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Review on Transdermal Drug Delivery in Diabetes Mellitus Treatment

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Abstract: *The following review paper describes about transdermal drug delivery system. Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. Conventional therapies, including oral hypoglycemic agents and injectable insulin, are effective but often face challenges such as poor patient compliance, gastrointestinal degradation, first-pass metabolism, fluctuating plasma drug levels, and discomfort associated with repeated injections. Transdermal drug delivery systems (TDDS) have emerged as a promising non-invasive alternative that can overcome these limitations by providing controlled, sustained, and targeted delivery of antidiabetic agents through the skin.This review discusses the principles and potential of TDDS in diabetes treatment, highlighting the physiological barrier of the stratum corneum and the need for permeation-enhancing strategies.*

Keywords: Transdermal Drug Delivery System, Diabetes Mellitus, Microneedles, Smart Patches

I. INTRODUCTION

NOVEL DRUG DELIVERY SYSTEM [NDDS]:

Novel Drug Delivery Systems (NDDS) represent advanced approaches to delivering pharmaceutical compounds in ways that enhance therapeutic efficacy, improve patient compliance, and reduce side effects. This section explores various innovative drug delivery technologies and their applications in modern pharmaceutical practice.[1]

TRANSDERMAL DRUG DELIVERY SYSTEM [TDDS]:

A transdermal drug delivery system (TDDS) is one of the systems lying under the category of controlled drug delivery, in which the aim is to deliver the drug through the skin at a predetermined and controlled rate. It has various advantages, like prolonged therapeutic effect, reduced side-effects, improved bioavailability, better patient compliance and easy termination of drug therapy.

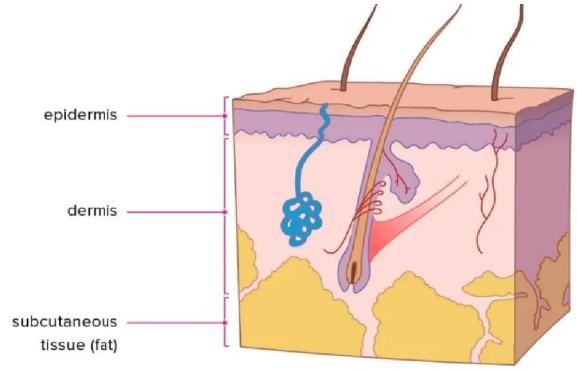

FIGURE 1: STRUCTURE OF SKIN.[2]

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PARTS OF THE SKIN:

The skin, the largest organ of the human body, is composed of three main layers, each serving unique structural and functional roles:

1. Epidermis – The outermost protective layer that acts as a barrier against environmental damage, pathogens, and water loss. It is mainly composed of keratinocytes and includes specialized cells such as melanocytes and Langerhans cells.
2. Dermis – The middle layer located beneath the epidermis, consisting of connective tissue, collagen, elastin fibers, blood vessels, lymphatics, and nerve endings. It provides mechanical strength, elasticity, and supports thermoregulation.
3. Hypodermis (Subcutaneous tissue) – The deepest layer made up of adipose tissue and connective tissue. It acts as insulation, energy storage, and cushioning for underlying structures such as muscles and bones. [3].

ADVANTAGES OF TDDS:

- Self-administration is possible and continuous, sustained release of the drug
- Avoids peak and trough drug levels and longer and multiday dosing intervals
- Avoids first-pass hepatic metabolism and enzymatic degradation by the gastrointestinal tract and also avoids gastrointestinal irritation
- Less frequent dosing improves patient compliance
- Alternate route for patients who are unable to take oral medications
- Dose delivery unaffected by vomiting or diarrhoea
- Drug administration stops with patch removal

DISADVANTAGES OF TDDS:

- Only small lipophilic drugs can be delivered currently through the skin
- Drug molecule must be potent because patch size limits the amount that can be delivered
- Not suitable for high drug doses
- Adhesion may vary with patch type and environmental conditions
- Skin irritation and hypersensitivity reactions may occur
- The barrier functions of the skin change from one site to another on the same person, from person to person and with age [4]

DIABETES MELLITUS:

Diabetes mellitus, or simply diabetes, is a group of metabolic diseases in which a person has high blood sugar, either because the pancreas does not produce enough insulin, or because cells do not respond to the insulin that is produced [5]

TYPES OF DIABETES MELLITUS (DM):

Type 1 DM results from the body's failure to produce insulin, and presently requires the person to inject insulin or wear an insulin pump. This form was previously referred to as "insulin-dependent diabetes mellitus" (IDDM) or "juvenile diabetes"

Type 2 DM results from insulin resistance, a condition in which cells fail to use insulin properly, sometimes combined with an absolute insulin deficiency. This form was previously referred to as non-insulin dependent diabetes mellitus (NIDDM) or "adult-onset diabetes".

The third main form, gestational diabetes occurs when pregnant women without a previous diagnosis of diabetes develop a high blood glucose level. [5] [7]

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RISK FACTORS:

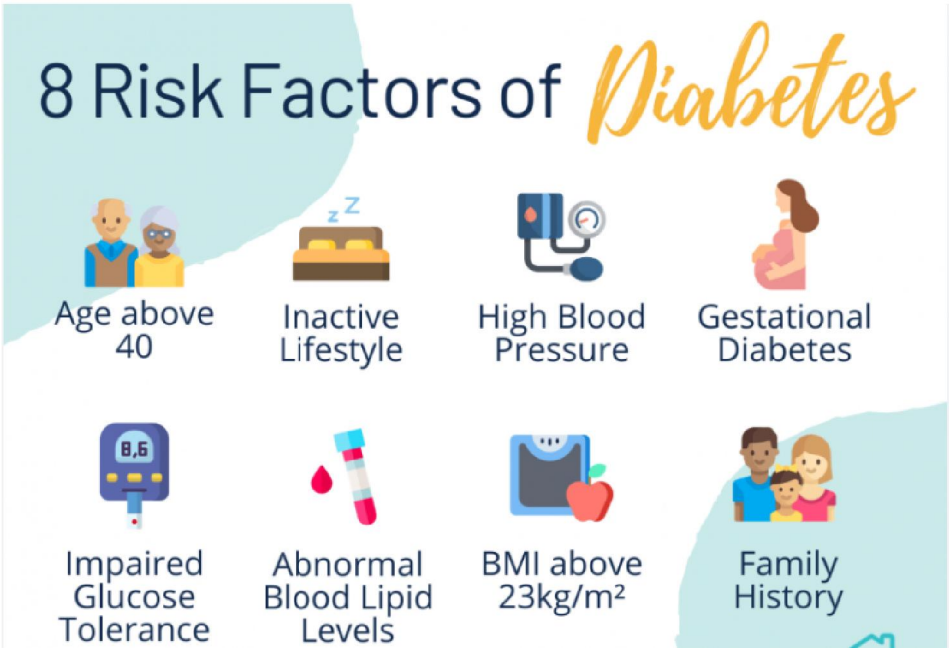

FIGURE 2: RISK FACTORS OF DIABETES[6]

PHYSICOCHEMICAL EVALUATION

- Physical Appearance: Visual inspection for colour, clarity, smoothness, and flexibility.
- Thickness Uniformity: Measured at multiple points using digital callipers.
- Weight Uniformity: Ensures consistent drug loading across patches.
- Folding Endurance: Number of folds before breaking, indicating flexibility
- Moisture Content & Uptake: Evaluated using desiccators with calcium chloride or potassium chloride.
- Flatness: Assesses deformation using percent constriction.
- Water Vapor Transmission Rate (WVTR): Indicates breathability and moisture control.
- Tensile Strength & % Elongation: Measures mechanical durability using force and elongation formulas.[8]

MECHANICAL PROPERTIES

- Tensile Strength: Indicates the maximum stress the patch can withstand before breaking. Measured in kg/mm² using a tensiometer.
- Folding Endurance: Patch is folded repeatedly at the same place until it breaks. Indicates flexibility and mechanical resistance.
- Peel Adhesion Test: Evaluates adhesive strength required to remove the patch. Measured using a texture analyser.[9]

IN-VITRO EVALUATION

- Drug Release Studies: Using Franz diffusion cell with artificial/synthetic membranes (e.g., cellulose acetate). Samples are withdrawn at intervals and analysed spectrophotometrically.
- Permeation Studies: Assess drug diffusion across animal or human skin. Used to calculate flux, permeability coefficient, and lag time.[10]

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IN-VIVO EVALUATION

- Pharmacokinetic Studies: Assesses drug plasma concentration over time, bioavailability, and half-life in animal models or humans.
- Skin Irritation and Sensitivity Test: Tested on animals (e.g., rabbit) to evaluate erythema, edema, or allergic responses. [11]

STABILITY STUDIES

Performed under ICH guidelines (temperature, humidity, light). Parameters tested include:

- Physical appearance
- Drug content
- Adhesive properties
- Drug release rate [12]

II. CONCLUSION

Novel Drug Delivery Systems (NDDS) represent a revolutionary advancement in modern pharmaceutics by addressing the limitations of conventional dosage forms such as poor bioavailability, systemic side effects, and low patient compliance. Among these, the Transdermal Drug Delivery System (TDDS) has emerged as a promising approach for achieving controlled, sustained, and targeted delivery of drugs, especially in chronic conditions like diabetes mellitus. Transdermal patches not only bypass first-pass metabolism but also provide improved therapeutic efficacy, reduced dosing frequency, reduce Lipoatrophy and enhanced patient adherence. The use of the Franz diffusion cell in evaluating transdermal formulations plays a critical role in determining drug release and permeation characteristics, ensuring reliability and reproducibility of results before in-vivo testing. By combining innovative carriers such as nanoparticles, liposomes, and ethosomes with advanced evaluation techniques, NDDS continues to open new avenues for safer, more efficient, and patient-friendly therapies. Overall, NDDS and TDDS contribute significantly to the future of personalized medicine, ensuring better therapeutic outcomes and improved quality of life for patients.

III. RESULT

From the overall review, it is clear that Transdermal Drug Delivery Systems (TDDS) have strong potential in the treatment and long-term management of diabetes mellitus. These patches help deliver drugs like insulin and anti-diabetic agents through the skin in a controlled and painless manner, reducing the need for frequent injections. Various studies show that transdermal systems can maintain steady drug concentration in the blood, helping to avoid sudden spikes or drops in glucose levels. This results in better glycemic control, improved patient comfort, and increased therapy adherence, especially for those who fear needles or struggle with daily dosing

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