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FILM-FORMING SYSTEMS IN TOPICAL DRUG DELIVERY: A COMPREHENSIVE REVIEW

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ABSTRACT

The topical route is an attractive alternative to oral and parenteral drug delivery but is limited by the stratum corneum barrier and poor patient compliance with conventional dosage forms. Film-Forming Systems (FFS) represent a novel approach in which a polymeric solution, emulsion, or gel forms a thin, invisible film upon solvent evaporation, ensuring sustained drug release and enhanced substantivity. This review discusses the structure of skin, challenges in dermal delivery, mechanism of film formation, formulation components, evaluation parameters, and applications of FFS. The versatility of FFS in enhancing therapeutic efficacy, improving patient adherence, and enabling controlled drug delivery positions it as a promising system for future transdermal and topical therapies.

KEYWORDS: Film-forming systems, Topical drug delivery, Sustained drug release, Transdermal therapy.

INTRODUCTION

The skin is the most readily accessible organ of the body and acts as a barrier against the micro and macromolecules of the environment because of its low permeability to such substances.[1] The pursuit of enhanced drug delivery through the skin has gained considerable prominence across a range of industries, particularly in the fields of pharmaceutical and cosmeceuticals.[2] Percutaneous absorption of drug through skin mainly occurs via stratum corneum. Stratum corneum is made up of dead, keratinized epidermal cells having thickness of 10 m and acts as a barrier for permeation of drugs. Therefore transport of drug molecules across the skin is difficult.[3]

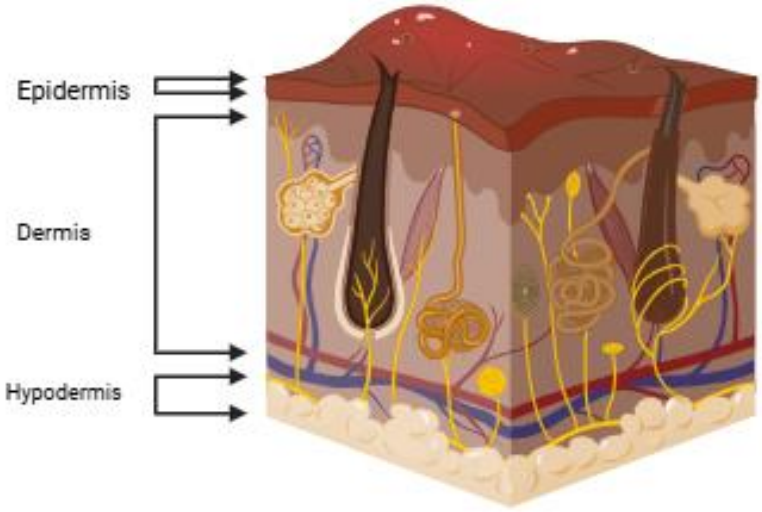
By employing innovative technologies and formulations, these industries are capable of transforming the field of drug delivery, ensuring that patients and consumers alike benefit from more effective therapeutic interventions. While topical drug delivery refers to the treatment of a localized area of the skin, transdermal drug delivery is a method

designed to deliver drugs through the skin and into the systemic circulation for therapeutic effects throughout the body.[4] both topical and transdermal drug deliveries are hindered by certain dis advantages, such as slow treatment speed and the potential for skin irritation, depending on the skin's condition. The most significant limitation is the inherent skin barrier, which serves to prevent the penetration of potentially harmful substances into the body.

Therefore, the advancement of drug delivery technologies through the skin relies not only on the development of new pharmaceuticals but also on the enhancement of techniques that enable the successful permeation of drugs across the skin barrier.[5-6]

Basic structure of skin

Starting from the outermost layer, the skin is essentially composed of the epidermis, dermis, and hypodermis.[7] The human epidermis typically consists of about 40 to 50 layers of stacked squamous epithelial cells, primarily derived from keratinocytes, which is the main cell type found in the epidermis. The epidermises generally formed by four layers: the stratum basale, stratum spinosum, stratum granulosum, and stratum corneum. The deepest layer of the stratum basale is composed of progenitor cells, which are the youngest and most undifferentiated keratinocytes, which continuously renew the epidermis. During differentiation, human keratinocytes may take 30–40 days to migrate from the basal layer to the skin surface to undergo desquamation.[8]



When keratinocytes divide vertically based on the basement membrane, they contribute to keratin formation through differentiation, and when they divide horizontally, they participate in wound recovery through proliferation. This layer is separated from the dermis through a basement membrane named basal lamina. The stratum spinosum and stratum granulosum are composed of nucleated keratinocytes. These two strata comprehend about 15 to 20 layers, and the stratum granulosum has many granules accounting for high levels of keratin synthesis. Langerhans cells can be found in all layers of the epidermis and are more frequent in the stratum spinosum. As the nucleus and intracellular organelles gradually decompose, keratin accumulates, forming the stratum corneum. As keratinization progresses, keratin further accumulates, generating a flexible and strong skin barrier composed of dead keratinocytes.Thestratumcorneumtypically

formsa10–20µm thick layer of keratinized keratinocytes, posing agreat challenge for the topical delivery of molecules.[9]

Topical drug delivery

Topical routes of drug delivery aim for systemic or local effects and offer various advantages, including avoiding first-pass metabolism and the effect of low pH and enzymes in the gastrointestinal tract, as well as a large available surface area.[10-16]

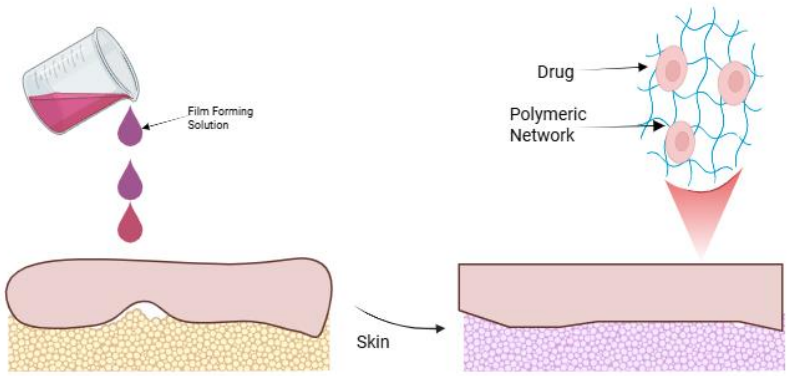
The topical route offers a large and varied surface in addition to the ease of application via self administration and provides an alternative to oral delivery of drugs as well as hypodermic injection[17] the rate and extent of drug absorption through skin depends on the skin physiology and physicochemical properties of drugs as well as the deliv ery system.The current dosage forms, i.e. patches, ointments, creams, etc., are associated with several limitations.

Patches have various disadvantages, most commonly skin irritation[18] because of their occlusive properties causing obstruction of sweat ducts, which in turn prevents loss of water vapor from skin surface, difficulty in applying on the curved surfaces, pain while peeling off and poor aesthetic appeal.Semisolid preparations like creams and ointments overcome some of these drawbacks but have other limitations.These do not ensure persistent contact with the skin surface and can be easily wiped off by patient's clothes[19] However, the concern is that patch preparations still leave drug residues after use and can be deliberately abused.[20] Patch preparations are also often associated with hypersensitivity, irritation, and blistering.[21] Problems in the scale-up of production are also often found where drugs are difficult to stabilise and can crystallise during storage[22] these leave a sticky and greasy feel after application leading to poor patient compliance. Therefore there is a need for development of a dosage form which permits less frequent dosing by maintaining a close contact with the skin for prolonged time period thereby improving the patient compliance.

Film forming system

As described, the main problem with dermal and transdermal application of drugs via liquid and semi-solid formulations is the washing and rubbing off of the formulations, so that the desired therapeutic effect cannot be achieved. For this reason, very few semi solid formulations are found in transdermal use. The idea behind the development of film-forming formulations is to develop formulations with increased substantivity against mechanical and water-based influences and improvement of the cosmetic properties, and thus patients' compliance. As dosage forms, sprays, gels, or emulsions may be formulated.[24-25]

Film forming system (FFS) is a novel approach which can be used as an alternative to conventional topical and transder mal formulations. It is defined as non-solid dosage form that produces a film in situ, i.e. after application on the skin or any other body surface. These systems contain the drug and film forming excipients in a vehicle which, upon contact with the skin, leaves behind a film of excipients along with the drug upon solvent evaporation.The formed film can either be a solid poly meric material that acts as matrix for sustained release of drug to the skin or a residual liquid film which is rapidly absorbed in the stratum corneum.[26]



Film forming mechanism

Film forming system is applied directly to the skin and it forms a thin, transparent film in situ upon solvent evaporation. After application of the formulation to the skin, the com position of the film forming system changes significantly due to the loss of the volatile components of the vehicle which results in formation of residual film on the skin surface. In this process the concentration of drug increases, reaching saturation level and with the possibility of reaching supersaturation level on the skin surface. Supersaturation results in the enhanced drug flux through the skin by increasing the thermodynamic activity of the formulation without affecting the skin's barrier, thereby reducing the side effects or irritation[27] FFS creates supersaturated systems immediately after ap plication to the skin, overcoming the problem of instability.Thus it improves the drug permeation through skin compared to other transdermal dosage forms. The film forming formulations showed a higher permeation than the commercial patch.[28]

Film forming system vs other formulation

In case of transdermal patches the drug is stored in a reservoir from which the drug release occurs slowly and the drug is absorbed into the capillaries from where it is transported to systemic circu lation or it is formulated as a topical patch so as to penetrate the skin to reach the target tissue for localized action. Drugs incorporated into semisolids show their activity on the skin surface or penetrate into skin layers to reach the site of action but systemic delivery of drugs is limited due to various factors. Film forming systems can function as both semisolids and patches and can provide topical as well as transdermal delivery as desired.[29]

	Film forming system	**Other formulation**
Visual appearance	Almost invisible	Visible (patch)
Skin feel	Non sticky, non-greasy	Sticky/ greasy(ointment)
Administration	convenient	convenient
Dose frequency	1-2 days	5-6 days
Sustain release	Yes	yes
Residual remains	No	Possible

Classification of film forming solution

FFS can be classified by their physical state before film formation, By the mechanism of drug release, or by intended site of delivery. Some major types mentioned below table:

Formulation	**Description**	**Example**
	In this method, the polymeric solution is sprayed or applied as a liquid to the skin, where it evaporates to create an almost translucent layer.[30]	For the biphasic administration of testosterone, Misra et al. created a liquid film-forming solution by

Solution/spray	To guarantee full dissolution of the polymer, the formulation preparation entails adding the polymer to the vehicle and stirring the mixture overnight. Other alternative excipients, like plasticiser or cross linker, are added when a clear polymeric solution is achieved. The solution is agitated for 24 hours after all excipients have been added.[31] The polymers are selected to act as anti-nucleating agents and crystallisation inhibitors, preventing drug crystallisation, for the physical stability of the API. These technologies create an undetectable, non-irritating, stable, fast-drying film that can be used for transdermal treatment.[32]	combining polyvinyl pyrrolidone and polyvinyl alcohol in iso propanol as film-forming polymeric solutions.[33] Ammar et al. used polyvinylpyrrolidone and eudragit in ethanol as film-forming agents to create a polymeric solution of ketorolac that formed films.[34] Gohel and Nagori created a fluconazole spray using Eudragit RS 100 and ethyl cellulose as film formers.[35]
Gel	The formulation needs to be highly flexible to adjust to the movement of the skin, highly substantiated, and have strong skin adhesion for continuous drug delivery and absorption. The administration of film forming gel entails applying a dose to the arms, shoulders, internal thighs, or abdomen to create a thin bioadhesive film on the skin. Therefore, the formulation includes gelling agents, film forming agents, plasticisers, preservatives, etc.[36] These systems provide better flexibility and elasticity, suitable consistency and adhesiveness, ease of use and application, and ease of production as compared to other forms. The primary application of film-forming hydrogels is in wound healing. A film that is resistant to physiological stress brought on by skin movement is produced by the formulation applied to the injured area.[37]	Vij and Saudagar created a film-forming gel to distribute terbinafine hydrochloride over an extended period of time. In order to create a matrix film that would enable the release of terbinafine over an extended period of time, Eudragit and hydroxypropyl cellulose were combined.[38] Li et al. used hydroxypropyl cellulose and carbomer 934 to create a film-forming gel formulation for rotigotine's prolonged release. The response surface analysis technique was used to improve this formulation.[39] Liu et al. created sustained release transparent film-forming hydrogels of tolterodine and used response surface techniques to investigate the effects on stratum corneum.[40] An et al. created a soft hydrogel of testosterone based on polyvinyl alcohol for transdermal administration. When applied to the skin, the formulation, which was in a semisolid phase inside the tubes, created thin coatings in two to three minutes.[41]
Emulation	In addition to the oil and aqueous phases, film-forming emulsions also contain a polymer that forms films. Film-forming emulsions have an advantage over semisolid formulations in that they can treat larger areas of affected skin with an extended contact time and adequate substantivity, enabling sustained dermal therapy of chronic diseases. This is because the volatile components in the emulsions evaporate, causing changes in the tissue that allow absorption of the drug.[42,43] The type of emulsion and the nature of the API determine how the medicine is delivered through the skin. No.[44]	Using Eudragit NE and RS 30D as film formers, Lunter et al. created film-forming emulsions for sustained cutaneous administration of nonivamide.[45] The in vitro skin penetration and permeation of nonivamide from the produced film-forming emulsions were examined in a different investigation by Lunter et al.[46]

Component of film forming system

Drug

For transdermal application of film forming systems, the drugs need to have suitable properties which are independent of the dosage form. Generally the drugs which are applicable to these systems are highly potent which permeate the skin rapidly, which cause no skin irritation and which are relatively stable to the enzymes present in the epidermis.

Some characteristic mentioned below: 29

Parameter	Characteristics
Dose	<10mg/day
Half-life	10hr or less
Molecular weight	<500daltan
Log P	1-3
Skin reaction	No irritation

Polymer

Polymers are the foundation of the FFS and a variety of polymers are available for the preparation of these systems. In order to achieve the desired film properties, these polymers can be used alone or in combination with other film forming polymers.[47] Polymers play a significant role in the success of FFS preparations. Aside from being a drug release controller, polymers also act as the film-forming base. Polymers can also prevent the transformation of molecules, such as the formation of unexpected crystals. General considerations in the selection of polymers are its ease of being washed away by water, stability, biodegradability, and non-irritating properties. Polymers used in FFS can be natural or synthetic as long as they have in situ gel or viscoelastic properties.[77] Some natural and synthetic polymer mentioned in below table:

Type	Polymer	Key Properties / Functions	Optimal Concentration / Combinations	Additional Notes	Ref.
Natural & Semisynthetic Polymers	**Cellulose**	Ethylcellulose forms films easily washed with water Used with Eudragit for better film properties.	5.02–5.25% (Ethylcellulose + Eudragit)	Films have excellent characteristics.	48-50
	HPMC (Hydroxypropyl Methylcellulose)	Slow drying time– Produces clear, thin, smooth films.	2%	Excellent film quality at this concentration.	51
	Na-CMC (Sodium Carboxymethyl Cellulose)	Thixotropic flow: becomes thinner under pressure, returns to original consistency after spraying Maintains stability and provides controlled release.	Max sprayable: 2.5%Optimal: 1.5%	Good sticking properties; ensures constant dose per spray	52
	Chitosan	Antimicrobial, antioxidant, and mucoadhesive properties– High surface tension (decreases with surfactants) Film forms with dense droplets (4–27 µm).	Uses **Tween 80** to reduce surface tension; **PEG 400** for stability and solubility.	Degree of deacetylation affects hydrophilicity, tensile strength ↑, and elongation ↓.	53-57

	Cyclodextrin	Maintains drug stability; prevents crystal deformation. Slightly increases viscosity for easy sprayability.	-	Improves spray performance and drug stability.	58-59
	Gellan Gum (GG)	Viscoelastic and thermosensitive; converts solution → gel on skin contact (30–40°C). Excellent mucoadhesive properties. Sensitive to pH changes.	Low acyl GG: better drug release; viscosity ↑ at ~35°C.High acyl GG: thickens at ~78°C.	Addition of NaCl as crosslinker increases yield stress.	60-62
	Xanthan Gum	Sprayability depends on viscosity. Surfactants decrease surface tension & droplet size. Spray angle and coverage decrease with higher concentration.	-	Viscosity/flow unchanged by surfactants; good control over sprayability.	63
Synthetic Polymers	**Carbopol**	Thixotropic and viscoelastic hydrogel. Good for open wounds (moisture control). Combines well with Poloxamer.	0.05% (Carbopol + Poloxamer)	Produces film with good sprayability and drug release; heat-resistant gels.	64-66
	Eudragit (Various Types)	Enhances drug permeation in skin. Transparent, shiny, flexible films (EPO, E100, RL100, RS100) . S100 dissolves above pH 7 (washable with water).	Eudragit RLPO (10.05%) + Ethylcellulose (5.02%) optimal.RS100 best ≤15%.	S100 non-irritant; RS100 gives good sprayability; RLPO + EC gives better films.	67-70
	Lutrol F-127	Similar film and spray pattern as Carbopol 940. Produces more uniform dose per spray. Better drug release, no irritation.	-	Consistent film quality and non-irritant.	71
	Plasdone	Inhibits crystallization; improves testosterone permeation.	-	Permeation order: **Plasdone > Eudragit EPO > PVP K30 > Eudragit RL.**	72-73
	Kollidon (e.g., Kollidon® 30, VA64)	Enhances solubility, permeability, and controls drug release. Transparent, thin, stable films (pH stable for 28 days).	-	Acts as antinucleant; inhibits testosterone crystallization	74-76

Solvent

The solvents form an important component in film formation. The solvent used in film forming systems help in solubilizing the drugs as well as have an impact on drug permeation. Commonly used solvents for topical and transdermal use. As these solvents are widely used, the safety of these has been established on long term use.[78]

- Glycols: Propyleneglycols, polyethyleneglycols
- Alcohols Ethanol, butanol, isopropanol, benzylalcohol etc.
- Other solvents: Ethylacetate, oleicacid, isopropylmyristate

Penetration enhancers

Penetration enhancers (also called permeation enhancers or sorption promoters) are substances that **temporarily increase the permeability of the skin** or other biological barriers to facilitate the absorption of drugs without causing permanent damage or irritation.

Eutectic blends are often used as enhancers to drug permeation.[79] One of the most potent eutectic blends is a mixture of camphor and menthol.[80] Camphor and menthol form a hydrophobic mixture, so it is suitable as a penetration enhancer for drugs that are also hydrophobic. However, camphor and menthol can cause leaching and the formation of pores in the skin.[79] A warm feeling followed by a cold feeling that builds slowly is characteristic of a mixture of camphor and menthol.[81]

Ideal Properties of a Penetration Enhancer

- Should be **non-toxic**, **non-irritating**, and **chemically stable**.
- Should reversibly alter the barrier function.
- Should enhance permeation of both hydrophilic and lipophilic drugs.
- Should be compatible with formulation components.
- Should have rapid onset and short recovery time for barrier function.

Example of penetration enhancer used in film forming system:

Permeation Enhancer / Mixture	Drugs Studied	Mechanism / Action	Remarks / Key Findings
Camphor + Menthol (Eutectic mixture)	Fluconazole, Clotrimazole, Voriconazole	Hydrophobic interaction with stratum corneum lipids = disrupts lipid packing	Significantly increased drug permeation of antifungal agents
Azone	Testosterone, Dexketoprofen	Increases lipid fluidity; enhances hydrophilic drug transport	Shows synergistic enhancement when combined with PG
Isopropyl Myristate (IPM)	Testosterone, Dexketoprofen	Acts as lipid solvent and partition enhancer	Commonly used in topical formulations
Propylene Glycol (PG)	Testosterone, Dexketoprofen	Co-solvent; enhances drug solubility and hydration of skin	Synergistic with azone
N-Methyl-2-Pyrrolidone (NMP)	Testosterone	Solvent-based enhancer	_
Lauryl Lactate (LA)	Dexketoprofen	Disrupts lipid structure; improves drug partitioning	Strong lipophilic enhancer

Plasticiser

In the film formation, the plasticiser maintains elasticity and prevents cracking of the film. Plasticisers can also maintain the stability of active substances.[57] Plasticizers are used in the film forming systems to impart flexibility to the film and improve the tensile strength of the film formed. The plasticizer used should be compatible with the polymers used and should have low skin permeability. Commonly used plasticizers are glycerine, polyethylene glycol, sorbitol, dibutylphthalate, propylene glycol, triethylcitrateetc.[82]

Polyethylene glycol also has a role as a solubiliser, which is also useful in carrying drugs through the skin. PG has a significant effect on the viscosity of the film- forming solution, so the concentration needs to be considered. The use of PG in a mixture with water and ethanol does not have a good effect as a mixed solvent in preventing the crystallisation of testosterone. The effective PG concentration for increasing drug permeation is below 5%.[83] PEG400 can also increase the volume per spray of a film-forming solution. The amount per spray increases with increasing PEG 400 concentrations. The covered sprayareaalsoincreaseswithincreasingPEG400 levels.[84]

Evalution of film forming system

pH

The pH value is measured and adjusted to improve the stability of the active substance or make it suitable for the area of application. For skin pH ranging from4–6,[85] the pH of diabetic wounds ranges from6.5–8, whereas faster healing time for burns occurs below pH7.32.[86] The pH adjustment of the preparation aims to prevent irritation and changes in the physiological condition of the wound in the healing process. Besides, the pH value of the dosage can also affect drug permeation through the skin based on the degree of ionisation.[87]

Viscosity

Each type and concentration variation of the polymer will result in a different viscosity. The viscosity of the film forming solution will affect its spray ability, so this is an important parameter, especially in MDS. Increasing the concentration of the film-forming solution can reduce the coverage area of the spray.[88-89]

Film flexibility

Film flexibility is evaluated on the basis of cracking and skin fixation and this is determined by stretching the skin in 2–3directions.The film is rated flexible if there is no cracking or skin fixation and non-flexible if there is cracking and skin fixation.

Drying time

For the evaluation of the drying time the formulation is applied to the inner side of the forearm of a volunteer. After a fixed time period a glass slide is placed on the film without pressure .If no liquid is visible on the glass slide after removal, the film is considered dry. If remains of the liquid a revisible on the glass slide the experiment is repeated with an increase in drying time. A good FFS should have a minimum drying time to avoid long waiting time for the patient.[90]

Stickiness

The stickiness of the film formed is determined by pressing cotton wool on the dry film with low pressure. Depending on the quantity of cotton fibres that are retained by the film, the stickiness is rated high if there is dense accumulation

of fibres on the film, medium if there is a thin fibre layer on the film and low if there is an occasional or no adherence of fibres. This evaluation parameter is essential, as the formulation should be non-sticky to avoid adherence to the patients' clothes.[91]

Determination of the water vapor permeability

The water vapor permeability is defined as the quantity of water transmitted through a unit area of film in unit time.These water vapor permeation data are important in determining the per meation characteristics of the film as they have influence on skin properties like hydration of stratum corneum, blood flow, and skin temperature.[92] Films are produced with a solvent evaporation technique on a Teflon plate and dried for 72 h at room temperature. Circular samples are cut from the dry film sheets. For the sample preparation glass vials with an opening are filled with distilled water, covered with the circular film samples and a silicone ring, and sealed tightly with an alu minumvial cap.The weight of the vial is determined and then placed into a desiccator creating an atmosphere of 58% rela tive humidity or low relative humidity (approximately 0%).They are kept at a determined temperature for 72 h and weighed after predetermined intervals. From the weight loss of the vials W(g) the water vapor permeability is calculated as the amount of water that permeates through the film in relation to the surface area A (cm2) and the time t (h).[93]

Film homogeneity

Raman spectroscopy provides information about the chemi cal composition of the polymeric films. The chemical maps obtained from Raman spectra provide a measure of chemical homogeneity of films. Techniques based on Raman scattering can also be used to track the permeation of topically applied compounds through the skin.[94]

In vitro diffusion study

The in vitro diffusion studies are used to predict the permeation characteristics of drug in vivo. Franz diffusion cell is used to determine the release profile of the drug from the film forming system.The cell is made up of two compartments, the donor and the receiver compartment between which the dif fusion membrane is attached (egg membrane or cellophane). The donor compartment is exposed to the atmosphere and the receptor compartment contains the diffusion medium. The sampling arm in the receptor compartment allows for sampling. Predetermined quantity of the drug containing film forming formulation is placed on the donor compartment.Samples are collected and analyzed by suitable spectroscopic method for drug release.[93]

Skin penetration studies

The formulation is applied evenly on the skin using a pipette or a spatula. After fixed time intervals (e.g. 15 min, 1 h, 3 h, 6 h, 8 h,etc.) post application, the remaining formulation is removed. The film is wiped off with the help of cotton pads and the amount of drug present in the cotton pads is calculated, which is equivalent to the amount of drug remaining in the film. Therefore the amount of drug penetrated can be calculated by subtracting the remaining amount from the total amount of drug present in the formulation.[95]

Ex vivo Skin Permeation Study

Drug permeation can be tested on the abdominal skin of mice or rabbits using Franz diffusion cells. The skin is cleaned of all attached fat tissue still using a cotton swab that has been soaked in propanol or isopropanol, then washed with normal saline solution. Diffusion media include phosphate buffer pH 7.4 or acetate pH 6.0. On the receptor compartment side, medium flow is achieved using flow-through cells connected to silica tubes at speeds of 0.3 mL-0.6

mL/hr. After the compartment system is ready, the film-forming solution is placed in the donor compartment. Aliquots are then taken from the receptor compartment at specific time intervals, and then the drug levels are measured using an instrument. New diffusion medium is added at the same time, replacing aliquots that are taken to maintain sink conditions.[96]

In vivo Skin Irritation Test

The film-forming solution is applied to the skin of test animals such as mice and rabbits after being shaved. Irritation, inflammation, erythema, oedema, papule forma tion, flakiness, and dryness are observed 24 hours– 7 days after application.[96]

Water Washability

The ease of film wetting is assessed in the dried film. The f ilm is washed with water and assessed in ordinal scale, ie easily washed, moderately washed, and poorly washed.97,98 The ease of sprinkling with water will be useful if the film-forming solutions contact with sensitive areas in the body such as eyes and mouth.

CONCLUSION

Film-Forming Systems have emerged as an innovative and patient-friendly alternative to conventional semisolid and patch formulations. Their ability to form a thin, flexible, and adherent film upon application allows prolonged drug residence and controlled release. The selection of appropriate polymers, solvents, and penetration enhancers determines the performance and user comfort. Future research should focus on developing biocompatible, stimuli-responsive polymers, exploring nanocarrier integration, and conducting long-term clinical studies to ensure efficacy and safety for commercial translation.

Future Perspectives

Film-forming systems (FFS) have shown remarkable potential as an innovative approach for topical and transdermal drug delivery. However, there remain several opportunities for advancement and research to optimize their clinical and commercial applicability.

- Development of Smart and Stimuli-Responsive Polymers Future research is moving toward “intelligent” film-forming polymers that can respond to physiological stimuli such as temperature, pH, moisture, or enzymatic activity. These responsive systems can enable controlled and on-demand drug release, improving therapeutic efficiency and patient comfort.
- Integration with Nanotechnology The incorporation of nanocarriers such as nanoparticles, liposomes, niosomes, and nanoemulsions into film-forming formulations can enhance drug permeation, stability, and controlled release. Nano-based FFS may provide targeted delivery for skin diseases, wound healing, and chronic inflammatory conditions.
- Biodegradable and Eco-friendly Polymers the use of natural or biodegradable polymers is gaining attention to reduce environmental impact and ensure skin compatibility. Polymers derived from natural sources such as chitosan, cellulose derivatives, and alginate offer promising biocompatibility and film-forming abilities.
- Enhanced Patient Compliance through Cosmetic Elegance Future FFS formulations should focus on aesthetic properties such as transparency, non-tackiness, quick drying, and pleasant sensory feel to improve patient adherence, especially in long-term therapies.

- Personalized and 3D-Printed Film Systems With advancements in 3D printing and digital formulation design, customized FFS with patient-specific dose and surface area can be developed. This approach could revolutionize individualized therapy in dermatology and wound management.
- Incorporation of Herbal and Natural Actives Research into herbal or phytochemical-loaded FFS may offer safe and effective alternatives for wound healing, antimicrobial, and anti-inflammatory therapies, particularly in traditional medicine integration.
- Clinical Translation and Regulatory Standardization Despite promising preclinical outcomes, only a few FFS products have reached the market. Future efforts should emphasize large-scale clinical evaluations, regulatory standardization, and stability studies to establish efficacy, safety, and patient acceptance for regulatory approval.
- Multifunctional Film-Forming Systems There is growing interest in developing multifunctional FFS that combine therapeutic, protective, and cosmetic functions — for instance, antimicrobial films with UV protection, antioxidant activity, or hydration properties for skin care and protection.

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