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Review Paper

A Review on Dual Drug Niosomal Transdermal Patches for Anti-Inflammatory Therapy

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ABSTRACT

The increasing incidences of chronic inflammatory diseases such as rheumatoid arthritis and osteoarthritis have further increased the necessities for effective drug delivery systems which can enhance therapeutic value along with minimization of systemic side effects. Ability to bypass first-pass metabolism, sustained drug release and improving patient adherence has positioned transdermal system as a potent alternative for conventional oral and parenteral administration of drugs. Despite the high adherence potentials, it is known that the stratum corneum functions as a strong barrier, which severely limits transdermal delivery of many drugs. Niosome-based nanocarriers have attracted significant interest due to their biocompatibility, physicochemical stability, high drug encapsulation efficiency and the capability of enhance skin permeation and regulated drug release. This review attempts to provide an overview of the recent progress in dual-drug niosomal transdermal patches specifically planned for anti-inflammatory therapy with particular emphasis on co-delivery approach for synergistic therapeutic outcomes associated with etodolac and curcumin combination. In this review, detailed information is provided on the structural nature of niosomes, formulation elements, preparation methods, mechanism of skin permeation enhancement and also approaches for chemical and physical strategies such as microneedles (MNs), iontophoresis (IP), sonophoresis and electroporation.

INTRODUCTION

Alternative drug administration techniques, such as topical (also known as dermal) and transdermal delivery systems of active pharmaceutical

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ingredients (APIs), are becoming increasingly significant in addition to conventional and parenteral oral dose forms. Topical and dermal formulations, on the other hand, are intended to produce systemic effects by penetrating the skin layers and achieving local effects on the skin's surface and superficial layers (such as the epidermis—topical delivery) as well as in the underlying tissues. Because other organs (such as joints, the central nervous system, hormone therapy, pain relief, etc.) might potentially be therapeutic targets, the skin/transdermal pathway is crucial for dermatological therapy[1]. Niosomes are tiny particles. Niosomes are used in targeted medication administration and have been shown in recent studies to greatly enhance transdermal drug delivery. It is primarily made by using cholesterol surfactants as an excipient. Additionally, a number of excipients are used. Niosomes are either unilamellar or multilamellar vesicles. They have a lot in common with liposomes. The size of niosomes can vary from 300 nm to 5000 nm, depending on how they are made.2,3 Natural products include curcumin. Commercially produced from the rhizomes of the Curcuma longa plant, it belongs to the Zingiberaceae family. Numerous human ailments have historically been treated with the spice. Other components include proteins, carbohydrates, and resins. Curcumin, the active ingredient that has been studied the most, makes up 0.z3-5.4 percent of raw turmeric. The body's complicated biochemical reaction to viruses, damaged cells, or irritants is inflammation.[2]

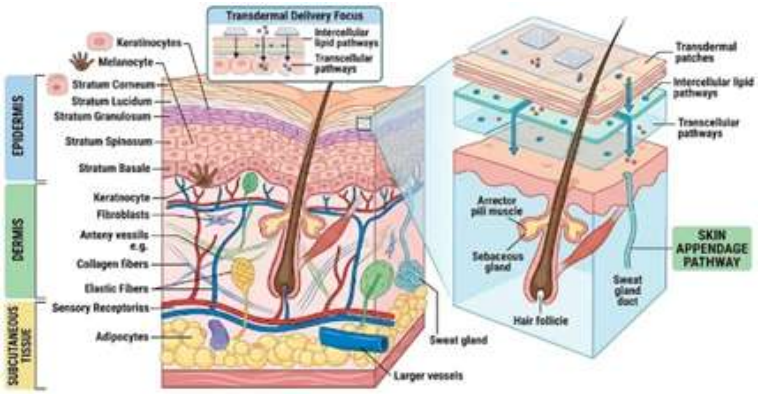

FIG:1 TRANSDERMAL DRUG DELIVERY

A disorder known as arthritis is characterized by inflammation, discomfort, stiffness, and deformity in one or more joints that limit range of motion. The term "arthritis" refers to a wide range of conditions that cause joint pain. Osteoarthritis (OSA), rheumatoid arthritis, reactive arthritis, gouty arthritis, and ankylosing spondylitis are a few types of arthritis.[3]

2. CHEMICAL METHODS FOR ENHANCING SKIN PERMEABILITY.

Many methods have been developed to increase skin permeability because the majority of medication molecules do not naturally fit the requirements for efficient transdermal delivery. These techniques can be divided into three main groups: physical, chemical, and nanotechnological. Chemical enhancers have the drawback of being rather expensive to make, but they can be easily designed and synthesized on a large scale, making them suitable for use in the production of a variety of formulations, including creams, gels, and even patches[4]. However,

because many strong chemical enhancers cause cytotoxicity, skin irritation, and allergic reactions, particularly when they can penetrate the corneum and reach the live epidermal cells, their safety profile serves as the primary barrier to their application. [4][5]

2.1 WATER

Water has long been recognized as a natural skin penetration enhancer; the hydration of the stratum corneum (SC) is essential for improving skin penetration. Generally speaking, transdermal medication passage increases with SC hydration. Water creates pools in the lipid bilayers, and the phase separation of water and lipids may change the structural integrity of the SC, albeit the precise mechanism is unknown. [6]

2.2 HYDROCARBONS

Alkanes, alkenes, squalane, squalene, and mineral oil are examples of hydrocarbons that can improve a drug's percutaneous penetration. They work by disrupting the lipid bilayer and relaxing the tight structure of SC. For example, alkanes with nine to ten carbon atoms demonstrated the greatest enhancement for medications like diazepam and propranolol, whereas shorter-chain alkanes were better at increasing the penetration of coffee. [4]

2.3 ALCOHOLS

Alcohols are widely used as carriers, solvents, or enhancers for the penetration of drugs in transdermal preparations. The major mechanisms of action are lipid and protein extraction from the SC, leading to swelling of the SC and increasing drug solubility in the formulation or distribution across the skin[6]

2.4 FATTY ACID

One of the most extensively studied skin penetration enhancers is long-chain fatty acids, particularly oleic acid. A key mechanism in many chemical and nanotechnological enhancers is lipid disruption. The SC offers a strong barrier to the majority of medications since it is made up of corneocytes embedded in a lipid matrix (commonly referred to as a "brick and mortar" paradigm). Fatty acids work by disrupting the SC's organized lipid domains, which increases drug penetration and promotes the creation of lipophilic drug–fatty acid complexes.[6]

2.5 ESTERS OF FATTY ACID

Fatty acid esters are commonly used as permeability enhancers, with isopropyl myristat being a popular example. Their mechanism of action is interpreted to be by disordering SC lipids. They also act by increasing the membrane fluidity, thereby allowing the penetration of drugs and improv improving of solubility in the SC[6]

2.6. AMINES

Amines have commonly been employed for improved percutaneous penetration of drugs. They are believed to work on the disruption of lipid bilayer structure or enhance local active compound distribution among the skin layers[6]

2.7.SURFACTANTS

A wide range of surfactants, including anionic, cationic, zwitterionic, and non ionic types, are skin permeability enhancers. Their activity depends on factors such as hydrophilic-lipophilic balance, charge, and lipid tail length. Surfactants can act by binding to or denaturing skin proteins, solubilizing or disrupting intercellular lipids, penetrating the SC, or interacting with corneocytes [6] so these all are the surfactants are the mainly using for the skin permeation and also various product will be present.[6]

2.8. ESSENTIOL OILS

Essential oils are known for their ability to enhance skin penetration and are concentrated on complex volatile chemicals derived from aromatic plants. Their primary mechanism of action is to disorganize the SC's densely packed intercellular lipids, increasing its permeability. Additionally, they might come into contact with SC structural proteins, which cause conformational changes that promote drug penetration. Low-molecular-weight essential oils are said to be safe since they are quickly digested, do not build up in the body, and are efficiently eliminated after topical administration. [6]

3. PHYSICAL METHODS FOR ENHANCING SKIN PERMEABILITY.

3.1 Iontophoresis

A low-intensity direct electrical current is used in iontophoresis, a non-invasive transdermal drug delivery method, to improve the penetration of ionized drug molecules through the skin. This technique involves placing a charged drug underneath an electrode that has the same charge. When an electric current is given, the drug molecules are repelled into the skin and eventually into the systemic circulation. By varying the current intensity and duration, the rate of drug administration can be accurately regulated. Local anesthetics, fentanyl, insulin, and anti-inflammatory medications have all been successfully delivered using iontophoresis, which is especially useful for hydrophilic and ionizable medications, such as peptides and proteins. However, the procedure necessitates specialized electrical instruments, and prolonged application or high current may produce moderate skin irritation, burning sensation, or erythema.[6]

3.2. Sonophoresis

Sonophoresis, sometimes referred to as phonophoresis, is a physical enhancement method that increases transdermal medication penetration by using ultrasonic waves. Cavitation, the process by which tiny gas bubbles develop and burst within the skin's lipids to create transient aqueous channels that aid in drug transport, is the main way that ultrasound enhances skin permeability. Enhanced diffusion is also a result of ultrasound's mild thermal effects. Hydrophilic medications and macromolecules, such as lidocaine, ketoprofen, insulin, and heparin, are especially well suited for sonophoresis. The method is non-invasive and efficient, but it needs specialist ultrasound equipment, and extended exposure to high-frequency ultrasound might irritate skin or cause tissue damage.[7]

3.3. Microneedles

Microneedles are minimally invasive devices made of tiny needles that temporarily open microchannels in the stratum corneum without getting to the dermal pain receptors. Peptides, proteins, vaccines, and other macromolecules that would not normally be able to enter the skin are much improved by this painless breach of the skin barrier. Different drug delivery strategies are provided by the solid, coated, dissolving, hollow, and hydrogel-forming varieties of microneedles. When compared to traditional injections, their main benefits are decreased discomfort, better patient compliance, and self-administration. However, there are certain drawbacks, such as a low drug-loading capacity, complicated fabrication, expensive manufacture, and sporadic mild skin irritation or erythema.[8]

3.4. Electroporation

Electroporation is a sophisticated transdermal medication delivery method that uses brief, high-voltage electrical pulses to temporarily open aqueous holes in the stratum corneum's lipid

bilayers. Large hydrophilic molecules, proteins, peptides, DNA, and vaccinations that often cannot pass through the skin barrier can now be transported thanks to these reversible holes, which greatly improve skin permeability. Pulse voltage, duration, and frequency can all be changed to regulate the amount of drug administration. While electroporation provides effective macromolecule distribution, it can cause skin irritation, pain, muscle activation, and temporary erythema. Additionally, its broad clinical application is restricted by the need for specialized electronic instruments and related expenses.[9]

3.5 Elongated Microparticles

A revolutionary minimally invasive transdermal delivery method called elongated microparticles (EMPs) is made up of freely moving small particles that, when gently rubbed, mechanically pierce the skin's outer layers. These particles produce transient microchannels that improve the epidermis's ability to absorb active medicinal substances. Because of their shallow penetration and ability to be administered over uneven skin surfaces, EMPs are very beneficial in minimizing cutaneous damage. They can be used in low-viscosity creams, gels, and lotions to transport tiny molecules, peptides, proteins, vaccines, cosmetics, and nanoparticles. After application, moderate discomfort and temporary erythema may occur, although these side effects normally go away quickly.[8]

4. Parameters Controlling Absorption

Conventional transdermal drug delivery is a passive process governed by Fick' s law, that is, the rate of absorption or flux (J) of any substance across a barrier is proportional to its concentration difference across that barrier For topically applied drugs, the concentration difference can be simplifed as the concentration of drug in the vehicle, C v, and the proportionality constant relating flux to concentration is the permeability coefficient, K p (equation 1). K p is composed of factors that relate to both drug and barrier, as well as their interaction. These factors are: K m , the partition coefficient; D , the diffusion coefficient; and L , the length of the diffusion pathway (equation 2). Thus, four factors control the kinetics of percutaneous drug absorption (equation 2); however, it is of great practical importance that two of the four (C v , K m) are highly dependent on one additional factor, the vehicle.[9]

5.PARAMETERS AFFECTING SKIN PERMEABILITY

The skin is a desirable location for medication distribution, as will be covered in more detail in the sections that follow. Nonetheless, a substantial barrier to medication absorption is provided by normal skin. To effectively administer medication through the skin, it is crucial to comprehend the factors that influence this barrier's permeability. On the other hand, local cutaneous effects are typically obtained by dissolving or suspending the medication in a semi-solid formulation that is administered topically (such as cream or ointment). The most common way to administer systemic medicine through the skin is with a patch. In both cases, the medication is applied to the skin's surface to diffuse into the stratum corneum with the goal of reaching therapeutic targets within the skin and/or systemic uptake via superficial dermal capillaries.[6][9]

6.LIMITATIONS OF CDDS

Controlled-release systems, or CDDS, have a number of drawbacks, such as high development costs because of sophisticated technology and long-term research, complicated formulation and manufacturing because of sophisticated drug carriers, limitations on drug properties, patient variability, the possibility of dose dumping, limited use in emergency situations, and

sensitivity to the environment and storage. Due to these features, CDDS may need to be stored according to stringent rules because of the possibility of deterioration under specificconditions, and it is not appropriate for conditions like extreme pain or cardiac arrest.[10]

Uses

- Management of chronic illnesses like cancer, diabetes, and high blood pressure
- Managed pain
- Neurological conditions (such as Alzheimer's and Parkinson's)

7 .NIOSOMES-INDRODUCTION

Niosomes are a novel drug delivery system, in which the medication is encapsulated in a vesicle. The vesicle is composed of a bilayer of non-ionic surface active agents and hence the name niosomes. The niosomes are very small, and microscopic in size. Their size lies in the nanometric scale. Although structurally similar to liposomes, they offer several advantages over them. Niosomes have recently been shown to greatly increase transdermal drug delivery and also can be used in targeted drug delivery, and thus increased study in these structures can provide new methods for drug delivery[11]

7.1 STRUCTURE OF NIOSOMES

Niosomes are spherical and consist of microscopic lamellar (unilamellar or multilamellar) structures **(Figure 2).** The bilayer is formed by nonionic surfactants, with or without cholesterol and a charge inducer [11]. Different types of surfactants at variable combinations and molar ratios are used to form niosomes . Examples of surfactants include alkyl ethers, alkyl glyceryl ethers, sorbitan fatty acid esters, and polyoxyethylene fatty acid esters. Addition of cholesterol maintains the rigidity of the bilayer, resulting in less leaky niosomes. Meanwhile, charge inducers provide charge to the vesicles and increase vesicle size, increasing drug entrapment efficiency. Negative charge inducers, including dicetyl phosphate, dihexadecyl phosphate, and lipoamino acid, and positive charge inducers, including stearylamine and cetylpyridinium chloride, help to stabilize the vesicle[12]

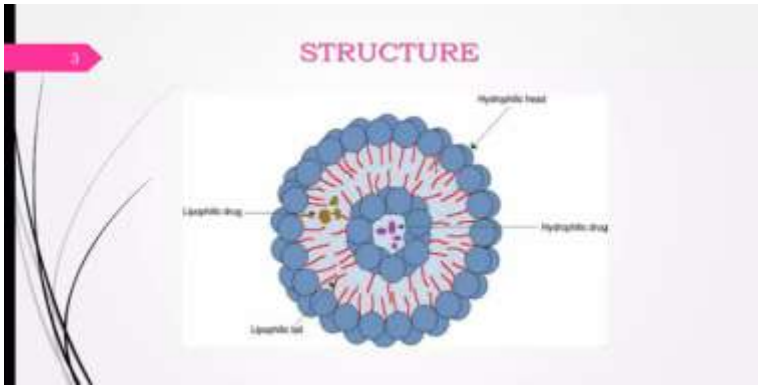

FIG:2 NIOSOME STRUCTURE

Table:1 Schematic Structure of a Niosome[12]

Outer Aqueous Phase	*Non-ionic Surfactant Bilayer*	Hydrophilic Drug (Core)
(Hydrophilic environment)	*(Span, Tween, Brij series)*	(Aqueous inner core)
	Cholesterol (bilayer stabilizer)	
Lipophilic Drug	→ *Entrapped in bilayer* ←	Cholesterol
(in bilayer)	*(amphiphilic region)*	(Structural integrity)

Table 2: Composition of a Typical Niosome Formulation :[11]

Component	Examples / Concentration	Function
Non-ionic Surfactant	Span 60, Span 80, Tween 80, Brij 52, Brij 72	Primary vesicle-forming agent; HLB value critical for vesicle formation
Cholesterol	20–50 mol%	Bilayer rigidity and stability; reduces permeability
Aqueous Phase	Phosphate buffer (pH 6.8–7.4) / distilled water	Hydration medium; dissolves hydrophilic drug
Drug (Hydrophilic)	Dissolved in aqueous phase	Entrapped in aqueous core
Drug (Lipophilic)	Dissolved in organic phase with surfactant	Incorporated in bilayer membrane
Charge Inducer (optional)	Dicetyl phosphate (negative) / Stearylamine (positive)	Improves colloidal stability; increases zeta potential

7.2 METHOD OF PREPARATION OF NIOSOMES

7.2.1 Ether Injection Method

In this method, a solution of the surfactant is made by dissolving it in diethyl ether. This solution is then introduced using an injection (14 gauge needle) into warm water or aqueous media containing the drug maintained at 60°C. Vaporization of the ether leads to the formation of single layered vesicles. The particle size of the niosomes formed depend on the conditions used, and can range anywhere between 50-1000 μM[11]

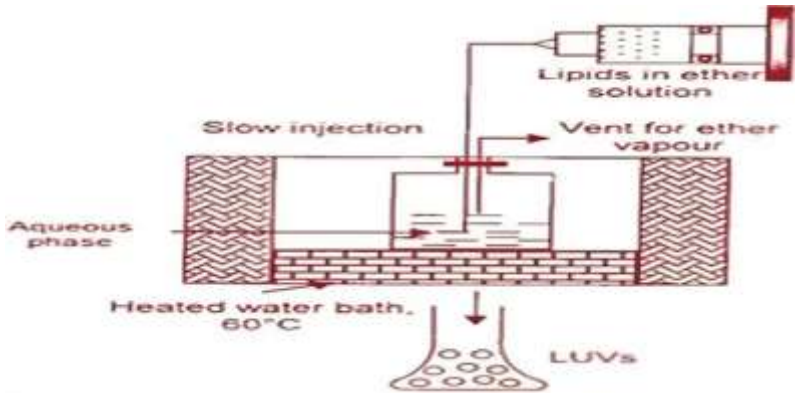

FIG: 3 Ether Injection Method

7.2.2 Hand Shaking Method (Thin Film Hydration Technique)

In this method a mixture of the vesicle forming agents such as the surfactant and cholesterol are dissolved in a volatile organic solvent such as diethyl ether or chloroform in a round bottom flask. The organic solvent is removed at room temperature using a rotary evaporator, which leaves a thin film of solid mixture deposited on the walls of the flask. This dried surfactant film can then be rehydrated with the aqueous phase, with

gentle agitation to yield multilamellar niosomes.[11][12]

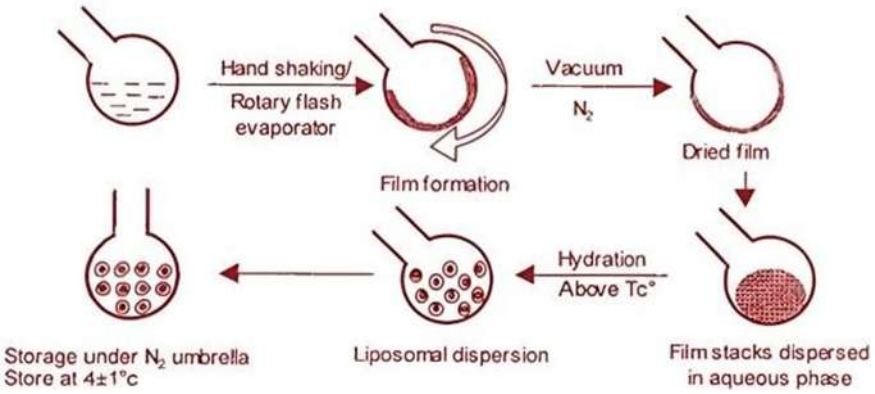

FIG 4 : Hand Shaking Method

7.2.3 Reverse Phase Evaporation Technique (REV)

This method involves the creation of a solution of cholesterol and surfactant (1:1 ratio) in a mixture of ether and chloroform. An aqueous phase containing the drug to be loaded is added to this, and the resulting two phases are sonicated at 4-5°C. A clear gel is formed which is further sonicated after the addition of phosphate buffered saline (PBS). After this the temperature is raised to 40°C and pressure is reduced to remove the organic phase. This results in a viscous niosome suspension which can be diluted with PBS and heated on a water bath at 60°C for 10 mins to yield niosomes.[12]

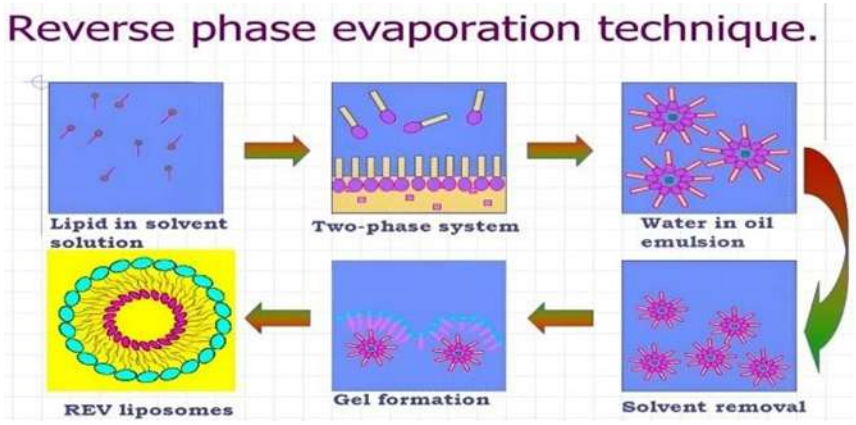

FIG 5: **Reverse Phase Evaporation Technique (REV)**

7.2.4 Micro Fluidization

Micro fluidization is a recent technique used to prepare unilamellar vesicles of defined size distribution. This method is based on submerged jet principle in which two fluidized streams interact at ultra high velocities, in precisely defined micro channels within the interaction chamber. The impingement of thin liquid sheet along a common front is arranged such that the energy supplied to the system remains within the area of niosomes formation. The result is a greater uniformity, smaller size and better reproducibility of noisome are formed.[11][13]

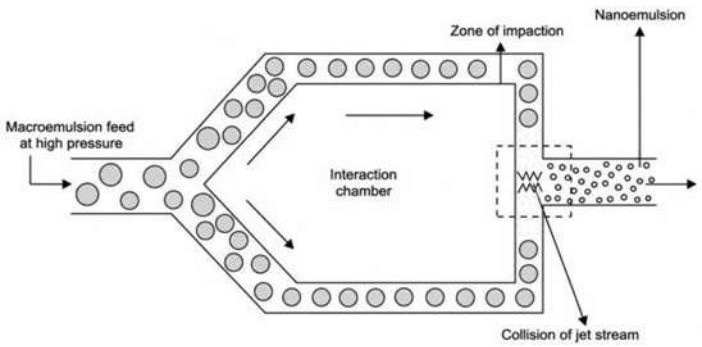

FIG 6 **Micro Fluidization**

7.2.5. Membrane pH Gradient

Molar ratios between cholesterol and surfactant must be taken in equal measures for this method by dissolving them in organic solvents with a polarity like chloroform. The organic solvent is removed by reduced pressure, forming a thin lipid layer on the flask's inner surface. The lipid layer is hydrated using a citric acid solution or any other acid with a similar pKa value. The resulting niosomes are subjected to freezing and thawing processes. A drug aqueous solution is then added and mixed with the aid of a vortex. Finally, the pH is adjusted using a phosphate solution to obtain large unilamellar niosomes. High encapsulation efficiencies are achieved with this type of niosome [15]

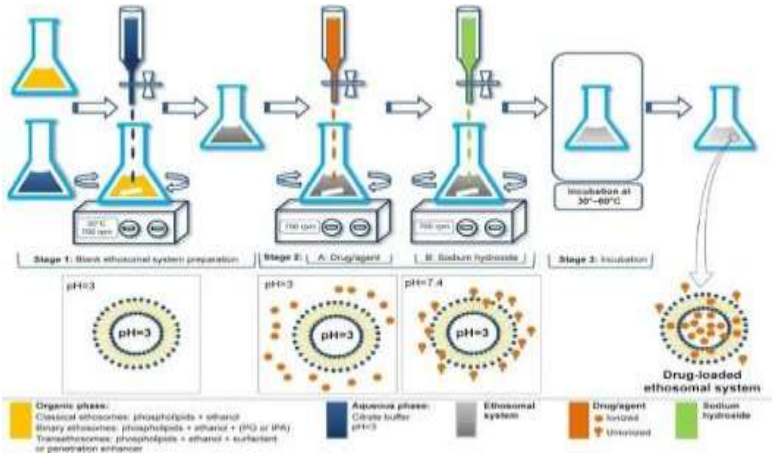

FIG:7: **Membrane pH Gradient**

7.3 ADVANDAGE AND DISADVANTAGE FOR NIOSOMAL CARRIER

Niosomes combine several advantages with respect to other nanocarriers:[16]

• Surfactants used to prepare niosomes are biodegradable, biocompatible, and not immunogenic[16]

• The method used for routine and large-scale production of niosomes does not involve use of unacceptable solvents[16]

• Due to the chemical stability of their structural composition, the handling and storage of niosomes does not require any special conditions[16]

• The physicochemical properties of niosomes, such as their shape, fluidity, and size, can be easily controlled by changing their structural composition and the method of production [16]

• Niosomes are able to encapsulate a large amount of mate rial in a small vesicular volume [16]

• The structure of niosomes protect drug ingredients from heterogeneous factors present both inside and outside the body, so niosomes can be used for the delivery of labile and sensitive drugs[16]

• Niosomes improve the therapeutic performance of drug molecules by delaying clearance from the circulation and restricting effects to target cells[16]

• Niosomes can be administered via different routes, such as oral, parenteral, and topical, and using different dos age forms such as powders, suspensions, and semisolids, improving the oral bioavailability of poorly soluble drugs and also enhancing the permeability of drugs through the skin when applied topically

• The aqueous vehicle-based suspension formulation results in better patient compliance when compared with oily dosage forms; in addition, niosomal dispersion, being aqueous, can be emulsified in a nonaqueous phase to regulate the drug release rate[16]

8. CHALLENGES AND LIMITATIONS

- Scale-up and reproducibility: Many nanocarrier formulations (niosomes, phospholipid complexes, lipid nanoparticles) are developed and characterized at laboratory scale; translating solvent evaporation, thin-film hydration or solvent casting methods to GMP-compliant industrial scale remains a significant hurdle
- Regulatory characterization: Nanomedicines require extensive physicochemical, batch-to-batch and long-term stability characterization (particle size, polydispersity, encapsulation efficiency, in vitro release) that adds complexity and cost to regulatory approval pathways
- Variable encapsulation efficiency: Encapsulation efficiencies for vesicular systems can vary widely (e.g., 12–86% for niosomal clarithromycin) depending on formulation ratios
- Device dependency for physical techniques: Microneedle, iontophoretic, sonophoretic and electroporation-based delivery require dedicated, portable and affordable devices for patient self-administration, which are not yet universally available
- Translational gap for combination nanotherapeutics: Co-delivery systems for pain management and in-silico-predicted drug synergies (e.g., etodolac–baicalein) remain largely at the preclinical or computational stage and require confirmatory in vivo and clinical validation[17]

8 FUTURE DIRECTIONS

- Integration of artificial neural network (ANN) and machine learning approaches with nanotechnology to enable predictive, personalized optimization of topical and transdermal formulations.
- Development of multifunctional, stimuli-responsive nanocarriers capable of releasing drug selectively in response to the inflamed joint microenvironment (pH, enzymatic activity, temperature).
- Continued exploration of combination and co-delivery nanoformulations to exploit pharmacodynamic synergies between established and novel anti-inflammatory/analgesic agents.
- Advancement of portable, low-cost physical enhancement devices (microneedle arrays, wearable iontophoretic/sonophoretic patches) to improve accessibility and patient self-administration.
- Application of Quality-by-Design (QbD) and design-of-experiments frameworks as a standard approach to formulation

optimization, supporting more efficient regulatory translation[18]

CONCLUSION

Transdermal and topical drug delivery has become a genuine alternative to oral and parenteral therapy for people living with chronic joint inflammation and ongoing pain, largely because of steady progress in nanocarrier engineering and physical permeation-enhancement techniques. Among the systems discussed, niosomes stand out alongside lipid nanoparticles, polymeric nanoparticles, and drug–phospholipid complexes for their proven ability to cross the stratum corneum barrier while improving drug stability, sustaining release, and boosting therapeutic outcomes. This is well illustrated by niosomal clarithromycin patches, which achieved more than a 200-fold improvement in transdermal flux, and by QbD-optimized etodolac–phospholipid films, which showed markedly stronger anti-inflammatory activity.

Physical enhancement methods such as microneedles, iontophoresis, and sonophoresis further widen what transdermal delivery can achieve, opening the door to macromolecules and hydrophilic drugs that would otherwise struggle to cross the skin. That said, real obstacles remain: scaling these formulations up to industrial production, meeting the rigorous characterization demands of regulators, and clinically validating combination or computationally predicted nanotherapeutics are all challenges the field still needs to work through.

Looking ahead, bringing together nanomedicine, physical drug-delivery engineering, and computational formulation tools — particularly Quality-by-Design and ANN-guided approaches — appears to be the most promising route toward the next generation of transdermal therapeutics for rheumatoid arthritis, osteoarthritis, and pain management.

REFERENCES

1. Lunter D, Klang V, Eichner A, Savic SM, Savic S, Lian G, Erdő F. Progress in topical and transdermal drug delivery research—focus on nanoformulations. Pharmaceutics. 2024 Jun 16;16(6):817..
2. Chaus W, Awale S, Ghalge M, Kodgire N, Patel S. An overview of curcumin loaded niosomal gel for anti-inflammatory effect. Int J Pharm Sci. 2024;2(12):1854-1860. doi:10.5281/zenodo.14447482.
3. Gaddala P, Choudhary S, Sethi S, Sainaga Jyothi VG, Katta C, Bahuguna D, Singh PK, Pandey M, Madan J. Etodolac utility in osteoarthritis: drug delivery challenges, topical nanotherapeutic strategies and potential synergies. Therapeutic Delivery. 2024 Dec 1;15(12):977-95.
4. Karande P, Mitragotri S. Enhancement of transdermal drug delivery via synergistic action of chemicals. Biochimica et Biophysica Acta (BBA)-Biomembranes. 2009 Nov 1;1788(11):2362-73.
5. Herman.A; Herman.P,Essentiol Oils and their constituents as skin permeation for transdermal drug delivery : A Review J pharmaceutical . 2015,67,473-485
6. Bakhrushina EO, Shumkova MM, Avdonina YV, Ananian AA, Babazadeh M, Pouya G, Grikh VV, Zubareva IM, Kosenkova SI, Krasnyuk Jr II, Krasnyuk II. Transdermal drug delivery systems: methods for enhancing skin permeability and their evaluation. Pharmaceutics. 2025 Jul 20;17(7):936.
7. Zhang, Y.; Yu, J.; Kahkoska, A.R.; Wang, J.; Buse, J.B.; Gu, Z. Advances in Transdermal Insulin Delivery. Adv. Drug Deliv. Rev. 2019, 139, 51-70.
8. Faraji Rad, Z .; Prewett, P.D .; Davies, G.J. An Overview of Microneedle Applications,

Materials, and Fabrication Methods. Beilstein J. Nanotechnol. 2021, 12, 1034-1046

9. Prausnitz MR, Elias PM, Franz TJ, Schmuth M, Tsai JC, Menon GK, Holleran WM, Feingold KR. Skin barrier and transdermal drug delivery. Dermatology. 2012 Jan;3(18):2065-73.
10. Sammal N, Dutta D, Kandpal A. Formulation and evaluation of transdermal patch of Etodolac. J Neonatal Surg. 2025;14(32s):3519-3528. Available from: https://www.jneonatalsurg.com
11. Chandu VP, Arunachalam A, Jeganath S, Yamini K, Tharangini K, Chaitanya G. Niosomes: a novel drug delivery system. International journal of novel trends in pharmaceutical sciences. 2012 Feb;2(1):25-31.
12. Yeo PL, Lim CL, Chye SM, Ling AP, Koh RY. Niosomes: a review of their structure, properties, methods of preparation, and medical applications. Asian Biomedicine. 2017;11(4):301-14.
13. Rajera R, Nagpal K, Singh SK, Mishra DN. Niosomes: a controlled and novel drug delivery system. Biological and pharmaceutical bulletin. 2011 Jul 1;34(7):945-53.
14. Diljyot K. Niosomes: a new approach to targeted drug delivery. Int J Pharm Phytopharm Res. 2012; 2:53-9.
15. Bautista-Solano AA, Dávila-Ortiz G, Perea-Flores MD, Martínez-Ayala AL. A comprehensive review of niosomes: composition, structure, formation, characterization, and applications in bioactive molecule delivery systems. Molecules. 2025 Aug 23;30(17):3467
16. Antonara L, Triantafyllopoulou E, Chountoulesi M, Pippa N, Lagopati N, Dallas PP, Rekkas DM, Gazouli M. Recent advances in niosome-based transdermal drug delivery systems. Current Opinion in Biomedical Engineering. 2025 Sep 1;35:100603.
17. Kaur IP, Aggarwal D, Singh H, Kakkar S. Improved ocular absorption kinetics of timolol maleate loaded into a bioadhesive niosomal delivery system. Graefe's Archive for Clinical and ExperimentalOphthalmology. 2010 Oct;248(10):1467-72.
18. Moghassemi S, Hadjizadeh A. Nano-niosomes as nanoscale drug delivery systems: an illustrated review. Journal of controlled release. 2014 Jul 10;185:22-36
19. Abiandu, I .; Ita, K. Transdermal Delivery of Potassium Chloride with Solid Microneedles. J. Drug Deliv. Sci. Technol. 2019,53, 101216.

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