MEDS Basic Medicine (2026)
Clausius Scientific Press, Canada

DOI: 10.23977/medbm.2026.040113
ISSN 2616-2091 Vol. 4 Num. 1

Research Trends of Dissolving Microneedles: A Bibliometric and Visualization Analysis Using CiteSpace and VOSviewer

Zhang Lijuan[1,a], Yi Yun[1,b], Liu Jinhui[1,c,*]

[1]Shaanxi University of Chinese Medicine, Xianyang, China
[a]2071100@sntcm.edu.cn, [b]yiyunaaaa@163.com, [c]2071021@sntcm.edu.cn
**Corresponding author*

Keywords: Dissolving microneedles; Bibliometrics; Transdermal delivery; Vaccines; Insulin

Abstract: This study systematically evaluated the research status, development trends, and emerging hotspots of dissolving microneedles (DMNs) using bibliometric and visualization methods. Publications related to DMNs from 2005 to 2025 were retrieved from the Web of Science Core Collection, and CiteSpace and VOSviewer were employed to perform bibliometric analyses, including publication trends, countries/regions, institutions, authors, journals, and keyword co-occurrence, with visual knowledge maps constructed to identify collaboration networks and research frontiers. A total of 1,514 publications were included, with annual numbers increasing significantly from 2 in 2005 to 301 in 2025, showing an approximate growth rate of 28.5% and indicating rapid expansion, particularly after 2018. China was the most productive country, followed by the United States, South Korea, and Northern Ireland, while major research clusters centered around Queen's University Belfast and leading Chinese institutions such as the Chinese Academy of Sciences and Sun Yat-sen University. Keyword analysis revealed that current research hotspots mainly focus on fabrication techniques, therapeutic delivery, nanoparticles, and applications in vaccines and insulin delivery, with cluster analysis further indicating widespread applications in vaccine delivery, wound healing, and rheumatoid arthritis treatment. Overall, DMN research is undergoing rapid expansion and increasing interdisciplinary integration, with current studies emphasizing material design, fabrication technologies, and biomedical applications, while future efforts should focus on improving mechanical properties, optimizing drug delivery performance, expanding clinical applications, and promoting large-scale production and clinical translation to advance DMNs as a promising delivery platform.

1. Introduction

Microneedles (MNs) have emerged as a promising transdermal drug delivery technology that combines the advantages of conventional transdermal patches and hypodermic injections. By creating temporary microchannels in the stratum corneum, MNs enable efficient drug transport into the skin with minimal pain and tissue damage, thereby improving patient compliance and allowing controlled drug release [1]. Owing to these advantages, MNs have been extensively investigated for the delivery of vaccines, proteins, peptides, and small-molecule drugs [2–4]. According to their structures and drug delivery mechanisms, MNs are generally classified into solid, coated, hollow, hydrogel-forming, and dissolving microneedles (DMNs) [5].

Among these platforms, DMNs have attracted particular attention because they are fabricated from biocompatible and biodegradable materials that dissolve rapidly after insertion into the skin, releasing encapsulated drugs without generating biohazardous sharps waste [6]. Compared with other MN systems, DMNs offer several advantages, including simple fabrication, accurate dosing, minimal drug loss, excellent biocompatibility, and painless administration [7]. Consequently, DMNs have been widely explored for the delivery of vaccines, hormones, proteins, antibiotics, and other therapeutic agents, with promising applications in skin diseases, diabetes, rheumatoid arthritis, wound healing, cancer therapy, and cosmetic medicine [8–11]. Continuous advances in biomaterials and microfabrication technologies have further accelerated the development of DMN-based drug delivery systems.

As the number of publications on DMNs has increased rapidly, a comprehensive understanding of the research landscape, collaboration patterns, and emerging trends has become increasingly important. Bibliometric analysis provides an effective quantitative approach for evaluating scientific output, identifying influential contributors, and revealing research hotspots and future directions. CiteSpace and VOSviewer are two widely used bibliometric tools for visualizing collaboration networks and knowledge structures through co-authorship, co-citation, and keyword co-occurrence analyses [12,13].

Although numerous reviews have summarized the fabrication strategies and biomedical applications of DMNs, a comprehensive bibliometric evaluation of this rapidly developing field remains lacking. Therefore, this study systematically analyzed publications related to DMNs retrieved from the Web of Science Core Collection (WoSCC) using CiteSpace and VOSviewer. Publication trends, countries, institutions, authors, journals, and keyword networks were comprehensively analyzed to identify the current research status, collaboration patterns, research hotspots, and emerging trends. The findings provide a comprehensive overview of global DMN research and offer valuable references for future scientific investigation and clinical translation.

2. Materials and methods

2.1. Data source

The Web of Science Core Collection (WoSCC) is a globally recognized academic database that indexes more than 20,000 high-quality journals with significant scholarly impact. To ensure the accuracy and reliability of the analysis, WoSCC was selected as the primary data source in this study. The data retrieval and collection process is illustrated in Figure 1. The search keywords were (“dissolving microneedle” OR “dissolvable microneedle”), with a time span from January 1, 2005 to December 31, 2025. After data cleaning (removing duplicates and irrelevant records), 1,514 papers were obtained. The retrieved records were downloaded with the option “Full Record and Cited References” and exported in plain text format. According to the requirements of CiteSpace, all downloaded files were renamed with the prefix “download” and saved in .txt format for subsequent analysis.

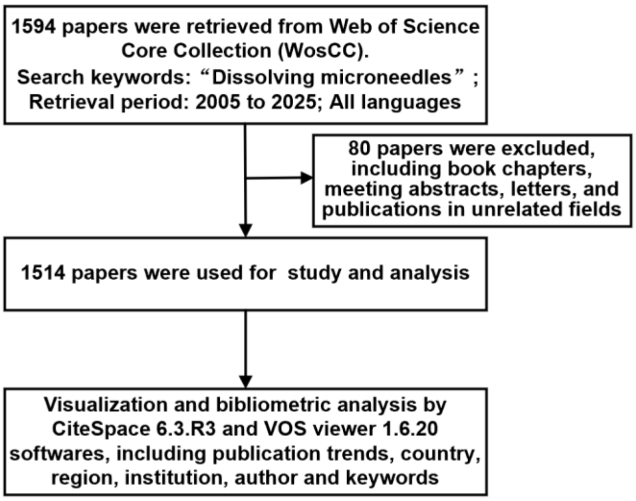

Figure 1. Flowchart of the literature search process.

2.2. Data analysis

VOSviewer (version 1.6.20) and CiteSpace (version 6.3.R3) were used in this study to conduct a bibliometric analysis of the literature, generating co-authorship networks of authors, countries/institutions, and keyword co-occurrence maps. CiteSpace was used for the visualization and clustering analysis of institutions and keywords. The parameters were set as follows: the time span was from 2005 to 2025, with a time slice of one year; the node types were set to Institution and Keyword; the selection threshold was Top 50; and the network pruning method was set to Pathfinder, with other parameters left at their default settings. VOSviewer was used to analyze co-occurrence relationships among countries/regions, authors, and keywords. The full counting method was applied, and relevant parameters were selected to generate the visualization maps. In the maps of countries and keywords, each element consists of a circle and a label. The size of the elements depends on factors such as node degree, link strength, and citation frequency, while different clusters are represented by different colors.

3. Results

3.1. Analysis of publication trends

The annual publication trend of DMNs research from 2005 to 2025 is shown in Figure 2. Overall, the number of publications increased steadily, indicating growing research interest in this field. From 2005 to 2013, DMN research remained at an early stage, with fewer than 30 publications annually. Between 2014 and 2018, publication output increased steadily, reflecting the gradual expansion of research activity. Since 2019, the field has entered a period of rapid growth, with annual publications increasing from 95 in 2020 to 301 in 2025. Overall, publication output rose from 2 papers in 2005 to 301 papers in 2025, corresponding to an approximate annual growth rate of 28.5%. These findings indicate that DMN research has developed rapidly over the past two decades and has become an increasingly active area of biomedical and pharmaceutical research.

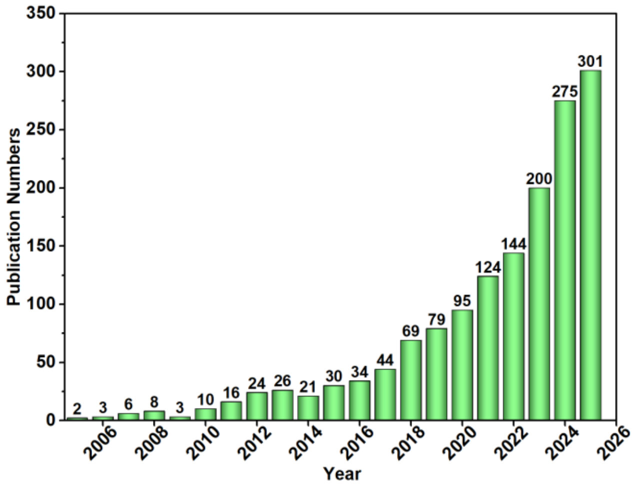

Figure 2. The publication numbers of DMNs research in WoSCC database from 2005 to 2025.

3.2. Distribution by country/region

A total of 68 countries and regions contributed to dissolving microneedle (DMN) research. China ranked first in publication output (355 publications), followed by the United States (168), South Korea (121), and Northern Ireland (115), demonstrating broad global participation in this field. Countries with more than five publications were further analyzed using VOSviewer, generating a collaboration network involving 38 countries (Figure 3). Total link strength (TLS) was used to evaluate international collaboration. China showed the highest TLS (521,953), followed by the United States (356,737), South Korea (278,273), India (266,702), and Northern Ireland (237,718), indicating that these countries occupy central positions in the global collaboration network. Overall, the results suggest that DMN research is characterized by extensive international collaboration, with China playing a leading role in both publication output and research cooperation.

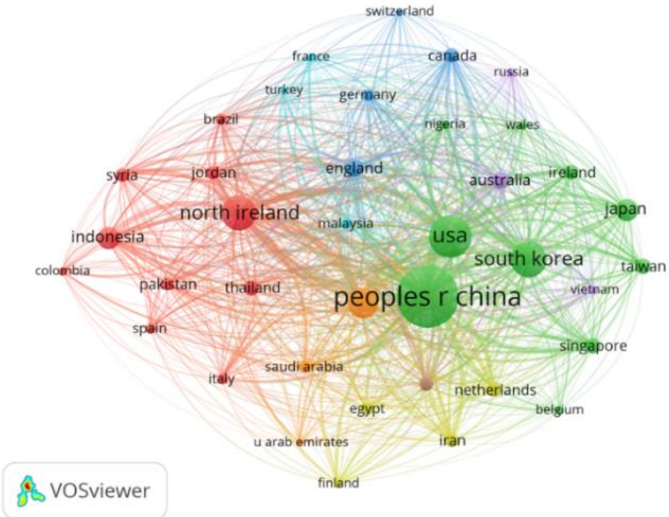

Figure 3. The countries' network visualization map was generated by VOSviewer.

3.3. Co-authorship network of authors

A total of 211 active authors were included in the co-authorship analysis. The collaboration network is shown in Figure 4, where nodes represent authors and links indicate collaborative relationships, with thicker links reflecting stronger collaboration. Among these authors, 36 researchers had published more than 10 papers, indicating relatively high research productivity. As shown in Figure 4, Donnelly, Ryan F. occupied a central position in the collaboration network and maintained close collaborations with Permana, Andi Dian; McCarthy, Helen O.; Anjani, Qonita Kurnia; Tekko, Ismaiel A.; McCrudden, Mael ɓsa T. C.; and Woolfson, A. David, forming one of the most influential research groups in the field. This network demonstrates strong and sustained collaboration among leading researchers and highlights the important role of collaborative research in advancing dissolving microneedle technology.

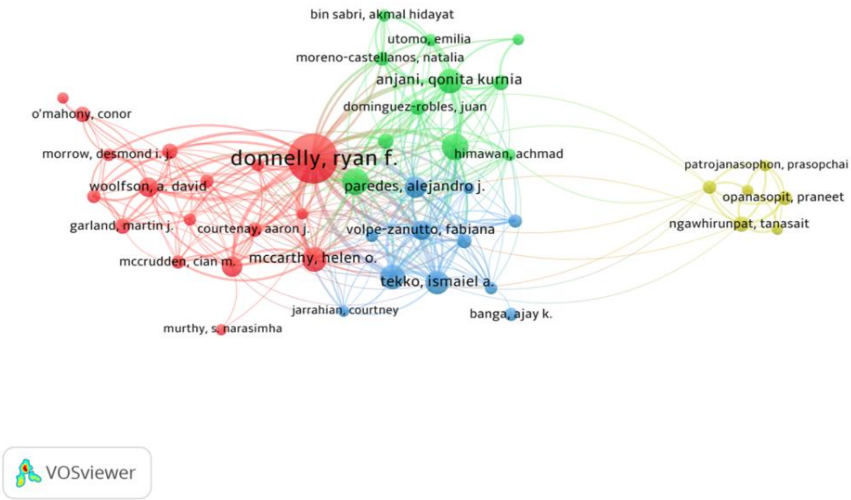

Figure 4. Co-occurrence map of authors by VOSviewer.

3.4. Institutional collaboration network

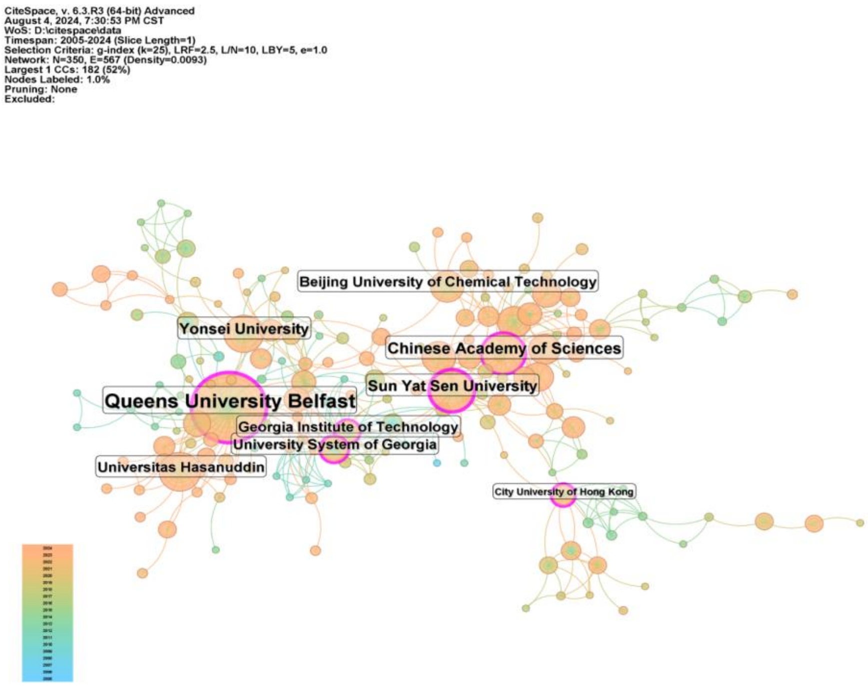

Figure 5. Co-occurrence map of institutions.

A total of 97 institutions contributed to DMNs research. Queen’s University Belfast ranked first in publication output (200 publications), followed by Georgia Institute of Technology (57), Chinese Academy of Sciences (42), Yonsei University (40), and Sun Yat-sen University (38). The institutional collaboration network generated by CiteSpace is shown in Figure 5. Two major collaboration clusters were identified, centered on Queen's University Belfast and the Chinese Academy of Sciences–Sun Yat-sen University partnership. These institutions occupy central positions in the collaboration network, indicating their important roles in promoting institutional cooperation and advancing DMN research.

3.5. Journal publication analysis

A total of 1,514 documents were analyzed, which were published across 200 journals. We further identified journals with more than 30 publications, which together account for 52% of all publications (787/1,514). The top five journals in terms of cumulative output are International Journal of Pharmaceutics (219 articles, 15%), Journal of Controlled Release (142 articles, 9%), European Journal of Pharmaceutics and Biopharmaceutics (87 articles, 6%), Pharmaceutics (73 articles, 5%), and European Journal of Pharmaceutical Sciences (62 articles, 4%). Together, these five journals published 583 articles, representing 39% of the total literature. Among them, Journal of Controlled Release (IF 2025 = 11.5) has the highest impact factor, highlighting its role in disseminating the latest advances and cutting-edge developments in this field.

3.6. Keyword co-occurrence analysis

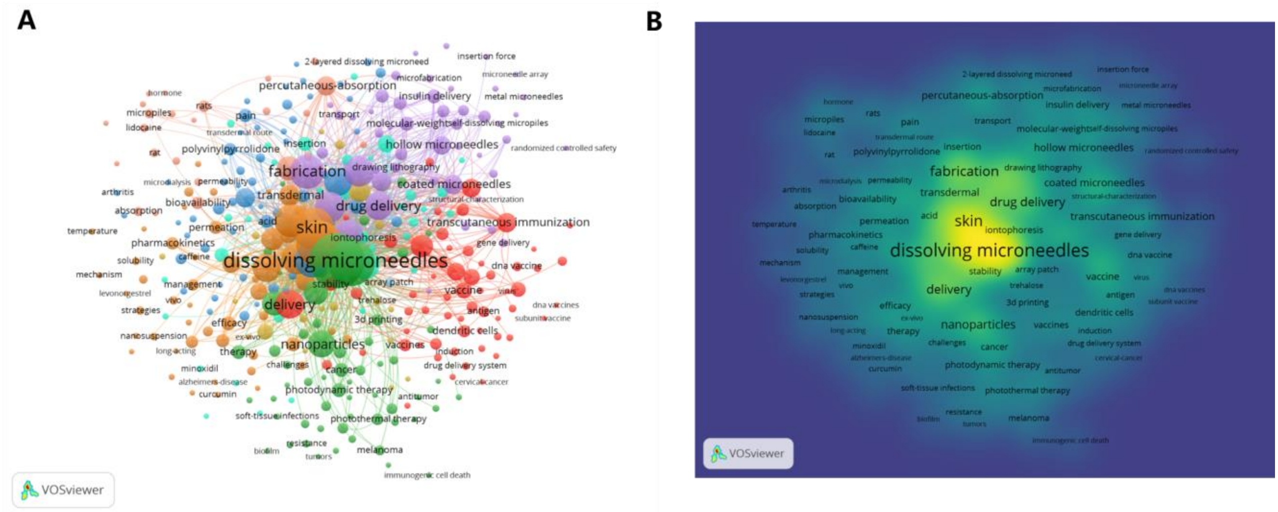

Figure 6. Keyword co-occurrence map.

Keyword co-occurrence analysis was performed using VOSviewer 1.6.20 to identify research hotspots and emerging trends in DMNs research. A total of 5,117 keywords were retrieved, of which 558 met the threshold for visualization (Figure 6A). In the co-occurrence network, larger nodes indicate higher keyword frequencies, while connecting lines represent the relationships among keywords. The most frequently occurring keywords included dissolving microneedles, skin, fabrication, delivery, drug delivery, and nanoparticles, reflecting the major research themes in this field. The keyword network revealed four main research directions. First, polymer microneedles represent the predominant type of DMNs because of their excellent biocompatibility, biodegradability, and suitability for transdermal drug delivery. Second, transdermal delivery and intradermal delivery remain the primary delivery strategies, highlighting the central role of DMNs in overcoming the skin barrier. Third, nanoparticles have become an important research focus, reflecting the increasing integration of nanotechnology with DMNs to improve drug stability, controlled release, and therapeutic efficacy. Finally, insulin is one of the most representative therapeutic applications, demonstrating the growing interest in DMN-based systems for diabetes management. The keyword density map (Figure 6B) further illustrates the distribution of research intensity, with high-density regions indicating the most active research topics. Overall, the keyword co-occurrence and density analyses demonstrate that material design, fabrication technologies, drug delivery, and biomedical applications remain the major research directions in the DMN field and are expected to continue driving future developments.

3.7. Keyword cluster analysis

Keyword clustering analysis was performed using CiteSpace, and cluster labels were generated using the log-likelihood ratio (LLR) algorithm (Figure 7). The clustering quality was satisfactory, with a modularity value of Q = 0.5815 and a mean silhouette value of S = 0.8243, indicating reliable and well-defined clustering results. Eight keyword clusters were identified and could be broadly grouped into two categories: biomedical applications and materials and experimental models. The application-related clusters included vaccine (#1), rheumatoid arthritis (#2), wound healing (#3), nanosuspension (#5), and transcutaneous vaccination (#6), reflecting the expanding applications of DMNs in drug delivery and disease treatment. The materials and experimental model-related clusters included patches (#0), needles (#4), and rat model (#7), highlighting continued research on device design, transdermal delivery systems, and preclinical evaluation. Overall, the clustering results indicate that current DMN research focuses on both technological innovation and biomedical applications, demonstrating a strong trend toward interdisciplinary research and clinical translation.

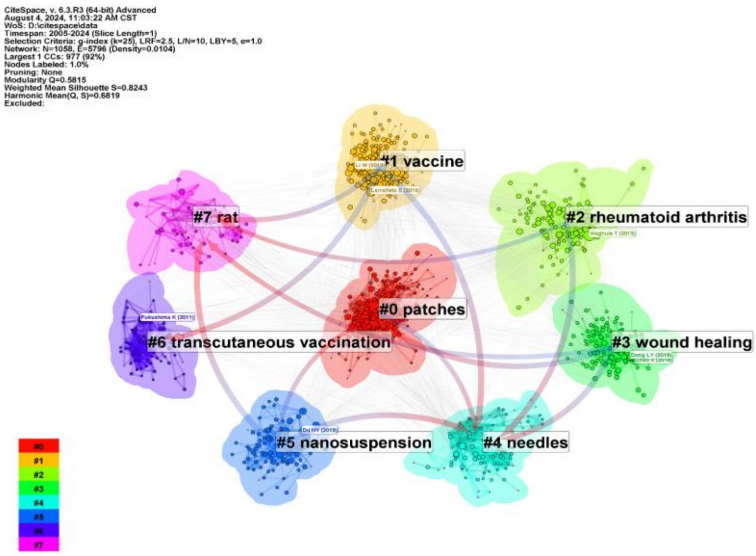

Figure 7. Cluster diagram of keywords.

4. Discussion

This study provides a comprehensive bibliometric analysis of dissolving microneedle (DMN) research based on the WoSCC database. The results demonstrate that DMN research has experienced rapid growth, particularly after 2018, reflecting increasing academic interest and the expanding application of DMNs in transdermal drug delivery. China has become the leading contributor in publication output, followed by the United States, South Korea, and Northern Ireland, while institutions such as Queen's University Belfast and major Chinese research organizations have played central roles in promoting scientific collaboration and innovation. Keyword co-occurrence and cluster analyses revealed that fabrication techniques, transdermal drug delivery, nanoparticles, vaccine delivery, insulin delivery, wound healing, and rheumatoid arthritis are the major research hotspots. The integration of nanotechnology with DMNs has further enhanced drug stability, controlled release, and therapeutic efficacy, highlighting the interdisciplinary nature of this rapidly evolving field. Despite these advances, several challenges remain. Improving the mechanical strength and insertion reliability of DMNs, achieving precise control of drug release, validating long-term safety through clinical studies, and addressing large-scale manufacturing and quality control are essential for successful clinical translation and commercialization. In addition, this study has several limitations. Only publications indexed in the WoSCC database were included, and differences in database coverage and search strategies may have introduced potential bias. Overall, DMNs represent a promising transdermal drug delivery platform with broad biomedical applications. Future research should focus on the development of advanced biomaterials, optimization of fabrication technologies, expansion of clinical applications, and strengthening international and interdisciplinary collaborations to accelerate large-scale production and clinical translation.

References

[1] Luo, X., Yang, L. and Cui, Y. (2023) Microneedles: Materials, fabrication, and biomedical applications. Biomed Microdevices, 25, 20.

[2] Zheng H, Xie X, Ling H, You X, Liang S, Lin R, Qiu R. and Hou H. (2023) Transdermal drug delivery via microneedles for musculoskeletal systems. J Mater Chem B, 11, 8327–8346.

[3] Zhang, Y., Gao TT, Jin ZH. and Jin S. (2024) A novel drug delivery approach for the treatment of keloids. J Clin Dermatol, 38, 827–832.

[4] Waghule T, Singhvi G, Dubey SK, Pandey MM, Gupta G, Singh M. and Dua K. (2019) Microneedles: A smart approach and increasing potential for transdermal drug delivery system. Biomed Pharmacother, 109, 1249–1258.

[5] Feng, M., Wu, C., Jiang, Y. and Zhao, C. (2024) Effects of matrix composition on the formation and penetration of resveratrol-loaded dissolving microneedles. J Guangdong Pharm Univ, 40, 108–114.

[6] Zong, Q., Guo, R., Dong, N., Ling, G. and Zhang, P. (2021) Design and development of insulin microneedles for diabetes treatment. Drug Deliv Transl Res, 1–8.

[7] Kim JS, Choi JA, Kim JC, Park H, Yang E, Park JS, Song M. and Park JH. (2020) Microneedles with dual release pattern for improved immunological efficacy of Hepatitis B vaccine. Int J Pharm, 591, 119928.

[8] Li Y, Ju XJ, Fu H, Zhou CH, Gao Y, Wang J, Xie R, Wang W, Liu Z. and Chu LY. (2023) Composite separable microneedles for transdermal delivery and controlled release of salmon calcitonin for osteoporosis therapy. ACS Appl Mater Interfaces, 15, 638–650.

[9] van der Maaden, K., Jiskoot, W. and Bouwstra, J. (2012) Microneedle technologies for (trans)dermal drug and vaccine delivery. J Control Release, 161, 645–655.

[10] Machekposhti, S.A., Kadian, S., Vanderwal, L., Stafslien, S. and Narayan, R.J. (2023) Novel hollow biodegradable microneedle for amphotericin B delivery. MedComm, 4, e321.

[11] Zhao W, Zheng L, Yang J, Li Y, Zhang Y, Ma T. and Wang Q. (2023) Dissolving microneedle patches-mediated percutaneous delivery of tetramethylpyrazine for rheumatoid arthritis treatment. Eur J Pharm Sci, 184, 106409.

[12] Xiang, M., Yang, C., Zhang, L., Wang, S., Ren, Y. and Gou, M. (2024) Dissolving microneedles for transdermal drug delivery in cancer immunotherapy. J Mater Chem B, 12, 5812–5822.

[13] Leone, M., Mönkäre, J., Bouwstra, J.A. and Kersten, G. (2017) Dissolving microneedle patches for dermal vaccination. Pharm Res, 34, 2223–2240.