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# Transdermal Patches: A General Overview

[1]Isha Balasaheb Nirbhavane [2]Pranjali Parit [3]Ragini Kadvekar

[1]Bpharm Student [2]Bpharm Student [3]Guide (Assistant Professor)

[1]Deapartment of Pharmacy

[1]Matoshri College of Pharmacy, Nasik, India

**ABSTRACT:**

A transdermal patch is a transdermal delivery method that can solve issues with oral medication administration and other traditional drug administration methods. Compared to oral administration, patches can offer controlled drug release and have benefits like avoiding first-pass metabolism, improving drug bioavailability, preventing gastrointestinal (GI) tract side effects, reducing patient variability, keeping a constant drug in plasma, and producing a stable therapeutic effect. The historical development, justification, and mechanism of drug absorption by transdermal patches—passive diffusion over the stratum corneum, epidermis, and dermis—are covered in this article. Numerous patches kind are investigated, such as drug-in-adhesive systems, reservoir, and matrix. Drugs with low molecular weight, lipophilicity, and high potency are ideal for TDDS, whereas patches need biocompatible polymers and strong adherence. Although transdermal systems provide benefits like regulated dosage and fewer adverse effects, they can have drawbacks including skin irritation and poor drug permeability. Clinically effective drugs include fentanyl patches, nitroglycerin, and nicotine. Nanotechnology-enabled patches, iontophoresis, and microneedles are potential future developments.

**Keywords:** Transdermal drug delivery, Transdermal patches, Controlled release, Skin permeability.

## 1. INTRODUCTION

The oral route is currently the most often used method of medication delivery. Although this has the noteworthy benefit of being simple to administer, it also has serious disadvantages, including low bioavailability because of hepatic metabolism (first pass) and a propensity to cause abrupt spikes in blood levels, both high and low, necessitating high or frequent dosing, which can be expensive and inconvenient. To get around these issues, a new drug delivery system must be created that will reduce the size and quantity of dosages while improving the therapeutic efficacy and safety of medications by placing them more precisely (i.e., site-specific), spatially, and temporally within the body. In order to deliver innovative, genetically modified medications (such as peptides or proteins) to their site of action without causing severe immunodeficiency or biological inactivation, a new drug delivery system is also necessary.[1] An ideal alternative to administering medications orally is transdermal delivery. Transdermal distribution has a number of advantages over oral administration.[2] The importance of transdermal drug administration has increased recently because of its possible benefits, which include avoiding hepatic first-pass metabolism, maintaining blood levels for a long period of time, lowering the frequency of doses, increasing doses, improving bioavailability, lessening gastrointestinal irritation caused by local contact with the stomach mucosa, and improving patient compliance.[3]

The term "transdermal therapeutic systems" refers to self-contained, discrete dosage forms that, when applied to undamaged skin, allow the drug or drugs to enter the systemic circulation at a controlled rate.[4,5] Transderm-Scop, the first transdermal drug delivery (TDD) product created in 1980, included the medication Scopolamine to cure motion sickness.[6] A transdermal medication delivery system is one that uses the skin to administer medications in order to have a systemic effect.[7] These dosage forms transport the medication to the reasonable epidermis and possibly dermal tissue of the skin, resulting in a local therapeutic effect.[8] Drugs with short biological half-lives that need frequent dosage can benefit from TDDS's stable infusion of the medication over an extended period of time, which improves patient compliance. This approach can also prevent side effects or treatment failure, which are often linked to intermittent dosage for chronic illness.[9]

## 2.HISTORICAL BACKGROUND

The origins of transdermal therapy date back to ancient civilizations. Egyptians, Greeks, and Romans used ointments, poultices, and plasters to deliver medicinal agents through the skin. However, the modern era of transdermal drug delivery began in the 20th century when researchers started to understand the physicochemical properties that enable drug molecules to penetrate the skin barrier.

The first landmark in transdermal technology was achieved in 1979, when the U.S. Food and Drug Administration (FDA) approved Transderm-Scop, a scopolamine patch developed by ALZA Corporation, for motion sickness prevention (Chien, 1992). This was followed by Nitro-Dur (nitroglycerin patch) in the early 1980s for angina pectoris, and later by Nicoderm CQ (nicotine patch) in the 1990s for smoking cessation. These patches demonstrated that controlled, sustained drug delivery through the skin was feasible and clinically beneficial.[10]

As the technology evolved, second-generation patches introduced permeation enhancers and more sophisticated adhesives, while third-generation systems incorporated microneedles, iontophoresis, and nanocarriers to improve penetration of hydrophilic and large molecular weight drugs.[11]

Today, transdermal delivery is a mature, research-intensive field encompassing over 40 commercially available products for various therapeutic indications, with several more in clinical development.[12]

## 3.TRANDERMAL PATCH

*Definition:* Transdermal patches are medicinal adhesive patches applied to the skin that allow a prescribed dosage to enter the bloodstream through the skin.[13]

A transdermal patch, often known as a skin patch, regulates the rate at which the liquid medication in the reservoir inside the patch can enter the bloodstream through the skin by using a unique membrane. To be utilised as a skin patch, some medications need to be mixed with substances that improve their penetration of the skin, including alcohol. Scopolamine (for motion sickness), nicotine (for quitting smoking), oestrogen (for menopause and to prevent osteoporosis after menopause), nitroglycerin (for angina), and lidocaine (for shingles pain; herpes zoster) are among the medications that are applied as skin patches. However, many chemicals, like insulin molecules, are too big to fit through the epidermis. Applying patches to the skin removes the need for pumps or syringes to gain vascular access.14,15]

This approach has many benefits over more conventional administration routes like oral or intravenous. Transdermal patches provide a regulated and prolonged release of drug, ensuring stable therapeutic levels in the bloodstream. This can minimize the frequency of dose and increase efficacy.[16]

A large amount of medication is injected into the body. A patch that is applied to the skin over an extended length of time. Because the patch has a higher concentration than the rest of the area, a diffusion mechanism is employed to disperse the medication straight into the bloodstream through the skin. The drug will continue to spread because of its high concentration [17,18]. Remaining in the bloodstream for a long time. Constant blood concentration of the medication.[19]

Fig 1. Transdermal Patch

## 3.TYPES OF TRANSDERMAL PATCHES

### 3.1 THE DRUG IN TDDS ADHESIVE

The medication is distributed throughout the system's pond's sticky layer. The adhesive layer helps to control the pace of drug distribution in addition to adhering the patch to the skin. A liner surrounds the adhesive layer. Two categories exist.[20]

- SINGLE LAYER DRUG IN ADHESIVE

In this system, the medication is also present in the sticky layer. In this kind of patch, the adhesive layer plays a dual role in releasing the medication and holding the numerous layers and the overall system to the skin. There is a temporary liner and a backing around the adhesive layer.[21]

- MULTI LAYER DRUG IN ADHESIVE

This kind of patch functions similarly to a single-layer patch in that drug release is facilitated by both sticky layers. Nevertheless, in this method, an additional layer that adheres to the medication is typically separated by a membrane, although this may not be always the case. There are both permanent and temporary liner layers in this patch.[22]

### 3.2 RESERVOIR

The drug reservoir in this system is contained between the rate-controlling membrane and the backing layer, and the medication is released via the microporous membrane. The medication may be distributed throughout the reservoir chamber in a solid polymer matrix or in the form of a solution, suspension, gel, or other mixture. [23]

### 3.3 MATRIX SYSTEM

The backing layer, which serves as the formulation's outer layer, and the adhesive are the primary constituents of the matrix system. Initially, medications are combined with additional ingredients like boosters and polymers to create a sticky solution, which is subsequently evaporated to create a matrix film. The backing film is then covered with the matrix film and glue. On the market, the most popular transdermal patch is the matrix-type patch. One benefit of this matrix approach is that the patch will form a thin and elegant preparation, making it easy to use and facilitating a quick, simple, and affordable production procedure.[24]

### 3.4 VAPOUR PATCH

This type of patch's adhesive layer not only holds the several layers together but also releases vapour. For a maximum of six hours, the freshly released vapour patches release the essential oils. The vapour patches, which are primarily used for decongestion, release essential oils. There are other controller vapor patches that improve the quality of sleep that can be purchased. [25]

### 3.5 MATRIX DISPERSION SYSTEM

The medications are uniformly distributed throughout the hydrophilic or lipophilic polymer matrix. The polymer-containing medications are placed on a certain base plate within a compartment made of a backing layer that is impervious to pharmaceuticals. To create a strip of adhesive rim, the adhesive is placed around the outside of the drug reservoir rather than on its front side.[26]

### 3.6 MICRO RESERVOIR SYSTEM

This system is the result of combining matrix dispersion and reservoir systems. To create thousands of insoluble tiny spheres of drug reservoirs, the drug is suspended in an aqueous solution of a water-soluble polymer and then uniformly distributed in a lipophilic polymer.[27]

## 4. RATIONALE AND NEED FOR TRANSDERMAL DELIVERY

### 4.1 NEED FOR TRANSDERMAL SYSTEMS

The oral route, though the most common and convenient, suffers from several limitations — enzymatic degradation, first-pass metabolism, variable absorption due to gastrointestinal pH, and irritation of the stomach mucosa. Injectable routes, while bypassing first-pass metabolism, are invasive, painful, and often associated with poor patient adherence.

TDDS address these limitations by allowing direct drug transport through the skin into systemic circulation. This enables steady-state plasma concentrations over prolonged periods, eliminates peak-trough fluctuations, and reduces side effects associated with high systemic drug levels.[28]

### 4.2 WHY THE TRANSDERMAL ROUTE IS ADVANTAGEOUS

- Bypasses first-pass metabolism: Avoids hepatic degradation that affects oral drugs.
- Controlled release: Maintains consistent plasma levels.
- Improved compliance: Non-invasive and user-friendly.
- Reduced systemic toxicity: Avoids drug concentration spikes.
- Self-administration and immediate termination: Can be easily applied or removed. [29]

## 5. MECHANISM OF DRUG DELIVERY AND ABSORPTION

Transdermal patches deliver drugs across the skin through a passive diffusion process governed by Fick's law. The process can be divided into sequential steps:

### 5.1 APPLICATION ON SKIN

When the patch is applied to the skin, the adhesive layer ensures intimate contact, while the occlusive backing layer reduces trans epidermal water loss and increases hydration. Increased hydration enhances permeability of the stratum corneum (Williams & Barry, 2004).

### 5.2 DRUG RELEASE AND PENETRATION PATHWAY

The drug diffuses from the reservoir or matrix layer through the adhesive and into the stratum corneum. The rate of release depends on drug concentration, solubility, and the diffusion coefficient of the polymer matrix.

#### a) Crossing the Stratum Corneum

The stratum corneum, a 10–20 µm thick outermost layer, is the primary barrier to drug transport. It consists of dead keratinized cells (corneocytes) embedded in lipid bilayers, often described as the "brick-and-mortar" model. Drugs can penetrate via:

- ❖ Intercellular route – between corneocytes through lipid pathways.
- ❖ Transcellular route – through corneocytes themselves.
- ❖ Appendageal route – via hair follicles and sweat glands (Elias, 1983).

#### b) Diffusion through Viable Epidermis and Dermis

Once the drug crosses the stratum corneum, diffusion through the viable epidermis and dermis is relatively rapid due to their hydrophilic nature. The dermis contains capillaries that absorb the drug into systemic circulation (Barry, 2001).[30]

#### c) Systemic Absorption and Therapeutic Effect

The drug enters the capillary network, achieving systemic therapeutic concentrations without hepatic metabolism. Controlled plasma levels reduce dosing frequency and enhance efficacy.[31]

**d) Removal of Patch**

Upon removal, further absorption ceases, offering safety and control over therapy. This immediate reversibility distinguishes TDDS from long-acting oral or injectable formulations.[32]

## 6. IDEAL PROPERTIES OF DRUG AND PATCH

### 6.1 IDEAL DRUG CHARACTERISTICS

For a molecule to be suitable for transdermal delivery, it must exhibit:

- Molecular weight < 500 Da.
- Balanced lipophilicity and hydrophilicity (log P 1–3).
- Low dose requirement (< 10 mg/day).
- High potency and stability.
- Non-irritating and non-sensitizing to the skin (Jain, 2012).[33]
- The ideal melting point is below 200°C.
- The drug's saturated solution should have a pH of 5 to 9.
- The medicine should have a half-life of fewer than ten hours.[34]
- Drugs that undergo GI tract degradation or are rendered inactive by the hepatic first-pass effect are good candidates for transdermal administration.
- Drugs that must be taken for extended periods of time or that have negative effects on tissues other than the intended target can also be prepared for transdermal delivery.[35]

### 6.2 IDEAL PATCH CHARACTERISTICS

- Adhesiveness: Strong but non-irritating adhesive for secure skin contact.
- Mechanical strength: Must withstand daily movements.
- Biocompatibility: Should not cause redness, itching, or inflammation.
- Controlled release: Predictable, consistent drug diffusion rate.
- Aesthetic acceptability Should be discreet and comfortable.[36]

## 7. ADVANTAGES OF TRANSDERMAL PATCHES

- Non-invasive administration improves patient comfort.
- Controlled drug release ensures steady plasma levels.
- Reduced dosing frequency enhances compliance.
- Bypasses GI tract and hepatic metabolism.
- Lower systemic side effects due to constant release.
- Immediate termination by patch removal.
- Useful for unconscious or vomiting patients.

- Improved bioavailability compared to oral forms. [37,38]

## 8. DISADVANTAGES OF TRANSDERMAL PATCHES

- Transdermal drug delivery is limited to powerful drug molecules due to its constraints, which are mostly related to the skin barrier function.
- Therapeutic levels are not achievable at high molecular drug levels.
- Risk of an allergic reaction
- Ionic drugs are incompatible with transdermal drug delivery systems.
- If the medicine or formulation irritates the skin, it cannot develop.
- The application site may experience minor discomfort.
- It is unable to provide pulsatile medication delivery

## 9.MARKETED PATCHES

The transdermal product market has been experiencing a notable uptrend, which is probably going to continue in the future. The table provides comprehensive details on the various medications that are delivered by this method, along with the common names that are used to sell them. It also lists the circumstances in which each system is utilised.

| **Product Name** | **Drug** | **Indication** |
|---|---|---|
| Alora | Estradiol | Post menstrual syndrome |
| Androderma | Testosterone | Hypogonadism in males |
| Captapres-TTS | Clonidine | Hypertension |
| Climaderm | Estradiol | Post menstrual syndrome |
| Climara | Estradiol | Post menstrual syndrome |
| Combipatch | Estradiol/Norethindrone | Hormone replacement therapy |
| Deponit | Nitroglycerin | Angina pectoris |
| Duragesic | Fentanyl | Moderate/severe pain |
| Estraderm | Estradiol | Postmenstrual syndrome |
| Fematrix | Estrogen | Postmenstrual syndrome |
| Fempatch | Estradial | Postmenstrual syndrome |

Table 1. TDDS Marketed Product [42]

## 10. APPLICATIONS

- The highest selling transdermal patch in the United States is the nicotine patch, which releases nocotine in controlled doses to help with cessation of tobacco smoking. The first commercially available vapour patch to reduce smoking was approved in Europe in 2007.[43]
- Two opioid medications used to provide round-the-clock relief for severe pain are often prescribed in patch form, fentanly CII (marketed as Duragesic) and buprenorphine CIII (marketed as BuTrans).[44]]
- Hormonal patches:
  - Estrogen patches are sometimes prescribed to treat menopausal symptoms (as well as post-menopausal osteoporosis) and to transgender women as a type of hormone replacement therapy.
  - Contraceptive patches (marketed as Ortho Evra ) and
  - Testosterone CIII patches for both men (Androderm) and women (Intrinsa).[45]
- Nitroglycerin patches are sometimes prescribed for the treatment of angina in lieu of sublingual pills.
- Transdermal scopolamine is commonly used as a treatment for motion sickness.[46]
- The anti-hypertensive drug clonidine is available in transdermal patch form. [47]
- Emsam a transdermal form of the MAOI selegiline, became the first transdermal delivery agent for an antidepressant approved for use in the U.S. in March 2006. [48]
- Daytrana, the first methylphenidate transdermal delivery system for the treatment of Attention Deficit Hyperactivity Disorder (ADHD), was approved by the FDA in April 2006.[49]
- Secuado, a transdermal form of the atypical antipsychotic asenapine was approved by the FDA in October 2019. [5]
- 5-Hydroxytyptophan (5-HTP) can also be administered through a transdermal patch, which was launched in the United Kingdom in early 2014.
- Rivastigmine, an Alzheimer treatment medication, was released in patch form in 2007 under the brand name Exelon.
- In December 2019 Robert S. Langer and his team developed and patented a technique whereby transdermal patches could be used to label people with invisible ink in order to store medical information subcutaneously. This was presented as a boon to "developing nations" where lack of infrastructure means an absence of medical records. The technology uses a "quantum dot dye that is delivered along with a vaccine ".
- Caffeine patches, designed to deliver caffeine to the body through the skin. [51,52,53]

## 11. RECENT ADVANCES AND FUTURE PROSPECTS

### 11.1 RECENT ADVANCES

Modern research focuses on overcoming the barrier properties of the stratum corneum.

- Microneedle patches: Create microscopic pores without pain, enabling delivery of peptides, vaccines, and insulin (Prausnitz, 2017).
- Iontophoresis and sonophoresis: Use electrical current or ultrasound to enhance drug diffusion.
- Nano-carrier systems: Liposomes, niosomes, ethosomes, and solid lipid nanoparticles improve solubility and stability.
- Smart patches: Integrate sensors and Bluetooth devices for feedback-controlled dosing.[54]

### 11.2 FUTURE PSOSPECTS

Future advances in drug delivery systems will use microemulsion, niosomes, and liposomes.

Improving the delivery of drugs with low intrinsic solubility in the majority of traditional formulation excipients is the goal of this work. Numerous possible medications are developed for distribution, including steroids, methotrexate, interferon, antifungal, antibacterial, and local anaesthetics. According to estimates, the transdermal patch market is expected to rise in the future and has lately grown at a rate of 25% annually. This number will rise in the future as new gadgets are developed and the number of transdermal medications on the market rises. As design continues to advance, transdermal distribution of analgesics is probably going to continue to gain traction. To improve safety and effectiveness, research is being conducted. to give more accurate medication administration linked to a longer duration of action, as well as to enhance practical aspects like the patch wearing experience. Other possible advancements include enhanced transdermal technology that, by changing the skin barrier or raising the energy of the drug molecules, uses mechanical energy to boost drug flow across the skin. Following the successful creation of patches by iontophoresis, several "active" transdermal technology modes are being researched for various medications. These include thermal energy (using heat to increase the energy of drug molecules and make the skin more permeable), sonophoresis (using low frequency ultrasonic energy to disrupt the stratum corneum), and electroporation (using brief high voltage electrical pulses to create temporary aqueous pores in the skin). The use of magnetophoresis, or magnetic energy, to enhance medication flux through the skin has been studied. For the treatment of both acute and chronic pain, the transdermal patch can be an underutilised therapy. Researchers anticipate that the popularity and usefulness of this drug administration method will rise with better distribution and a greater selection of analgesics. With over 40% of drug delivery candidate items undergoing clinical trials related to transdermal or dermal systems, transdermal routes of drug delivery systems are now the most successful novel research topic in new drug delivery systems when compared to oral treatment. An easier, safer, and alternate method of systemic drug delivery is the transdermal drug delivery system (TDDS).[55]

## CONCLUSION

Transdermal patches have transformed pharmaceutical therapy by offering a convenient, controlled, and patient-friendly route for systemic drug delivery. Transdermal patch technology is an extremely efficient way to administer drugs, and it has many benefits over other ways. Patches are able to circumvent the first-pass effect and evade the digestive system. Drugs are continuously produced over a long period of time through metabolism. They are widely used to deliver drugs for a variety of ailments, such as hormone replacement therapy, motion sickness, chronic pain, and other medical requirements. The development of total dissolved solids units, which carry peptide and protein molecules, including insulin and growth hormone, will be an important development. Despite challenges like limited drug permeability and potential for irritation, ongoing research in nanotechnology, polymer science, and wearable devices continues to expand their potential. The future of transdermal systems lies in personalized, intelligent, and multifunctional drug delivery platforms that integrate technology with therapy, ensuring safer and more effective treatment outcomes.

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