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# Role of Emulgel in Enhancing Skin Delivery: A Review

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**Abstract:** Emulgel is a semisolid topical delivery platform that combines an emulsion with a three-dimensional gel network. This hybrid architecture is particularly useful for skin delivery because the emulsion phase can accommodate lipophilic drugs, while the gel phase improves spreadability, residence, rheological behavior and user acceptability. The formulation can also support controlled release and, depending on the oil phase, surfactant system, droplet size, penetration enhancers and polymer, alter drug partitioning into the stratum corneum. This review summarizes the rationale for emulgel based skin delivery, mechanisms that may improve dermal permeation, formulation components, preparation, characterization, therapeutic applications, advantages, limitations and future prospects. Evidence from foundational and recent reviews indicates growing interest in conventional emulgels, microemulsion based emulgels and nanoemulgels for anti-inflammatory, analgesic, anti-acne, antifungal and other topical applications.

**Keywords:** Emulgel, Topical Drug Delivery, Skin Permeation, Dermal Delivery, Nanoemulgel, Penetration Enhancement, Controlled Release

## Introduction

Topical and transdermal drug delivery are attractive because they can provide drug directly to the skin or, for suitable molecules, through the skin while reducing gastrointestinal exposure and avoiding first-pass hepatic metabolism. However, the stratum corneum is a highly effective barrier, and drug flux depends on molecular size, lipophilicity, ionization, thermodynamic activity and the vehicle [1-3]. Conventional creams and ointments can deliver many dermatological agents, but greasiness, poor spreadability, limited drug release and instability may reduce convenience or performance. Emulgels were developed to combine useful characteristics of emulsions and gels, especially for poorly water soluble drugs [1,4,5]. The central formulation concept is straightforward: an oil-in-water (o/w) or water-in-oil (w/o) emulsion is prepared and subsequently incorporated into a gelled continuous phase. This creates a system in which the dispersed phase can solubilize lipophilic drug while the gel network contributes viscosity, spreadability and residence. Recent literature describes emulgels as promising platforms for topical delivery and highlights their expanding commercial and translational potential [1,4].

## Emulgel Enhancing Skin Delivery

Skin delivery is governed by sequential events: release of drug from the formulation, partitioning into the stratum corneum, diffusion through skin pathways and, for systemic delivery, passage into viable epidermis and dermis followed by uptake into the circulation. Emulgel can influence several of these steps simultaneously. The dispersed oil phase can increase solubilization of lipophilic molecules, surfactants can reduce interfacial tension and modify barrier interactions, and selected cosolvents or penetration enhancers

can increase drug partitioning. Meanwhile, the gel network controls mobility and residence time and can produce a sustained release profile [1,4,6]. Microemulsion and nanoemulsion variants may provide additional advantages because small droplets provide a large interfacial area and can improve drug distribution within the formulation. Reviews of nanoemulgels report enhanced permeability and improved topical pharmacokinetic/pharmacodynamic profiles for several lipophilic compounds, although the magnitude of benefit is drug and formulation dependent [7,8].

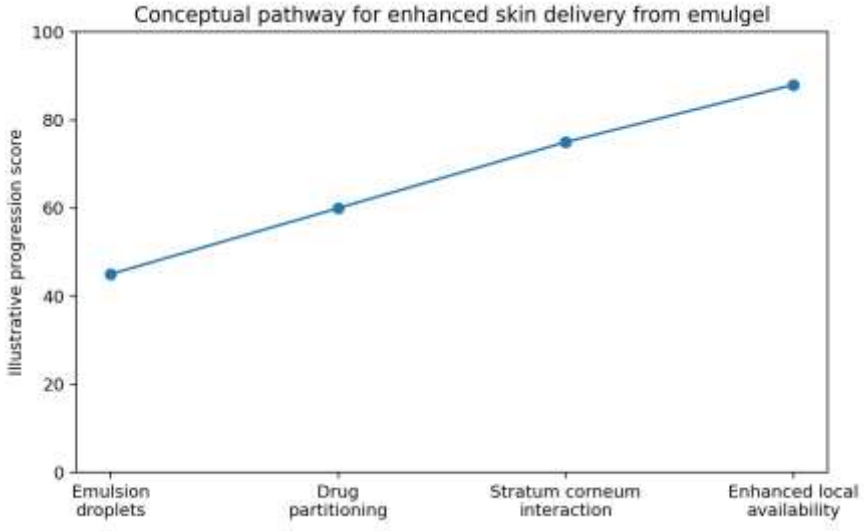


**Fig 1:** Conceptual pathway illustrating enhancing skin delivery

## Mechanisms of Enhanced Dermal Permeation

### Improved Drug Solubilization

The oil phase provides a reservoir for lipophilic drugs that have limited aqueous solubility. Greater apparent solubility can increase the amount of drug available for partitioning into the skin, provided that thermodynamic activity is maintained [1,4].

### Modification of Skin Partitioning

Oils, surfactants, alcohols and selected cosolvents can alter drug partitioning between vehicle and stratum corneum. The optimal balance is formulation specific because excessive solubilization in the vehicle can sometimes decrease the thermodynamic driving force for skin uptake [2,3].

### Surfactant and Interfacial Effects

Emulsifiers stabilize droplets and may interact with skin lipids. Non-ionic surfactants such as polysorbate and sorbitan based systems are frequently used in emulgel development. Their concentration must be optimized to balance stability, permeation and irritation [4,5].

### Occlusion and Hydration

A semisolid vehicle can increase residence time and, depending on composition, reduce water loss from the skin. Increased stratum corneum hydration can reduce barrier resistance and facilitate diffusion of some compounds [2,3].

### Controlled release and prolonged residence

The gel network increases viscosity and can retard diffusion, while the emulsion provides a second microenvironment for drug partitioning. This dual structure can therefore support controlled release and longer contact with the application site [1,4].

### Nanoemulgel effects

Nanoemulsion droplets may enhance contact area and drug distribution at the skin surface. Evidence supports their potential for lipophilic molecules, but claims of universally higher penetration should be avoided because droplet size, composition, drug properties and skin model strongly influence outcomes [7,8].

**Formulation Components**

**Table 1: Common components used in emulgel formulations and their functions [4,5]**

| Component | Examples | Primary Role |
|---|---|---|
| Oil phase | Isopropyl myristate, oleic acid, mineral oil, plant oils | Solubilization; emolliency; possible permeation enhancement |
| Aqueous phase | Purified water; buffers | Hydration and continuous phase |
| Emulsifier | Polysorbates, sorbitan esters, polyvinyl alcohol | Droplet stabilization and interfacial control |
| Gelling agent | Carbopol/carbomer, HPMC, HEC, CMC | Viscosity, residence and release control |
| Cosolvent/enhancer | Ethanol, propylene glycol, PEGs | Solubilization and possible permeation enhancement |
| Drug | Hydrophilic or lipophilic API | Therapeutic payload |
| pH modifier | Triethanolamine, citrate/phosphate buffers | pH adjustment and polymer neutralization |

**Preparation and Optimization**

Typical preparation involves three broad stages: (1) Preparation of the emulsion (2) Preparation of the gel base (3) Incorporation of the emulsion into the gel with controlled stirring. Temperature, order of addition, homogenization energy, polymer concentration, surfactant ratio and neutralization can substantially influence droplet size, viscosity and physical stability [5]. Optimization should use a quality by design approach where practical. Critical quality attributes may include appearance, pH, viscosity, spreadability, extrudability, droplet/globule size, polydispersity where relevant, drug content, *in-vitro* release, *ex-vivo* permeation, skin retention, irritation and stability. For nanoemulgels, droplet size and size distribution become particularly important [7,8].

**Evaluation Parameters**

**Table 2: Key Evaluation Parameters For Emulgel Development [1,4,5]**

| Parameter | Purpose |
|---|---|
| Appearance/homogeneity | Detect phase separation, grittiness and visual instability |
| pH | Assess suitability for skin and formulation stability |
| Viscosity/rheology | Characterize flow, spreadability and application behavior |
| Spreadability/extrudability | Estimate ease of application and dose handling |
| Globule/droplet size | Assess emulsion structure and physical stability |
| Drug content | Confirm uniformity and dose consistency |
| In-vitro release | Compare release kinetics among formulations |
| Ex-vivo skin permeation | Measure flux, permeability and skin retention |
| Skin irritation | Evaluate local tolerability |
| Stability | Assess changes during storage under defined conditions |

**Evidence from Representative Studies**

Published studies illustrate the potential of emulgels to improve topical performance. In a calcipotriol emulgel study, an optimized formulation showed 86.42 ± 2.0% drug release over 8 h and demonstrated higher release/permeation through dialysis membrane and rat skin than a commercial ointment, supporting the role of formulation design in enhancing topical delivery [9]. Reviews also describe applications for analgesic, anti-inflammatory, anti-acne and antifungal drugs [1,4,5]. Importantly, enhanced delivery should not be equated with enhanced systemic exposure in every case. A well designed emulgel may instead increase local skin retention while limiting systemic absorption. The desired endpoint therefore depends on whether the formulation is intended for local dermatological action or transdermal systemic delivery [2,3,7].

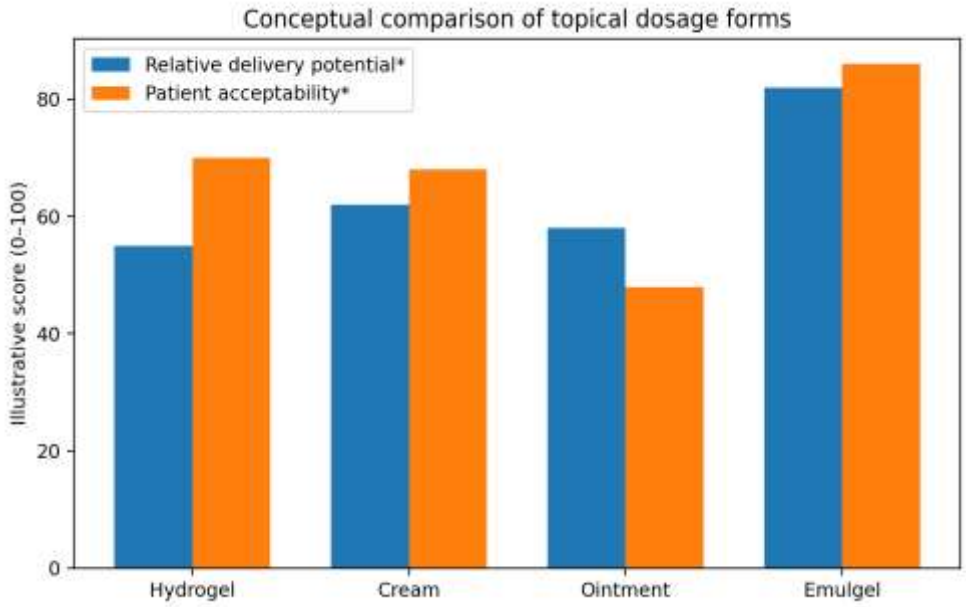


**Fig 2:** Conceptual Comparison of Topical Dosage Forms

## Therapeutic Applications

**Table 3: Selected Applications of Emulgel Based Topical Delivery**

| Application | Potential Role |
|---|---|
| Anti-inflammatory/analgesic | Local delivery can increase drug availability at affected tissue while potentially reducing gastrointestinal exposure associated with oral dosing [4,5]. |
| Anti-acne | Emulgels can accommodate lipophilic actives and provide cosmetically acceptable spreadability and residence [4,5]. |
| Antifungal | Oil and surfactant phases can assist incorporation of poorly water-soluble antifungals; prolonged contact may support local action [4]. |
| Psoriasis/keratinization disorders | Emulgel can improve handling and topical distribution of hydrophobic or moderately lipophilic agents; calcipotriol provides a representative example [9]. |
| Cosmeceuticals | The same platform can carry lipophilic cosmetic actives and improve sensory properties compared with greasy bases [1,4]. |

## Advantages and Limitations

Advantages include good spreadability, reduced greasiness compared with many ointments, improved acceptability, and incorporation of lipophilic drugs, potential controlled release, and formulation flexibility. The combined emulsion-gel structure also allows tuning of both the internal phase and the rheological properties of the final product [1,4,5]. Limitations include possible phase separation, surfactant-related irritation, instability caused by inappropriate polymer/emulsifier ratios, complex optimization, and variability between *in-vitro*, *ex-vivo* and *in-vivo* permeation results. Emulgel does not automatically overcome the stratum-corneum barrier; the formulation must be optimized for the specific API and therapeutic target [2,3,7].

## Future Perspectives

Future development is likely to focus on nanoemulgels, stimulus-responsive polymers, natural and biodegradable gelling agents, skin-targeted delivery, combination therapies and systematic quality by

design optimization. Cellulose derivatives and natural gums are being explored as alternative gelling materials, while nanoemulgel research continues to investigate delivery of poorly soluble lipophilic drugs [7,10]. More clinically meaningful research should prioritize standardized human-skin permeation methods, skin-retention measurements, irritation and sensitization assessment, pharmacodynamic endpoints, and well designed clinical trials. Translational success will depend not only on higher permeation but on achieving the intended site and duration of drug exposure with acceptable safety and patient adherence [1].

## Conclusion

Emulgel represents a versatile hybrid platform for enhancing topical skin delivery by integrating the solubilization and interfacial advantages of an emulsion with the residence, rheological and sensory benefits of a gel. Its greatest value is not simply increased permeation, but the ability to tune drug release, partitioning, local retention and patient acceptability in a single dosage form. Evidence across reviews and representative studies supports continued development for dermatological and cosmetic applications, while emphasizing the need for drug-specific optimization and clinically relevant evaluation.

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