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A Review on the Mechanisms, Applications, and Clinical Trials of Advanced Technologies in the Transdermal Drug Delivery System

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Abstract Transdermal Drug Delivery Systems (TDDS) have emerged as a promising method for administering therapeutic agents due to their non-invasive nature and patient-friendly approach. However, the effectiveness of this system is limited to drugs with specific physicochemical properties that allow for transdermal

delivery as the skin acts as a barrier. To address this limitation, researchers have been exploring alternative approaches to improve drug delivery through the stratum corneum, ensuring consistent drug distribution at controlled rates. Third-generation delivery systems have been developed to facilitate the delivery of various drugs across the skin barrier by disrupting the stratum corneum while protecting deeper skin tissues from injury. This review has explored various approaches that have gained popularity in enhancing drug delivery through TDDS, including microneedle-mediated, nanoparticle-enabled, thermal ablation-enhanced, and electroporation-driven delivery systems. It has discussed the mechanisms of drug delivery and potential applications for different types of drugs and detailed the clinical studies. This review has also highlighted the significant advancements in TDDS, offering valuable insights into both the pharmaceutical field and biomedical applications. The continued exploration and refinement of these delivery systems, particularly with the incorporation of Internet-of-Things (IoT) technology, Artificial Intelligence (AI), and machine learning, hold promise for expanding the scope of therapeutic interventions.

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