Open Access Journal of Toxicology
ISSN 2474-7599

Juniper Publishers
key to the Researchers

Research Article
Volume 6 Issue 3 - September 2025
DOI: 10.19080/OAJT.2025.06.555689

Open Acc J of Toxicol


# Formulation and Evaluation of Alendronate-Loaded Transdermal Microemulsion in Therapeutic Use

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**Submission:** August 19, 2025; **Published:** September 02, 2025

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## Abstract

This study aims to develop a novel transdermal drug delivery system of alendronate using a microemulsion-based formulation. The objective is to enhance bioavailability and patient compliance while mitigating gastrointestinal side effects associated with oral alendronate. The research was conducted in two phases: formulation and characterization (Phase 1), followed by pharmacodynamic evaluation using an osteoporosis-induced animal model (Phase 2). The microemulsion system was evaluated for physicochemical parameters, permeability, stability, and in-vivo pharmacokinetics. Anti-osteoporotic potential was assessed through biochemical, densitometric, and histopathological parameters.

**Keywords:** Alendronate; 2-mercaptoethanol; Microemulsion; Photomicrographs; O-cresol Phthalein; Immunomodulation

**Abbreviations:** HPLC: High-Performance Liquid Chromatography, ALD: Alendronate, 2ME: 2-mercaptoethanol, OPA: o-phthalaldehyde, TEM: Transmission Electron Microscopy, ESR: Erythrocyte Sedimentation Rate, ALP: Alkaline Phosphatase, PDI: Polydispersity Index, NaOH: Sodium Hydroxide, EDTA-Na2: Disodium Ethylenediaminetetraacetic Acid

## Introduction

Alendronate, a bisphosphonate, is widely used for the treatment of osteoporosis but suffers from poor gastrointestinal absorption and side effects upon oral administration. Transdermal delivery offers an alternative route, bypassing the hepatic first-pass metabolism and improving patient adherence. Microemulsions, due to their thermodynamic stability and nano-sized droplets, serve as ideal carriers for transdermal systems. This study focuses on formulating an alendronate-loaded microemulsion for transdermal use and evaluating its anti-inflammatory activity.

## Materials and Methods

Substantial quantity of alendronate (ALD). Pamidronate disodium has been obtained as gift sample. AOT (dioctyl sodium sulfosuccinate), isopropyl alcohol, propylene glycol, ethanol, span 80, Tween 80, and isopropyl myristate, Labrasol, Transcuto P, Labrafac, and Capryol 90 were obtained from deferent sources. Sodium hydroxide (NaOH) and disodium ethylenediaminetetraacetic acid (EDTA-Na2) Colle ted from own laboratory. HPLC grade ACN was used. Freshly collected water was used to prepare the aqueous mobile phase for HPLC analysis [1].

### Phase 1: Formulation and Characterization

Microemulsion Preparation

Pseudo-Ternary Phase Diagrams

Phase diagrams were developed to identify the microemulsion region through the use of different combinations of oil, surfactant, co-surfactant, and aqueous phases.

Characterization of microemulsion

- Particle Size Analysis:
- Transmission Electron Microscopy
- Drug Composition
- Refractive Index
- Viscosity
- Stability Studies
- In Vivo Pharmacokinetics

HPLC Analytical Method and Calibration for Alendronate (ALD)

## Methodology

Alendronate (ALD) was quantified using a modified High-Performance Liquid Chromatography (HPLC) method. To improve detectability, the technique pre-column derivatizes ALD with o-phthalaldehyde (OPA). A HPLC system with fluorescence was used for the HPLC analysis, and a C-18 ODS Hypersil column was used for chromatographic separation. Acetonitrile–0.4% EDTA-$Na_2$ (16:84, v/v) with 0.034% NaOH made up the mobile phase, which was administered at a rate of 1 mL/min [2]. The internal standard was pamidorate disodium. Separate working solutions were utilized for quality control and calibration, while ALD stock solutions were made in 0.05 M NaOH. Every day, fresh OPA derivatizing reagent was made with ethanol and 2-mercaptoethanol (2ME). Before being injected into the HPLC system, the derivatized samples were prepared in a multi-step procedure that included centrifugation, reconstitution, and buffer adjustments. The ratio of the ALD peak area to that of pamidronate was plotted against the ALD concentration in plasma to create calibration curves. Calibration standards ranging from 4.00 to 500 ng/mL were examined.

### Preparation of Microemulsion

An aqueous solution of ALD was employed to systematically titrate an oily mixture of accurately measured IPM, AOT, and labrasol to formulate the microemulsion. At room temperature, the microemulsion formed a transparent, monophasic liquid spontaneously. Ternary phase diagrams facilitated the generation of microemulsion formulations with varying component concentrations [3]. The formulations were regularly assessed for drug precipitation or phase separation.

### Component Selection for Microemulsion

Oils and surfactants were selected for the ALD solubility investigations because they have been shown to aid in the transdermal penetration of hydrophilic medications. The solubility of several oils was evaluated. An excess of ALD was added to 1 mL of each vehicle, and the mixture was shaken at 100 rpm to ascertain the solubility. 48 hours at room temperature. To get rid of any extra or undissolved medication, the samples were centrifuged for ten minutes at 12,000 rpm. HPLC was used to determine the drug content in the supernatant of surfactant samples following dilution with distilled water. For oil samples, phase separation was allowed for 48 hours by shaking the supernatant one more with distilled water.

### Phanta-Ternary Phase Diagram Construction

The concentration range of each microemulsion component (oil phase, aqueous phase, and surfactant) was determined using pseudo-ternary phase diagrams prior to the preparation of the ALD-loaded microemulsion. Using sodium decussate as a surfactant and labrasol as a co-surfactant in weight ratios of 1:1, 2:1, 3:1, 4:1, and 5:1, five phase diagrams were examined [4]. Under moderate magnetic stirring, an aqueous drug solution was introduced dropwise to the S/Cos and oil combination; the solution becoming turbid is regarded as an endpoint.

### Zeta Potential and Globule Size

The ALD microemulsion, prepared according to ternary phase diagrams, was assessed for globule size and polydispersity index using standard operating procedures at room temperature. Measurements were conducted in triplicate, and values were calculated. TEM transmission electron microscopy was employed to examine the morphology of the ALD-loaded microemulsion. A microemulsion droplet containing ALD was deposited onto a copper grid. Following the drying of the grid at room temperature, transmission electron microscopy (TEM) was employed to produce photomicrographs.

## Content of Drugs

A measured volume of distilled water was used to dilute the ALD-loaded microemulsion after it had been precisely weighed. After then, the mixture was vigorously agitated for a minimum of twenty-four hours. After the samples were filtered, the previously mentioned HPLC method was used to determine the percentage of ALD [5].

### Calorimetry using Differential Scanning

The behavior of free or bound water in the formulation can be utilized to ascertain the microemulsion structure, whether it is oil-in-water (o/w) or water-in-oil (w/o). Differential scanning calorimetry (DSC) was employed to analyze the thermal characteristics of IPM, blank microemulsion, and ALD-loaded microemulsion. The samples, weighing between 4 to 8 mg, were hermetically sealed in a 40 µl aluminum pan and stored overnight at -70 °C in a deep freezer. The samples were heated at a rate of 1 °C per minute within the temperature range of -40 to 150 °C. A sealed aluminum pan devoid of contents functioned as a comparative reference.

### Calorimetry using Differential Scanning

The ex-vivo penetration profiles of the ALD-loaded microemulsion at various dosages were assessed and compared to those of the pure drug solution. Rat skin was excised and positioned on Franz diffusion cells (area 0.90 $cm^2$) with the stratum corneum oriented towards the donor chamber to assess permeation efficiency. At regular intervals, 500 µL aliquots of the acceptor medium were collected, and each aliquot was substituted with an equivalent volume of freshly preheated PBS [6]. The HPLC method was employed to quantify the penetration of ALD into rat skin and to measure the concentrations of ALD in the collected samples.

### Stability Study

The samples were kept at 25 ± 2 °C and 60 ± 5% relative humidity for six months in order to examine the physical and chemical stability of the ALD-loaded microemulsion. After being


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taken out at predetermined intervals, the samples were examined visually and for globule size. Using HPLC, the drug content was evaluated.

### In Vivo Pharmacokinetic Investigations

Male Wistar rats weighing 200-220 g were employed for the pharmacokinetic evaluation of ALD microemulsion at various dosages compared to the pure drug. The protocol was developed in compliance with CPCSEA one week prior to the initiation of the investigation. Rats were given standard pelletized chow and had unrestricted access to filtered water, but food was withheld for 12 hours prior to the trial. The animals were acclimated and housed in plastic cages within standard laboratory conditions, maintaining a temperature of 24 ± 1 °C, relative humidity of 55 ± 10%, and a 12-hour light/dark cycle. The animals' health condition was systematically evaluated throughout the acclimation phase. Male Wistar rats were divided into five groups (n = 6). The animals in three groups received a transdermal microemulsion of ALD, with hair removed from an area of approximately 10 $cm^2$ on the skin. In the three groups, ALD microemulsion was applied to the depilated skin at a dosage of 30 mg/kg [7]. Blood samples were collected at designated time intervals. Blood samples were collected in dipotassium EDTA vacutainers to prevent coagulation. The plasma was extracted by centrifuging blood samples at 4000 rpm for 20 minutes at 4 °C and stored at -20 °C until further analysis. ALD plasma concentrations were determined using HPLC.

### Serum Calcium Levels

A rapid colorimetric method using a stable O-cresol phthalein complexon reagent was employed to quantify serum calcium levels. The process entails the interaction of calcium ions (Ca2+) from the sample with o-cresol phthalein complexone in an alkaline solution, leading to the formation of a distinct violet complex that demonstrates peak absorption at 577 nm. The absorbance is measured at 570 nm and 660 nm. The increase in absorbance of the reaction mixture is directly proportional to the calcium concentration in the sample.

### Hematological Analysis

Following therapy, the right femurs were excised, preserved in 4% buffered formaldehyde, and embedded in paraffin blocks. Paraffin blocks were sectioned into 5 mm thick slices. The effects of ALD, blank microemulsion, and ALD microemulsion on selected animals were assessed. An experiment was assessed to assess the impact of ALD, including both the pure medication and its formulation [8]. The application of microemulsion on induced animals enhanced the levels of RBC and Hb compared to control animals. The WBC count and ESR were significantly reduced after application of microemulsion compared to control animals. In present study, control rats showed a reduced RBC count, reduced Hb levels, and an increased erythrocyte sedimentation rate (ESR). All these symptoms indicate anemic conditions results severe inflammatory conditions. The microemulsion treated groups showed a significant recovery from the anemia and inflammation. The significant increase in leukocyte count in induced rats may be due to the stimulation of immune system and significant decrease in microemulsion treated groups showed its immunomodulation effect. This clearly indicates the anti-inflammatory activity of microemulsion.

### Activity of Alkaline Phosphatase (ALP)

ALP activity was assessed in four groups: control, ALD pure drug solution, blank microemulsion, and ALD-loaded microemulsion. MG-63 cells were plated in well plates at a density of 1×10^5 cells. After overnight incubation, ALD microemulsion, ALD solution, or blank microemulsion was applied, and cultures were sustained for 3, 7, and 10 days. The ALP was evaluated by measuring the conversion of p-nitrophenyl phosphate to p-nitrophenol. The measurement of optical density was conducted at a wavelength of 405 nm [9].

## Results and Discussion

The retention time for ALD was measured at 5.7 minutes, as shown in Figure 1. The method exhibited a linear response across the concentration range of 5-600 ng/mL. The calibration curve is plotted. Linear consistency was noted throughout this concentration range in all analytical runs (Figure 1). The peaks displayed a clear structure with advantageous area and shape, indicating the method's suitability for further investigation (Table 1).

**Table 1:** The solubility Study of ALD.

| Component | Solubility (mg/mL) (±SD) |
|---|---|
| Isopropyl Myristate (IPM) | 0.734 ± 0.094 |
| Isopropyl Palmitate (IPP) | 0.516 ± 0.094 |
| Labsrasol | 1.021 ± 0.076 |
| Span 80 | 0.713 ± 0.094 |
| Docusate Sodium (AOT) | 0.822 ± 0.06 1 |

### Pseudo-Ternary Phase Diagrams and Preparation of Microemulsion

Phase diagrams were drawn to identify the monophasic microemulsion region with the combination of selected components. Oil, water, and S/CoS mixture were denoted as oil, water, and Smix in the phase diagram, respectively (Figure 2). The shaded portion in phase diagrams represents the existence of isotropic, clear, and transparent w/o microemulsion region. IPM is used as an oil phase as it reportedly had maximum solubility for ALD amongst tested oils. Additionally, its usage in the transdermal system has supplementary benefits as a biocompatible permeation enhancer [10]. The reason why AOT was chosen as surfactant in the study is that AOT can be one of the most effective surfactants used in the formation of w/o microemulsion with IPM. AOT also has high water solubilizing capability even when the aqueous phase has higher drug loadings. As well as this, water-solubilizing


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proficiency increases with a mixture of surfactants than with a single surfactant. This synergistic influence is reportedly observed in the case of AOT when it is combined with a non-ionic surfactant like. The IPM-AOT-Labrasol system delivered a larger microemulsion region than any other combination used in the preliminary ternary phase studies. Therefore, in this study, we chose AOT, labrasol, IPM, and water w/o microemulsion formulations, which are all acceptable in pharmacy and were used to improve the percutaneous absorption of the active molecules.

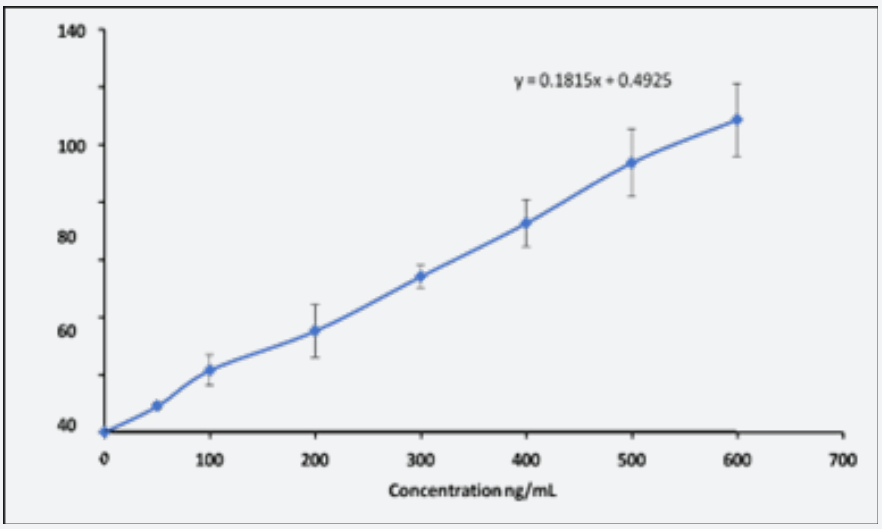


**Figure 1**

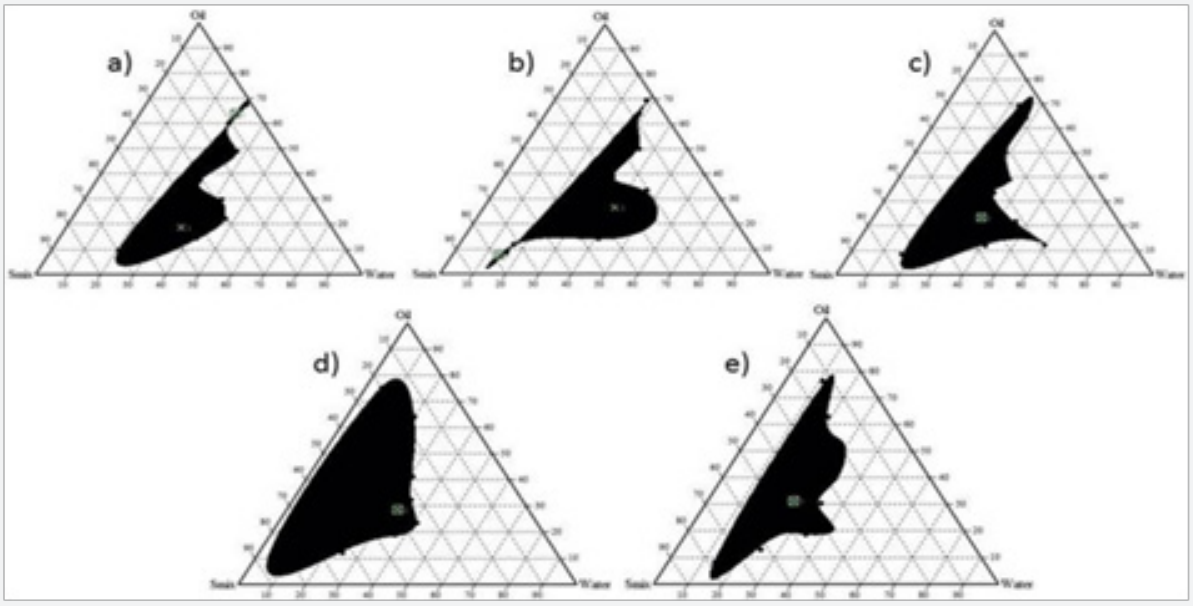


**Figure 2:** Ternary phase diagrams for water-Aerosol OT/Labrasol- Isopropyl Myristate combination with varying ratios of Aerosol OT: labrasol.



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Five pseudo-ternary phase diagrams were constructed, as illustrated in the experiment by water titration. Figure 2 depicts the pseudo-ternary phase diagram of AOT and labrasol with varying weight ratios. A sizeable monophasic region was obtained in each plot, and it was majorly confined to the oil-Smix axis, which indicates the formation w/o microemulsion. An ample amount of water was solubilized with the help of the chosen surfactant mixture without resulting in phase separation [11]. Mitra and Paul have previously reported improving water solubilization ability in w/o microemulsion with a mixture of AOT and non-ionic surfactants. Adding a non- ionic surfactant, labrasol, to AOT played a major role in increasing the solubilization of a high amount of water, resulting in a wide microemulsion region. We observed that with an increase in the ratio of AOT: labrasol to a certain extent (from 1:1 to 4:1), the monophasic microemulsion region grows in the area, beyond which (at 5:1) microemulsion domain reduced a little. This behavior is explained by a few studies which clarify that expansion of the microemulsion region depends on the mole fraction of a non-ionic surfactant and can increase or decrease beyond it. As labrasol has an HLB of 13 (ideal for o/w microemulsion), decreasing its percentage may be able to form a surfactant mixture favorable to form w/o microemulsion when combined with AOT (HLB 10), which is an amphiphilic surfactant.

On the other hand, Kantaria S. found no clear indication between this particular pattern with the HLB of surfactants and recommends performing ternary studies with multiple ratios of surfactant mixture, similar to what we did here, to get an exact idea about which surfactant ratio would be best to use for the formation of w/o microemulsion. The inspection of phase diagrams concludes that at an AOT/labrasol ratio of 4:1, maximum water solubilization was possible. A higher percentage of water in stable microemulsion can prove beneficial in incorporating water-soluble drugs like ALD [12]. The final formulation was prepared by keeping the surfactant weight ratio at 4:1. From the phase behavior studies, the composition of the microemulsion was determined accordingly. To incorporate the drug, a few points of the phase diagram were selected according to the maximum percentage of water to achieve a higher drug load. Microemulsions formulated with (S/CoS) ratio of 4:1 have shown the most stable behavior with the least globule size and were considered for further investigation. The final drug concentration in microemulsion was around 0.2 %w/w. The composition of ALD microemulsion is given in Table 2.

**Table 2:** AOT: Aerosol OT (Docusate sodium), IPM: Isopropyl myristate.

| Excipients | % of components (w/w) |
|---|---|
| Oil (IPM) | 42 |
| Surfactant (AOT) | 24 |
| Co-surfactant (labrasol) | 6 |
| Water | 20 |

### Globule Size and Zeta Potential

The particle size is often used to characterize nano-formulations because it enables an understanding of the dispersion and aggregation processes. Further, particle size affects the biological handling of the nano systems, and the sub-hundred-nanometer particle size is said to be beneficial in drug delivery as nanoparticles in this size range have been shown to have higher cellular and tissue uptake. The size analysis of the ALD-loaded microemulsion exhibited a mean globule size in a nano-size range with a mean diameter of 91 ± 8.5 nm. The polydispersity index (PDI) was observed as 0.197 ± 0.02. The zeta potential gives information on the stability of the prepared nano-formulations and is strongly influenced by the particle's surface charge; as a result, the type of surfactant used. Particles with large negative or positive zeta potentials (> ± 30 mV) tend to form stable colloidal suspensions since they tend to repel each other and thereby reduce aggregation. The zeta potential of the ALD-loaded microemulsion was found to be -51.0 ± 2.6 mV. In earlier studies, the negatively charged sulfonate group of AOT on the surface of a nanoparticle is suggested to contribute to the negative zeta potential of drug-loaded formulations. So, the increased zeta potential could be observed due to the presence of AOT in the ALD formulation. Similar excipients have been previously used instable formulations and have been displayed to play an important role in the controlled delivery of a drug. Thus, we concluded that AOT formed a stable microemulsion with the combination of IPM and labrasol [13].

### Transmission Electron Microscopy

The transmission electron microscopy (TEM) result for the ALD microemulsion is illustrated in Figure 3. It displayed spherical- shaped droplets of the microemulsion with a size of around 100nm, similar to those indicated by globule size studies.

## Drug Content

The drug content of the ALD microemulsion was found to be 92 ± 0.6% w/v. Even though the drug content of the ALD microemulsion is optimum, higher drug content was expected as ALD is highly soluble in the internal aqueous phase. The contribution of electrostatic interactions to drug loading in nanoparticles can be considered here. As explained before, the negative charge on AOT molecules could have influenced the drug content in microemulsion. Conversely, the solubility of the drug in water and labrasol could have helped incorporate the reported percentage of the drug [14]. As the structure of the drug molecule also plays an important role, it is important to note that other interactions (hydrophobic, hydrogen bonding) could have also contributed, to some extent, to the observed drug inclusion into microemulsion.

### Refractive Index

The Refractive index of the drug-loaded microemulsion stayed unchanged as that of the blank microemulsion. Refractive


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indices of o/w microemulsion are usually slightly lower than w/o microemulsion due to the lower refractive index of the external water phase (RI=1.34) than most pharmaceutically used oils. The refractive indices of prepared formulations in this study are like the refractive index of

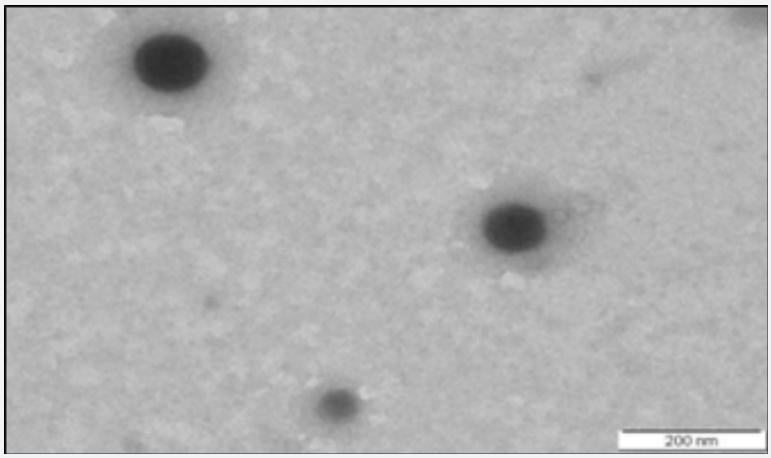


Figure 3: TEM image of alendronate microemulsion.

### Viscosity

The blank and ALD-loaded microemulsion displayed low viscosity, a characteristic of the microemulsion.

### Density

The density of blank and ALD microemulsion remained unchanged as a small amount of drug did not have any significant effect ($p>0.04$) on the density of microemulsion.

### Stability Study

Investigating stability profiles is crucial for evaluating the efficiency of nanocarrier systems. The stability analysis was performed effectively for 6 months, and satisfactory results were obtained with globule size and drug content. No drug precipitation or visual aggregation was reported as well. As a result, it is suggested that the prepared microemulsion is stable for at least 6 months. Stability studies of ALD microemulsion: analysis of globule size and drug content for the period of three months (Table 3). Based on the pharmacokinetic study results, the w/o microemulsion proved to be an effective carrier system to deliver ALD across the skin. Oil from a continuous phase of w/o microemulsion is compatible with sebum from hair follicles. For hydrophilic drugs like ALD, the hair follicular route is the main path for permeation through the skin. The globule size of the microemulsion carrier is generally smaller than the size of the opening of a hair follicle and hence, can help penetration of the drugs [15]. The hair follicle provides a larger surface area, a compromised stratum corneum, and a thick network of blood capillaries around the follicle enhances the systemic absorption of the drug. Also, using permeation enhancers in the microemulsion, in the form of oil and surfactants, can contribute to the increased permeation of drugs upon transdermal application. When taken together as a chemical mixture, these individual microemulsion components can synergistically enhance transdermal drug delivery. Based on the pharmacokinetic profiles of ALD given by different routes, we observed that reduction in the dose of transdermal microemulsion gave an insignificantly different plasma profile than oral. On the other hand, transdermal microemulsion with the same dose as that of the oral solution resulted in a significant increase in exposure (AUC) and bioavailability.

**Table 3**

| Time (months) | Globule size (nm) | Drug content (%) |
|---|---|---|
| 0 | 92.61 ± 5.2 | 86.56 ± 2.2 |
| 1 | 91. 29 ± 3.3 | 86.76 ± 7.6 |
| 2 | 90.93 ± 5.5 | 85.81 ± 3.2 |
| 3 | 89.96 ± 2.1 | 83.65 ± 6.1 |
| 6 | 87.23 ± 8.3 | 81.31 ± 2.1 |

## Conclusion

This study effectively demonstrates the efficacy of lipid formulations, such as water-in-oil microemulsion systems, in the systemic distribution of a hydrophilic drug, specifically alendronate. The transdermal route was an effective alternate approach for administering alendronate microemulsion formulated with meticulously chosen permeation-enhancing excipients. In comparison to oral alendronate, the administration of microemulsion provided a superior pharmacokinetic profile, potentially benefiting osteoporosis treatment. The encapsulation of alendronate, a bisphosphonate, in a microemulsion may maintain its osteogenic and anabolic capabilities, as indicated by the results of an anti-inflammatory study performed on a bilateral


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ovariectomized rat model. The transdermal microemulsion minimally impacted the rat's uterine and hormonal functions while effectively circumventing the oral side effects of alendronate.

Consequently, the utilization of microemulsion as a trans-epidermal delivery strategy is expected to enhance the therapeutic efficiency of bisphosphonates and augment patient compliance by circumventing significant gastrointestinal adverse effects.

## References


1. Ramadon D, McCrudden MT, Courtenay AJ, Donnelly RF (2022) Enhancement strategies for transdermal drug delivery systems: Current trends and applications. Drug Deliv Transl Res 12(4): 758-791.
2. Aundhia C, Shah N, Patel S, Maheshwari R, Seth A (2020) Bioavailability Enhancement of Alendronate by Nanoparticle Formulation for Treatment of Osteoporosis. Int J Pharm Res 12: 584-591.
3. Larrañeta E, Moore J, Vicente-Pérez EM, González-Vázquez P, Lutton R, et al. (2014) A proposed model membrane and test method for microneedle insertion studies. Int J Pharm 472: 65-73.
4. Noor AH, Ghareeb MM (2021) Transdermal Dissolvable Microneedle-mediated Delivery of Controlled Release Ondansetron Hydrogen Chloride Nanoparticles. IJDDT 11: 858-863.
5. Singh P, Carrier A, Chen Y, Lin S, Wang J, et al. (2019) Polymeric microneedles for controlled transdermal drug delivery. J Control Release 315: 97-113.
6. Conti T, Modena F, Pavanetto (2001) Long-term release of clodronate from biodegradable microspheres, AAPS Pharm Sci Tech 2: 10.
7. CV Odvina, JE Zerwekh, DS Rao, N Maalouf, FA Gottschalk, et al. (2005) severely suppressed bone turnover: a potential complication of alendronate therapy. The Journal of Clinical Endocrinology & Metabolism 90(3): 1294-1301.
8. Williams AC & Barry BW (2012) Penetration Enhancers. Adv Drug Deliv Rev 64: 128-137.
9. Menon GK (2002) New Insights into Skin Structure: Scratching the Surface. Adv Drug Deliv Rev 54: S3-S17.
10. Benson HA & Watkinson AC (2012) Topical and Transdermal Drug Delivery: Principles and Practice. Wiley; Hoboken, NJ, USA.
11. MP Jeremiah, BK Unwin, MH Greenawald (2015) Osteoporosis: Diagnosis, prevention, and treatment. Am Fam Physician.
12. H Katayama (2009) Enhancement of the percutaneous absorption of alendronate by ion exchange resin complexes in rats. Biol Pharm Bull 32(8): 1364-1368.
13. Sandby-Møller J, Poulsen T, Wulf HC (2003) Epidermal thickness at different body sites: Relationship to age, gender, pigmentation, blood content, skin type and smoking habits. Acta Derm Venereol 83(6): 410-413.
14. Kumbhar MD, Karpe MS, Kadam VJ (2020) Development and characterization of water-in-oil microemulsion for transdermal delivery of Eperisone hydrochloride. Appl Clin Res Clin Trials Regul Aff 7(1): 45-64.
15. Naniwa T, Maeda T, Mizoshita T, Hayami Y, Watanabe M, et al. (2008) Alendronate induced esophagitis: possible pathogenic role of hypersensitivity to alendronate. Intern Med 47: 2083-2085.



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