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TRANSDERMAL DRUG DELIVERY AS A BOON

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ABSTRACT

Majority of the drugs are taken by the oral route but it is not effective. To improve the effectiveness a route emerged known as Transdermal route. This give rise to Transdermal drug delivery system. Transdermal drug delivery systems (TDDS) are dosage forms that involves drug transport to viable epidermal or dermal tissues of the skin for therapeutic effect while a major fraction of drug is transported into the systemic blood circulation. Transdermal drug delivery can be improved by the use of involves the use of penetration enhancers which penetrate into skin to reversibly reduce the barrier resistance. Transdermal delivery have various advantages such as avoidance of presystemic and systemic first pass metabolism ,controlled release, provides non-invasive and easily terminable means for systemic as well as topical drug delivery. This article provides an overview of TDDS, its advantages over conventional dosage forms, drug delivery routes across skin, penetration enhancers, various components of Transdermal patches, types of Transdermal patches, methods of preparation, methods of evaluation, marketed preparations.

Keywords: TDDS, Patch, Market, Techniques.

Introduction

Transdermal drug delivery system are the dosage forms that is applied to the body surface and is designed to deliver the therapeutic effective amount of drug across the skin, into the systemic circulation.[1]Currently, transdermal drug delivery is one of the most prominent way for drug delivery to the systemic circulation via skin.[2] conventional methods of drug administration are effective for most of the drugs but some drugs are unstable,toxic and have narrow therapeutic ranges. Oral drug delivery is by far the most convenient mode of delivering drugs especially when repeated or routine administration is required. As the two faces of a coin TDDS has advantage of easy administration, but has significant drawbacks also such as poor bioavailability due to hepatic metabolism and the tendency to produce rapid blood level spikes, leading to a need for frequent dosing, which is inconvenient.[3]Controlled delivery of drugs through human skin has been the field of research for investigators and transdermal devices have been developed for drugs such as clonidine,estradiol, testosterone,fentanyl,scopolamine,nitroglycerin,estrogen etc.[4]

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Advantages of TDDS

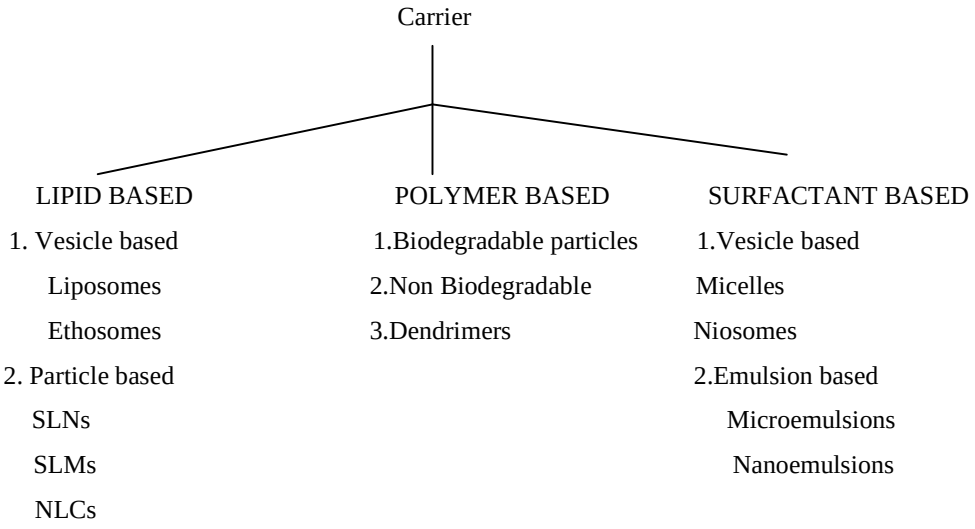
- Avoidance of first pass metabolism thus increasing bioavailability and efficacy of drugs.
- Suitable for unconscious patients,thus act as a substitute to oral drug delivery(in case of vomiting).
- Avoidance of gastro intestinal incompatibility.
- Non invasive in nature thus avoid the risk and inconvenience of intravenous administration of drugs.
- Maintain plasma concentration of potent drugs.
- Dose reduction.
- Reduced inter and intra patient variations.
- Therapy can be terminated at any point of time just by removing the patch.

- Greater patient compliance due to elimination of multiple dosing profiles.
- No fluctuations of drug levels in plasma and blood.
- Predictable and extended duration of activity.
- Improved physiological and pharmacological response.
- No effect of food intake.
- Extended therapy avoiding frequent dose administration.[5,6]

Disadvantages of TDDS

- Potent drugs are the suitable candidates as certain drugs are skin impermeable.
- Skin irritation and inflammation occurs sometimes due to application of patches.
- System components may cause dermatitis at the site of application thus discontinuation becomes necessary
- It cannot be used for molecules of size greater than 500 Daltons.
- The bacteria acting as a host on skin break certain drugs before penetration of it through stratum corneum.
- Achievement of high drug levels in plasma cannot be attained.
- Metabolic enzymes present in the skin metabolises some of the drugs before penetration through its layers.
- Significant lag time cannot be attained
- Tolerance inducing drugs or hormones requiring chronopharmacological management is not suitable candidates for TDDS.
- Use of TDDS is uneconomic. [7, 8]

Carrier based TDDS



Drug delivery routes across the human skin

Drug molecules can enter the skin by three major pathways.

- Through sweat glands with the help of hair follicles
- Through sebaceous glands
- Through stratum corneum

Skin has excellent barrier property, this is the utmost problem associated with dermal delivery system. [9].Figure 1 represents the pathways for delivery of drugs across the skin.

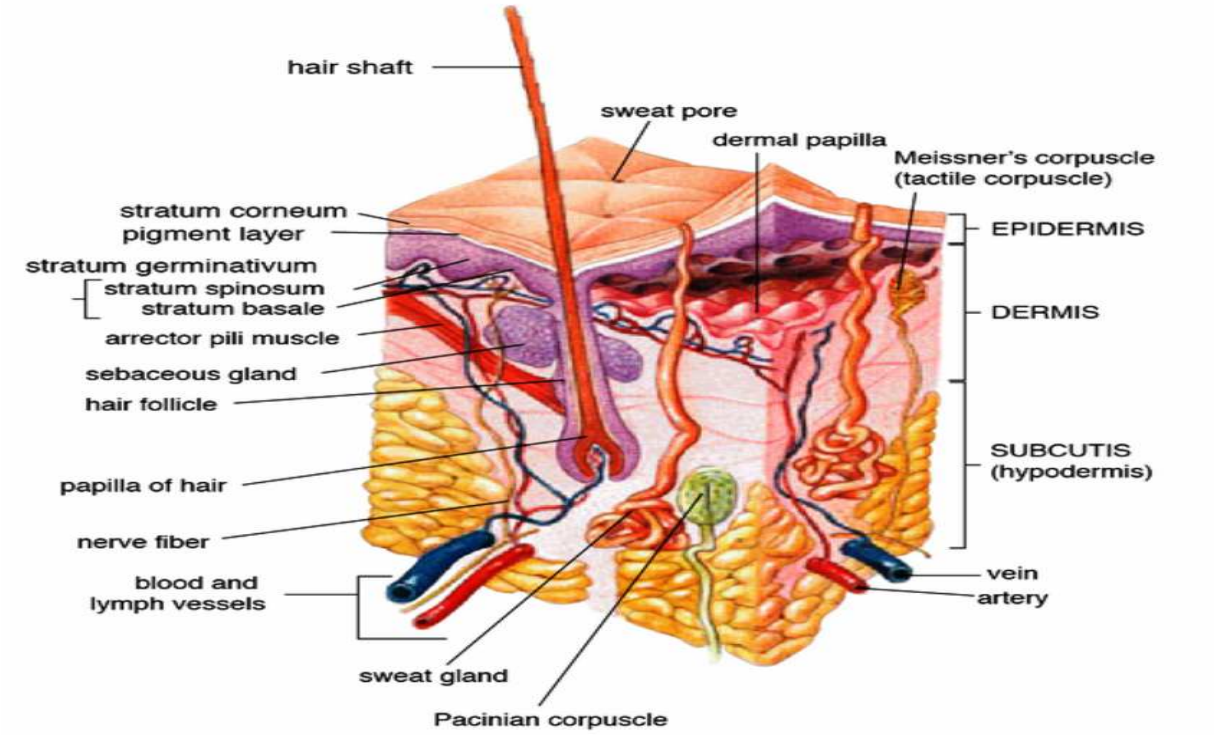
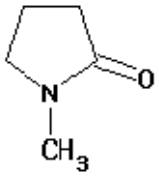
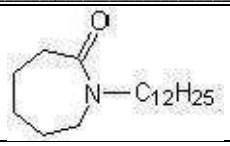
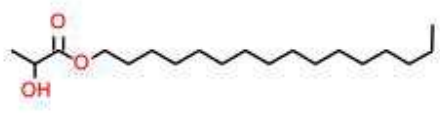
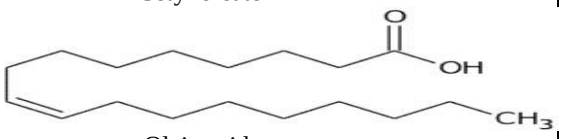
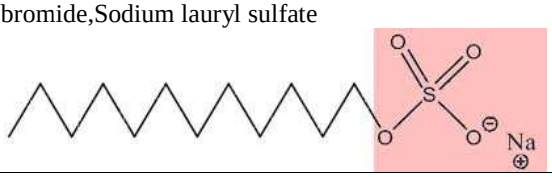
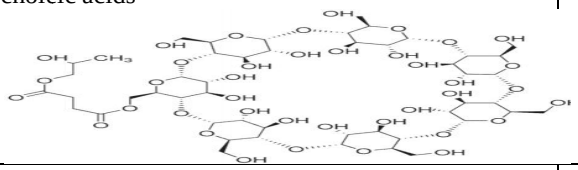
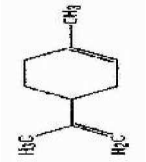
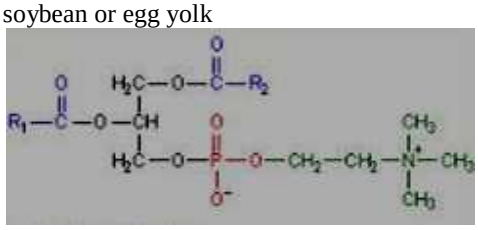


Fig 1: Representation of permeation of drugs through sweat glands(via hair follicles), stratum corneum, sebaceous glands

Penetration enhancers

Table 1 shows the penetration enhancers for Transdermal drug delivery system

Class	Representative compounds	Mechanism of action
Water	-	Increase the solubility of the permeate[10]
Alcohols	Ethyl alcohol C_2H_5OH	Co-permeates with the drug through the lipid channels,partial extraction of lipids[11]
	Polyols: polyethylene glycol HOCH2 - (CH2 - O - CH2)n - CH2OH.	Replaces bound water in the intercellular space, enhances penetration of lipophilic drugs.[12]
Pyrrolidones	N-methyl 2-pyrrolidone 	Increases the diffusivity, and reduces passage through the non polar route by decreasing diffusivity and partitioning.Interacts with both the keratin and lipid component of the Stratum corneum. [13,14]
Azone®	1-Dodecylhexa-hydro-2H-azepine-2-one	Disruption of skin

		lipids[15,16,17]
Fatty acids and esters	Oleic acid, lauric acid, linolic acid, myristic acid,cetyl oleate  Cetyl oleate  Oleic acid	Increases the fluidity of intercellular lipids[18,19]
Surfactants	Polysorbates (Tweens)Polyoxyethylene alkylphenols,Dodecyltrimethyl ammonium bromide,Sodium lauryl sulfate 	Penetrates into skin, causing micellar solubilization of Stratum corneum lipids. Extract lipid from stratum corneum. [20]
Bile salts	sodium choleate, an ox bile extract containing the sodium salts of taurocholic, glycoeolic, desoxycholic and cholic acids, and of the free choleic acids 	enhance the transcutaneous penetration of progesterone and prednisolone[21]
Essential oils,terpenes,terpenoids	Limonene Ascaridole; 1,8-cineole; l-menthol; d-limonene; menthone; nerodidol; carvone; carvacrol; linalool; pulegone; α-pinene  Limonene	Modify the solvent nature of stratum corneum,thus improving drug partition into tissues.[22]
Phospholoipids	Phosphatidylcholine from soybean or egg yolk 	Diffuses into Stratum corneum, disorders intercellular lipids,Enhances drug partitioning into skin[23]

Components of TDDS

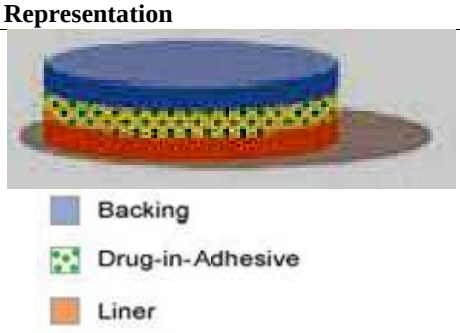
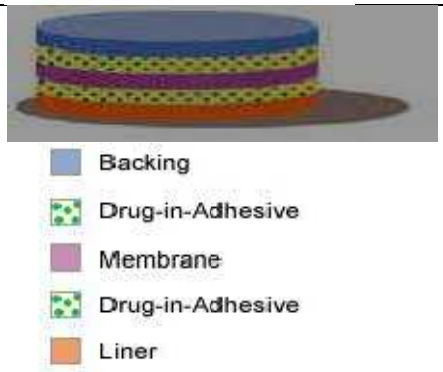
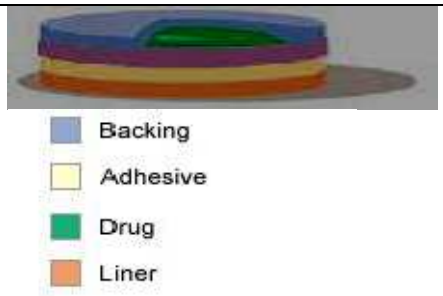
Table 2: Shows components and their characteristics

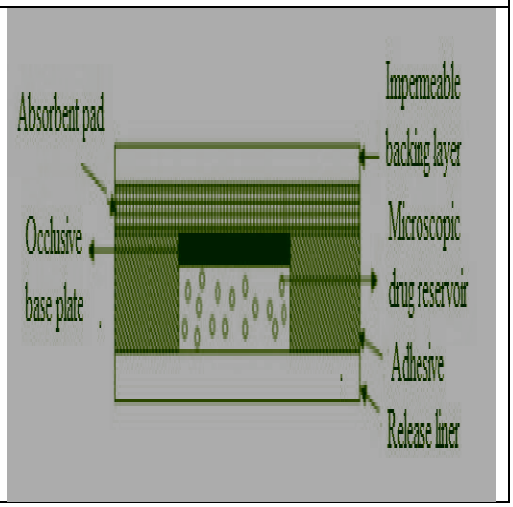
Components	Characteristics
Polymer matrix/Drug reservoir	Mechanism of drug release depends on the physicochemical properties of drug and polymer Classification of polymers used in TDDS is as follows: 1. Natural polymers: e.g. cellulose derivatives, zein, gelatin, shellac, waxes, gums, natural rubber andchitosan *etc.* 2.Synthetic elastomers: e.g. polybutadiene,polyisobutylene, silicon rubber, nitrile, acrylonitrile,neoprene, butylrubber *etc*. 3.Synthetic polymers: e.g. polyvinyl alcohol,polyvinylchloride, polyethylene, polypropylene,polyacrylate, polyamide, polyurea, polyvinylpyrrolidone, polymethylmethacrylate *etc*.[24]
Drug	The ideal characteristics of drug are as follows: 1.should have some degree of solubility of lipophilic and hydrophilic character (ideally greater than 1 mg/ml) 2.should have melting point less than 200 °C. 3.should have molecular weight of less than 1000 units. 4. Saturated aqueous solution of the drug should have a pH value between 5 and 9. 5. Hydrogen bonding groups should be less than 2. 6. should have short biological half life 7. should be non irritant to human skin 8.Tolerance to drug must not develop under near zero order release profile of transdermal delivery 9. should not get irreversibly bound in the subcutaneous tissue 10.The should not get extensively metabolized in the skin [25]
Permeation enhancers	1. interacting with structural components of stratum corneum *i.e.*, proteins or lipids to attain higher therapeutic levels of the drug and increase the permeability 2.chemically modify the barrier functions leading to increased permeability of stratum corneum[26-27]
Adhesive layers	1.must be skin-compatible 2.must be able to dissolve drug and Excipient in quantities sufficient for the desired effect(pharmacological) Three major classes of adhesives used are as follows: Polyisobutylene type pressure sensitive adhesives Acrylic type pressure sensitive adhesives Silicone type pressure sensitive adhesives
Release liners	1. Prevents the loss of the drug that has migrated into the adhesive layer during storage. 2. Prevents contamination. 3.It is composed of a base layer, which may be nonocclusive or occlusive, and a release coating layer made of silicone,teflon
Backing laminates	1. Provide support. 2. Prevent drug from leaving the dosage form through top. 3. Must be impermeable to drugs and permeation enhancers. 4. Should have low moisture vapor transmission rate. 5. Must have optimal elasticity, flexibility, and tensile strength. 6. Must be chemically compatible with the drug, enhancer, adhesive and other excipients.

	7. Must be relatively inexpensive and must allow printing and adhesive lamination.
Rate controlling membrane	Made of polymeric material such as chitosan,poly-2-hydroxyethyl methacrylate (PHEMA)

Types of transdermal drug delivery system

Table 3: Shows representation, characteristics and types of TDDS

Type	Characteristics	Representation
Single layer Drug in adhesive	1.Adhesive layer contains the drug,adhere the various layers together and also responsible for the releasing the drug to the skin. 2.The adhesive layer is surrounded by a temporary liner and a backing.	
Multi layer Drug in adhesive	1.It is composed of a immediate drug release layer and other layer will be a controlled release along with the adhesive layer. 2.This patch also has a temporary liner-layer and a permanent backing.	
Matrix	It is of two types: 1.Drug in adhesive system 2.Matrix dispersion system	
Reservoir	1.Drug reservoir is embedded between an impervious backing layer and a rate controlling membrane. 2.The drug releases only through the rate controlling membrane, which can be micro porous or non	

	porous.	
Vapour patch	1.Adhesive layer adheres various layers together and act as release vapour 2.These patches help to improve sleep conditions and cessate smoking	
Microreservoir system	1. The drug reservoir is formed by first suspending the drug in an aqueous solution of water soluble polymer and then dispersing the solution homogeneously in a lipophilic polymer to form, spheres of drug reservoirs. 2. It is stabilized quickly by cross-linking the polymer in situ.[28-32]	

Methods of preparation

Table 4: Shows various methods of preparation of TDDS

Methods	Description
Assymetric TPX membrane method	(1) Backing membrane-It is heat sealable polyester film with concave diameter of 1 cm. (2) Drug sample is dispensed into the concave membrane (3) Concave membrane is covered by TPX{poly(4-methyl-1-pentene)} and sealed by an adhesive. [(**Asymmetric TPX membrane preparation):** Dry/wet inversion process – (1)TPX is dissolved in a mixture of solvent (cyclohexane) and nonsolvent additives at 60°C to form a polymer solution. (2)The polymer solution is kept at 40°C for 24 hrs and casted on a glass plate to a pre-determined thickness. (3)The casting film is evaporated at 50°C for 30 sec. and then the glass plate is to be immersed immediately in coagulation bath [25°C]. (4)After 10 minutes of immersion, the membrane can be removed, air dry in a oven at 50°C for 12 hours.[33]
Circular teflon mould method	Solutions containing polymers in various ratios are used in an organic solvent. (1) Calculated amount of drug is dissolved in half the quantity of same organic solvent.

	2) Enhancers in different concentrations are dissolved in the other half of the organic solvent and then added. 3) Di-N-butylphthalate is added as a plasticizer into drug polymer solution. 4) The total contents are to be stirred for 12 hrs and then poured into a circular teflon mould. 5) The moulds are to be placed on a leveled surface and covered with inverted funnel to control solvent vaporization in a laminar flow hood model with an air speed of 0.5 m/s. 6) The solvent is allowed to evaporate for 24 hrs. 7) The dried films are to be stored for another 24 hrs at 25±0.5°C in a desiccators containing silica gel before evaluation to eliminate aging effects. 8) The films are to be evaluated within one week of their preparation.[34]
Mercury substrate method	1) Drug is dissolved in polymer solution along with plasticizer. 2) The above solution is to produce a homogenous dispersion and poured in to a leveled mercury surface, covered with inverted funnel to control solvent evaporation.[35]
Isopropyl myristate membrane method	1) Drug is dispersed in a mixture of water and propylene glycol containing carbomer 940 polymer and stirred for 12 hrs in magnetic stirrer. 2)The dispersion's viscosity is increased by the addition of triethanolamine. 3)The formed gel is incorporated in the IPM membrane.[36]
Ethylenevinylacetate copolymer (EVAC) membranes method	1)Drug is dissolved in propylene glycol, carbopol resin will be added to the solution (1% carbopol reservoir gel, polyethelene (PE), ethylene vinyl acetate copolymer (EVAC)) and neutralized by using 5% w/w sodium hydroxide solution. 2)The drug (in gel form) is placed on a sheet of backing layer covering the specified area. 3)EVACmembrane is placed over the gel and the edges are sealed by heat to obtain a leak proof device.[37]
Free film method	1)Free film of cellulose acetate is prepared by casting on mercury surface. 2)A polymer solution 2% w/w is prepared by chloroform. Plasticizers are incorporated at a concentration of 40% w/w of polymer weight. 3)Five ml of polymer solution are poured in a glass ring which is placed over the mercury surface in a glass petri dish. 4)The film formation is noted by observing the mercury surface after complete evaporation of the solvent. 5)The dry film will be separated out and stored between the sheets of wax paper in a desiccator until use[38]
Aluminium backed adhesive film method	1)It is a suitable method in case where loading dose is greater than 10 mg. 2)Chloroform is a solvent of choice 3) The drug is dissolved in chloroform and adhesive material is added to the drug solution and dissolved. 4)A custom-made aluminium former is lined with aluminium foil and the ends blanked off with tightly fitting cork blocks.[39]
Proliposomes method	1)The proliposomes are prepared by taking 5mg of mannitol powder in a round bottom flask (60-70°C) and the flask is rotated at 80-90 rpm and mannitol is dried at vacuum for 30 minutes. 2)Temperature of the water bath is adjusted to 20-30°C. 3)Drug and lecithin (0.1:2.0) are dissolved in a suitable organic solvent mixture; a 0.5ml aliquot of the organic solution is introduced into the RBF at 37°C, after complete drying second aliquot (0.5ml) of the solution is added. 4)After the last loading, the flask containing proliposomes are connected to a lyophilizer and subsequently drug loaded mannitol powders (proliposomes) are placed in a desiccator over night and then sieved through 100 mesh.

	5)The collected powder is put into a glass bottle and stored at the freeze temperature.[40]

Evaluation of TDDS

1. **Interaction studies:** (1) The stability of a formulation depends on the compatibility of drug with excipients.
   (2) Interaction studies are commonly carried out by Thermal analysis, FT-IR, UV and chromatographic techniques. [41]
2. **Thickness of the patch:**The thickness of the drug loaded patch is measured by using a digital micrometer [42]
3. **Weight uniformity:** A specified area of patch(predried at 60°C) is cut in different parts of the patch and weighed. The average weight and standard deviation values are calculated from the individual weights.[43]
4. **Folding endurance:** (1) A strip(specific area) is cut evenly and repeatedly folded at the same place till it broke.
   (2)The number of times the film could be folded at the same place without breaking is the value of the folding endurance.[44]
5. **Percentage Moisture content:** (1)The prepared films are weighed individually and kept in a desiccators(containing fused calcium chloride) for 24 hrs. The films are reweighed and percentage moisture content is determined.[45] Percentage moisture content = [Initial weight- Finalweight/ Final weight] ×100
6. **Percentage Moisture uptake:**1.The weighed films are kept in a desiccator for 24 hrs (containing saturated solution of KCl) in order to maintain 84% RH. The films are reweighed and percentage moisture uptake is determined.[46] Percentage moisture uptake = [Final weight- Initialweight/ initial weight] ×100
7. **Water vapour permeability (WVP) evaluation:(**1)Water vapour permeability is determined with foam dressing method. (2).Natural air circulation oven is used.[47] The WVP can be determined as: WVP=W/A Where, WVP is expressed in gm/m^2 per 24hrs, W is the amount of vapour permeated through the patch expressed in gm/24hrs A is the surface area of the exposure samples expressed in m^2.
8. **Drug content:**A specified area of patch is dissolved in a suitable solvent . Solution is filtered through a filter medium and drug content is analysed. [48]
9. **Polariscope examination:**. Drug crystals examined by polariscope and A specific surface area of the piece is kept on the slide and observe for the drugs crystals to distinguish whether the drug is present as crystalline form or amorphous form in the patch.[49]
10. **Shear Adhesion test:** Cohesive strength of an adhesive polymer is determined and An adhesive coated tape is applied onto a stainless steel plate; a specified weight is hung from the tape. Shear adhesion strength is determined by measuring the time it takes to pull the tape off the plate. The longer the time take for removal, greater is the shear strength.[50]
11. **Peel Adhesion test:** A single tape is applied to a stainless steel plate and then tape is pulled from the substrate at a 180º angle and The force required for tape removed is measured.(PEEL ADHESION FORCE)[51]
12. **Thumb tack test:** The thumb is pressed on the adhesive & Relative tack property is detected.[52]
13. **Flatness test:**Three longitudinal strips are cut from each film at different portions (one from the center, other one from the left side, and another one from the right side.) and The length of each strip was measured and the variation in length because of non-uniformity in flatness was measured by determining percent constriction, with 0% constriction equivalent to 100% flatness.[53]
14. **Percentage Elongation break test:**1.It is determined by noting the length just before the break point.The percentage elongation can be determined as:. Elongation percentage = L1-L2 ×100 Where, L1is the final length of each strip and L2 is the initial length of each strip.[54]
15. **Rolling ball tack test:** Softness of a polymer is measured. & Stainless steel ball is released on an inclined track so that it rolls down and comes into contact with horizontal, upward facing adhesive. The distance the ball travels along the adhesive provides the measurement of tack, which is expressed in inch.[55]
16. **Quick Stick (peel-tack) test:**Tape is pulled away from the substrate at 90ºC at a speed of 12 inches/min. The peel force required to break the bond between adhesive and substrate is measured and recorded as tack value.[56]

17. **Probe Tack test:**Probe(tip) with a surface roughness is brought into contact with adhesive, A bond is formed between probe and adhesive.The subsequent removal of the probe mechanically breaks it. The force required to pull the probe away from the adhesive at fixed rate is recorded as tack.[57]
18. ***In vitro* drug release studies:**The paddle over disc method (USP apparatus V) is used for assessment of the release of the drug from the prepared patches. Dry films is cut into definite shape, weighed, and fixed over a glass plate with an adhesive. The glass plate is then placed in a 500-ml of the phosphate buffer (pH 7.4), and the apparatus is equilibrated to 32± 0.5°C.The paddle is set at a distance of 2.5 cm from the glass plate and operated at a speed of 50 rpm. Samples (5-ml aliquots) can be withdrawn at appropriate time intervals up to 24 h and analyzed by UV spectrophotometer.[58]
19. ***In vitro* skin permeation studies:** Diffusion cell is used for the study.Hair from the abdominal region(Wistar rats weighing 200 to 250g) are removed by a clipper; the dermal side of the skin is cleaned with water to remove any adhering tissues, equilibration is done for an hour in dissolution medium before starting the experiment and is placed on a magnetic stirrer with a small magnetic needle for uniform distribution of the diffusant.The temperature of the cell is maintained at 32 ± 0.5°C.The isolated rat skin piece is mounted between the compartments of the diffusion cell, with the epidermis facing upward into the donor compartment. Sample volume of definite volume is to be removed from the receptor compartment at regular intervals, and an equal volume of fresh medium is to be replaced. Samples can be analyzed spectrophotometrically. [59]

Marketed preparations

Table 5: Shows the market preparations of TDDS

Drug	Application	Marketed Preparation
Lidocaine	For neuropathic pain relief[60]	Lipoderm®
Apomorphine HCl	For parkinson's disease[61]	Passport TM Apomorphine patch
Fentanyl	For management of persistent, moderate to severe chronic pain that: 1.Requires continuous, round-the-clock opioid administration for an extended period of time 2.Cannot be managed by other means such as nonsteroidal analgesics, opioid combinations, or immediate-release opioids [62]	DURAGESIC®
Nicotine	help people stop smoking cigarettes[63]	Nicoderm®CQPatch,Nicotrol® PatchProstep , Habitrao
Nitroglycerine	For angina pectoris[64]	Deponit,Minitran,Nitrodisc, Nitrodur,TransdermNitro
Clonidine	For hypertension	Catapres-TTS
Estradiol	For postmenstrual syndrome	Climara ,Vivelle, Estraderm, Esclim,Alora
Ethinyl Estradiol	For postmenstrual syndrome	Ortho Evra
Testosterone	For hypogonadism in males	Androderm
Nor ethindrone	For hormone replacement therapy	Combipatch
Diclofenac epolamine	Treatment of pain and inflammation	Flector

Buprenorphine	As analgesic for chronic pain	Bu Trans
Iselegiline	For depression	Emsam
Rigotine	For early-stage idiopathic Parkinson's disease	Neupro®
Diclofenac diethylamine	Antiinflammatory	Nupatch
Nitroglycerin estradiol	For angina pectoris	Minitran Climaderm
Oxybutynin	For bladder disorder	Oxytrol®
Estrogen	For hormone replacement therapy	Nuvelle TS
Scopolamine	For motion sickness	Transderm Scop®

For hypertension patches have been made for the following drugs: Timolol maleate, Nicardipine hydrochloride,Indapamide, Pinacidil, Verapamil hydrochloride.

Conclusion

This article reveals prominent knowledge regarding the transdermal drug delivery systems and its evaluation parmeters. These review work conclude that, older drugs by formulating them in new dosage forms has generated enthusiasm among the pharmaceutical scientists to develop new dosage forms TDDS have great potentials, being able to use for both hydrophobic and hydrophilic active substance into promising deliverable drugs. In addition, new dosage forms are essential for other drugs in order to enhance their performance by reducing their dose, increasing absorption, delivering to the target site etc.

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