Acta Pharmaceutica Sinica B 2026;16(1):658−659

Chinese Pharmaceutical Association
Institute of Materia Medica, Chinese Academy of Medical Sciences

Acta Pharmaceutica Sinica B

www.elsevier.com/locate/apsb
www.sciencedirect.com

COMMENTARY

Advancing psoriasis therapy through oxygen-boosted dual-section microneedle technology

KEY WORDS

Psoriasis;
Microneedle;
Photodynamic therapy;
Reactive oxygen species;
Microenvironmental modulation

Psoriasis is a chronic inflammatory skin disease that remains difficult to treat owing to epidermal thickening and a dysregulated immune microenvironment. Conventional topical and systemic therapies are frequently constrained by poor penetration into thickened skin[1].

Photodynamic therapy (PDT) utilizes light-activated photosensitisers to generate cytotoxic reactive oxygen species (ROS) in the presence of oxygen, allowing selective targeting of hyperproliferative keratinocytes in psoriatic lesions[1]. However, despite its non-invasive and spatially controlled nature, PDT efficacy is limited by the hypoxic conditions typical of psoriatic skin[2]. Although basal ROS levels are elevated inside psoriatic tissues and contribute to persistent inflammatory signalling, they are inadequate to induce therapeutic cytotoxicity, while hypoxia suppresses oxygen-dependent ROS generation, highlighting the need for approaches that achieve localized, high-intensity ROS production irrespective of tissue oxygen availability[3,4].

In this study, the authors introduce an innovative oxygen-boosted dual-compartment microneedle (MN) platform that overcomes these limitations through the synergistic integration of controlled drug delivery and local microenvironment modulation.

The dual-layer MN patch consists of a needle-tip layer and a base layer. The needle tips encapsulate nanoparticles carrying the photosensitiser and triamcinolone acetonide (TA), a corticosteroid for anti-inflammatory therapy, and are further coated with a reactive oxygen species (ROS)-responsive shell. The base layer contains sodium percarbonate, which serves as an in-situ oxygen generator. This design simultaneously tackles two central challenges in psoriasis therapy, namely, insufficient drug penetration through the hyperkeratotic barrier[3], and impaired PDT efficacy under hypoxia[5].

Upon insertion into skin, the rapid dissolution of the base layer in interstitial fluids generates oxygen that enhances nanoparticle permeation through the thickened epidermis and restores the oxygen supply necessary for photodynamic activity[1]. The nanoparticles then degrade in the ROS-rich psoriatic microenvironment, enabling sustained release of TA while preserving the photodynamic capability of the photosensitiser. Upon light irradiation, the activated photosensitiser transfers energy to surrounding molecular oxygen, producing cytotoxic ROS that selectively eliminate hyperproliferative keratinocytes[1].

The system couples acute, spatially confined cytotoxic ROS (*via* PDT) with sustained immunosuppression (*via* TA), simultaneously debulking the hyperplastic epidermis. This dual action explains the superior lesion resolution and durability observed in comparison with PDT or corticosteroid therapy alone[6].

The authors demonstrate that this strategy achieves enhanced cellular uptake under hypoxic conditions, elevated singlet-oxygen generation upon irradiation, and superior control of keratinocyte hyperproliferation. Notably, a single application of the MN patch, when combined with near-infrared irradiation, produces strong therapeutic benefit in a psoriatic mouse model. The treatment significantly suppresses inflammatory cytokines, lowers epidermal thickness, and minimizes splenomegaly, indicating both local and systemic anti-inflammatory improvement. The patch also shows excellent biosafety, rapid micropore closure, and negligible systemic TA absorption, highlighting its translational potential[1].

This work exemplifies the growing shift toward biomechanically informed drug-delivery systems that dynamically interact with pathological microenvironments. By integrating oxygen generation, ROS-responsive release, and MN-enhanced

Peer review under the responsibility of Chinese Pharmaceutical Association and Institute of Materia Medica, Chinese Academy of Medical Sciences.

https://doi.org/10.1016/j.apsb.2025.12.025

penetration[7], the MN patch provides a useful solution that bridges the gap between topical corticosteroid therapy and emerging nanomedicine-based approaches[3,8]. Importantly, this platform offers a modular structure, *i.e*., its photodynamic component, corticosteroid payload, or oxygen-releasing chemistry may be tuned for other inflammatory or hyperproliferative skin diseases[1].

Overall, this study represents a significant advance in transdermal therapeutic design and expands the potential of MN technologies in treating skin diseases. The system not only improves the delivery of conventional immunosuppressive agents such as TA but also unlocks the therapeutic capacity of photodynamic therapy within the challenging psoriatic niche. Its combination of targeted delivery, sustained drug release, and microenvironmental modulation positions it as a promising candidate for future clinical translation and a new direction in multimodal psoriasis therapy.

References

1. Yuan Y, Jiang P, Xiao C, Lei J, Cheng B, Hu H, et al. Oxygen-boosted dual-section microneedle patch for enhanced drug penetration and improved photodynamic and anti-inflammatory therapy in psoriasis. *Acta Pharm Sin B* 2025. Available from: https://doi.org/10.1016/j.apsb.2025.09.037.
2. Sun M, Wang X, Wang H, Tang C, Bai J. Regulation of tumor hypoxic microenvironment by cyanobacteria-photosensitizer hybrid bioplatform for enhanced photodynamic therapy. *Sci Rep* 2025. Available from: https://doi.org/10.1038/s41598-025-30813-9.
3. Jia H, Yang Q, Hong J, Ding R, Liu T, Yang Q, et al. Microneedles loaded with dexamethasone and epigallocatechin-3-gallate reverse the imbalance of subcutaneous immune homeostasis for the treatment of psoriasis. *Adv Therapeut* 2024;**7**:2300233.
4. Lin X, Huang T. Oxidative stress in psoriasis and potential therapeutic use of antioxidants. *Free Radic Res* 2016;**50**:585−95.
5. Li Y, He G, Fu LH, Younis MR, He T, Chen Y, et al. A microneedle patch with self-oxygenation and glutathione depletion for repeatable photodynamic therapy. *ACS Nano* 2022;**16**:17298−312.
6. Zhou Z, Song J, Nie L, Chen X. Reactive oxygen species generating systems meeting challenges of photodynamic cancer therapy. *Chem Soc Rev* 2016;**45**:6597−626.
7. Zhang J, Li H, Albakr L, Zhang Y, Lu A, Chen W, et al. Microneedle-enabled therapeutics delivery and biosensing in clinical trials. *J Control Release* 2023;**360**:687−704.
8. Albakr L, Du H, Zhang X, Kathuria H, Fahmi Anwar-Fadzil A, Wheate NJ, et al. Progress in lipid and inorganic nanocarriers for enhanced skin drug delivery. *Adv NanoBiomed Res* 2024;**4**:2400003.

Lamyaa Albakr[a,b], Lifeng Kang[a,c,*]

[a]*School of Pharmacy, Faculty of Medicine and Health, University of Sydney, Sydney, NSW 2006, Australia*

[b]*Department of Pharmaceutics, College of Pharmacy, King Saud University, Riyadh 11451, Saudi Arabia*

[c]*Sydney Nano Institute, University of Sydney, NSW 2006, Australia*

*Corresponding author.

E-mail address: lifeng.kang@sydney.edu.au (Lifeng Kang).