangzhou,

China,

E-mail: zubohong@gmail.com

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