Annals of Pharmacy Practice and Pharmacotherapy
ISSN: 3062-4436
2023, Volume 3, Page No: 127-136

Available online at: www.galaxypub.co/page/journals

Galaxy Publication

Evaluation of Jordanian Pharmacists' Knowledge and Perspectives on Microneedle Technology

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Received: 15 April 2023; **Revised:** 08 August 2023; **Accepted:** 12 August 2023

ABSTRACT

Microneedles represent a novel, minimally invasive, patient-friendly, and self-administered method for drug delivery that has attracted considerable interest. This study aimed to assess Jordanian pharmacists' knowledge, awareness, and acceptance of microneedle technology and to determine factors predicting higher awareness levels. A cross-sectional survey was conducted online in Jordan during January and February 2023, and binary logistic regression was applied to identify predictors of greater familiarity with microneedles as a delivery system.A total of 474 pharmacists participated, with 67.9% indicating prior familiarity with transdermal drug delivery methods. University education was the most frequently reported source of information on microneedles (85.1%). Nearly half of the respondents (47.5%) recommended cleaning the application site with water or an alcohol swab. The three main perceived advantages of microneedles compared to other transdermal systems were faster site healing (43.7%), ease of administration (41.1%), and painless delivery of the active pharmaceutical ingredient (40.7%). Participants demonstrated a moderate level of knowledge, with an average score of 4.3 (SD 1.6) out of 7. Regression analysis showed that pharmacists with 5–10 years of professional experience were significantly more likely to be knowledgeable about microneedles ($p \leq 0.01$).Pharmacists generally possessed a solid understanding of microneedle technology, though gaps remained regarding their benefits, design, and applications. Enhanced educational initiatives are suggested to address these gaps and strengthen pharmacists' expertise in this area.

Keywords: Pharmacists, Acceptance, Jordan, Drug delivery, Microneedles, Knowledge

How to Cite This Article: Chen D, Wang L, Scott R. Evaluation of Jordanian Pharmacists' Knowledge and Perspectives on Microneedle Technology. Ann Pharm Pract Pharmacother. 2023;3:127-36. https://doi.org/10.51847/gofGIODMbW

Introduction

Drug delivery systems have become essential tools for ensuring the safe and effective administration of therapeutic agents [1]. These systems are crucial for controlling drug release profiles, overcoming physiological barriers, and enhancing the therapeutic efficacy of medications. The most commonly employed routes for drug administration are oral and intravenous (IV) [2]. While oral administration has notable advantages, it also has significant limitations [3]. Oral drugs are subject to degradation by gastrointestinal secretions and first-pass metabolism. Moreover, oral delivery can be challenging for pediatric patients, individuals with swallowing difficulties, those with mental disorders, or unconscious patients [4, 5]. IV administration, on the other hand, requires trained healthcare personnel and specialized facilities, which can be inconvenient and reduce patient adherence. Additionally, around 10% of individuals experience some degree of needle phobia due to the pain associated with IV injections [6].

The transdermal route offers an alternative that can address many of the limitations of oral and IV drug delivery. This method provides noninvasive or minimally invasive access to systemic circulation, bypassing the gastrointestinal tract and first-pass metabolism [7, 8]. Transdermal drug delivery was first approved in 1979 with the US FDA authorization of a scopolamine patch for motion sickness [9]. Between 1979 and 2002, only one transdermal patch was approved every 2.2 years; however, this pace increased dramatically to one patch every 7.5

months from 2003 to 2007. Such growth underscores the promise of transdermal systems, with current estimates exceeding one billion patches produced annually [10, 11].

Microneedle (MN) technology represents an innovative advancement in transdermal drug delivery. MNs have gained considerable attention due to their minimally invasive, patient-friendly, and self-administered characteristics [12]. They are designed to deliver therapeutic agents either locally or systemically through the skin [10]. MNs consist of arrays of microscopic needles, typically 250–1000 μm in length, which penetrate the stratum corneum to create microchannels for drug delivery [13]. Since they are shorter than the skin's nerve endings, MNs enable virtually pain-free administration [14]. The concept of MNs emerged in 1976, with experimental research reported in 1998 [15, 16], and since then, interest has grown significantly in their application for delivering diverse therapeutic molecules [17].

Should MN-based therapies receive approval from regulatory authorities such as the FDA, pharmacists will play a pivotal role in guiding patients on correct application techniques. They will also need to be knowledgeable about safety precautions, labeling regarding usage frequency, and potential drug interactions. Furthermore, if pharmacists are authorized to act as primary prescribers, especially for over-the-counter (OTC) medications, their responsibilities will expand considerably.

This study aims to evaluate the awareness and acceptance of MN technology among Jordanian pharmacists and to identify factors that predict their level of knowledge and readiness to adopt this novel drug delivery system.

Materials and Methods

Study design

A cross-sectional survey was conducted among pharmacists in Jordan from January to February 2023. The research team developed a structured questionnaire aimed at assessing pharmacists' knowledge and attitudes toward microneedle (MN) technology. The survey, administered online in English (the academic and professional language in Jordan), included six items testing knowledge and eight items exploring opinions. To ensure content validity, the questionnaire was reviewed and pretested by experts in pharmaceutical technology and practicing pharmacists from various specialties.

Data collection

Pharmacists were recruited via targeted social media campaigns and Facebook groups dedicated to Jordanian pharmacists. Participation was entirely voluntary, and no formal informed consent was required; the study objectives were outlined in the introduction accompanying the questionnaire. Eligibility criteria included: (a) holding at least a pharmacy diploma and (b) currently practicing in Jordan. Pharmacists who were unemployed at the time of the study were excluded.

Sample size

The Raosoft® sample size calculator was used to determine a representative sample. The formula $n = P \times (1 - P) \times z^2/d^2$ was applied, using a 5% margin of error, 95% confidence level, and 50% assumed response distribution. Based on these parameters, a minimum of 379 participants was recommended [18-20]. Ultimately, 474 pharmacists completed the survey.

Statistical analysis

Data analysis was conducted using SPSS version 25 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean ± standard deviation, while categorical data were reported as frequencies and percentages. Binary logistic regression was performed to identify factors associated with greater awareness of MN technology, using the sample's average knowledge score as the cut-off for dichotomizing the outcome variable. Statistical significance was set at $p < 0.05$ with a 95% confidence interval.

Patient and public involvement

No patients or members of the public were involved in this research.

Abbreviations

MN: microneedle; IV: intravenous; SC: stratum corneum; FDA: Food and Drug Administration.

Results and Discussion

Demographic characteristics of participants

The study included 474 pharmacists. Over half (56.5%) held a bachelor's degree in pharmacy, and approximately 41.0% had less than two years of professional experience. About one-third (34.6%) worked in independent community pharmacies, and the majority (92.6%) graduated from local universities. Nearly 42.0% reported working in their current practice setting for 1–5 years. Additional demographic details are summarized in **Table 1.**

Table 1. Participants' demographic characteristics

Variable	Frequency	Percentage
Pharmacy qualification		
Diploma	83	17.5%
Bachelor of Pharmacy	268	56.5%
Doctor of Pharmacy (PharmD)	39	8.2%
Master's in Pharmacy	57	12.0%
PhD in Pharmacy	27	5.7%
Years of professional experience		
0–2 years	194	40.9%
2–5 years	113	23.8%
5–10 years	78	16.5%
More than 10 years	89	18.8%
Current workplace sector		
Independent community pharmacy	164	34.6%
Pharmaceutical company	77	16.2%
Chain pharmacy	76	16.0%
Hospital pharmacy	55	11.6%
Government health facilities	15	3.2%
Military healthcare facilities	7	1.5%
Other settings	80	16.9%
Country where latest degree was obtained		
Local university	439	92.6%
Foreign university (outside Jordan)	35	7.4%
Duration in current practice setting		
Less than 1 year	147	31.0%
1–5 years	199	42.0%
6–10 years	62	13.1%
More than 10 years	66	13.9%

Awareness of microneedles as a transdermal drug delivery system

Among the pharmacists surveyed, 67.9% reported having knowledge of administering medications through the skin, such as via transdermal delivery. The majority cited university education as their main source of information on microneedles (85.1%). When asked about the availability of transdermal drugs in the Jordanian market, 41.0% estimated that only 1–3 products are accessible. Additionally, 74.3% of participants indicated familiarity with microneedle-related terminology, with 68.2% attributing this understanding to their academic training. Most respondents (84.0%) also expressed support for introducing and gaining FDA approval for microneedles as a new transdermal delivery platform in Jordan. Detailed results regarding pharmacists' awareness of microneedles are provided in **Table 2.**

Table 2. Participants' awareness of microneedles as a transdermal drug delivery system

Variable	Frequency	Percentage
Familiarity with delivering drugs through the skin (transdermal delivery)		
Yes	322	67.9%
Sources of information on transdermal delivery (multiple answers allowed)		
University courses or academic training	274	85.1%
Internet	91	28.3%

Pharmaceutical company representatives	74	23.0%
Social media platforms	56	17.4%
Other sources	89	27.6%
Perceived number of transdermal drugs in the Jordanian market		
None	60	12.7%
1–3 drugs	194	40.9%
4–7 drugs	124	26.2%
More than 7 drugs	96	20.3%
Familiarity with microneedle terminology		
Yes	352	74.3%
Sources of knowledge about microneedles (multiple answers allowed)		
University courses or academic training	240	68.2%
Internet	101	28.7%
Social media platforms	70	19.9%
Pharmaceutical company representatives	59	16.8%
Other sources	98	27.8%
Support for commercialization and FDA approval of microneedles in Jordan		
Yes	398	84.0%

Knowledge of microneedles as a transdermal drug delivery system

Table 3 summarizes participants' responses to questions assessing their knowledge of microneedles (MNs) for transdermal drug delivery. Nearly half of the pharmacists (47.5%) stated that the primary advice they would provide patients—if MNs were commercially available—would be to clean the application site with water or disinfect it using an alcohol swab around 40.0% considered patient age to be irrelevant when recommending MNs. Approximately 48.0% identified the groups most likely to benefit from MNs as patients with injection-related anxiety, those with chronic conditions such as hypertension or emphysema, and individuals experiencing temporary ailments or pain, including headaches. Almost half of the participants (49.8%) believed that MNs could improve patient adherence to treatment regimens. The three advantages of MNs most frequently cited over other transdermal methods were faster recovery at the application site (43.7%), simplicity of administration (41.1%), and painless delivery of the medication (40.7%).

Table 3. Knowledge of microneedles as a transdermal drug delivery system

Variable	Frequency	Percentage
Primary patient guidance if commercial microneedles were available*		
Clean the application site with water or disinfect using an alcohol swab	225	47.5%
Gently press the microneedle patch to ensure skin penetration	130	27.4%
Hydrate the area with an appropriate w/o emulsion	58	12.2%
No patient education needed; the patch is self-explanatory	61	12.9%
Recommended patient age for microneedle use (multiple answers allowed)*		
Adults	236	49.8%
Elderly	110	23.2%
Children	83	17.5%
Age does not affect suitability	191	40.3%
Groups expected to benefit most from microneedles*		
Patients with needle phobia	93	19.6%
Patients with chronic conditions such as hypertension or emphysema	87	18.4%
Patients with temporary illnesses or pain (e.g., headache)	66	13.9%
All of the above	228	48.1%
Immediate impressions of microneedles as a pharmacist (multiple answers allowed)		
Could improve patient adherence to therapy	236	49.8%
Easier to use compared to other dosage forms	205	43.2%
May support better management of polypharmacy	180	38.0%
Uncertain; may function like any other technology	87	18.4%
Perceived advantages over other transdermal systems (multiple answers allowed)		
Faster recovery at the application site	207	43.7%
Simplicity of administration	195	41.1%

Painless delivery of medication	193	40.7%
Eliminates needle-related fear	174	36.7%
Capable of delivering large molecules	151	31.9%
Enables rapid drug delivery using an electronic micro-pump	147	31.0%
Allows controlled drug release	142	30.0%
Targets specific skin areas for delivery	128	27.0%
May enhance drug efficacy, potentially lowering dose	124	26.2%
Reduces risk of microbial entry	108	22.8%
Well tolerated; minimal long-term erythema or edema	104	21.9%
**Microneedles are more effective than other transdermal systems (Yes)*	365	80.6%
**Enhance transdermal delivery of various molecules (Yes)*	382	80.6%
**Enable painless systemic drug delivery (Yes)*	375	79.1%
**Can be self-administered (Yes)*	345	72.8%
Potential difficulty in patients with muscle disorders (Yes)	236	49.8%
Concern about mild irritation or erythema (Yes)	324	68.4%

* Items used to calculate participants' knowledge score.

Determinants of knowledge regarding microneedles as a drug delivery method

Pharmacists participating in the study demonstrated a moderate understanding of microneedles (MNs) for drug delivery, with a mean score of 4.3 (SD 1.6) out of 7, equivalent to 61.4% of the total possible score. Analysis using binary logistic regression revealed that those with 5–10 years of cumulative professional experience were significantly more knowledgeable about MNs than pharmacists in other experience categories ($p \leq 0.01$). In **Table 4**, "total years of experience" refers to overall time spent working in the pharmacy profession, while "experience in practice settings" specifies the duration spent in particular workplaces such as hospitals or community pharmacies. Other demographic factors did not show significant associations with MN knowledge ($p \geq 0.05$).

Table 4. Factors associated with higher knowledge of microneedles as a drug delivery system

Variable	Odds Ratio (95% CI)	p-value
Pharmacy qualification		
Diploma (reference)	1.00	–
Bachelor of Pharmacy	1.05 (0.73–1.52)	0.778
Doctor of Pharmacy (PharmD)	1.60 (0.82–3.11)	0.167
Master's in Pharmacy	1.32 (0.76–2.30)	0.329
PhD in Pharmacy	1.88 (0.84–4.21)	0.122
Total years of professional experience		
0–2 years (reference)	1.00	–
2–5 years	0.77 (0.50–1.18)	0.228
5–10 years	2.03 (1.23–3.34)	0.006*
More than 10 years	1.56 (0.98–2.49)	0.061
Current workplace sector		
Independent community pharmacy (reference)	1.00	–
Pharmaceutical company	1.08 (0.66–1.77)	0.748
Chain pharmacy	0.64 (0.39–1.05)	0.074
Hospital pharmacy	1.13 (0.64–1.97)	0.682
Government health facilities	0.71 (0.25–2.01)	0.515
Military healthcare facilities	0.42 (0.08–2.20)	0.307
Country of latest degree		
Local university (reference)	1.00	–
Foreign university (outside Jordan)	1.03 (0.87–1.23)	0.702
Duration of experience in practice settings		
Less than 1 year (reference)	1.00	–
1–5 years	1.03 (0.72–1.48)	0.873
6–10 years	1.08 (0.63–1.84)	0.775
More than 10 years	1.44 (0.85–2.42)	0.176

*Significant at $p \leq 0.01$

The findings of this study highlight several important observations regarding pharmacists' knowledge and perceptions of microneedles (MNs) as a transdermal drug delivery system. More than two-thirds of the participants (67.9%) indicated familiarity with transdermal drug delivery, while 74.3% reported being knowledgeable about MN technology. This high level of awareness regarding relevant terminology reflects a solid foundation that could support the integration of MNs into clinical practice. University education emerged as the primary source of information on MNs for most pharmacists (85.1%), emphasizing the critical role that academic programs play in promoting understanding of emerging drug delivery innovations within the pharmaceutical workforce.

Regarding patient counseling, 47.5% of pharmacists stated that their main advice would involve instructing patients to clean the application site with water or disinfect it using an alcohol swab. Such guidance reflects an awareness of the importance of minimizing microbial contamination when using MNs. Currently, regulatory guidance on MN use from agencies such as the Medicines and Healthcare Products Regulatory Agency (MHRA) or the US Food and Drug Administration (USFDA) is lacking. These findings suggest an urgent need for regulatory authorities to establish comprehensive guidelines outlining recommended patient counseling and best practices for MN implementation, which would standardize procedures and ensure safe and effective utilization of this technology.

Nearly half of the pharmacists (48.0%) identified MNs as potentially beneficial for patients with injection phobia, chronic illnesses such as hypertension or emphysema, and acute or temporary conditions like headaches. Injection phobia, a recognized psychiatric condition affecting approximately 3–4% of the US population, can cause severe fear, avoidance, dizziness, or fainting, and may hinder adherence to therapy [21]. In Canada, around 8% of children and 7% of adults reported that needle phobia prevented them from receiving vaccinations [22]. MNs, by virtue of their microscopic size and ability to penetrate only the stratum corneum (SC) without reaching deeper layers of skin, offer a virtually painless and minimally invasive alternative to conventional hypodermic needles [23]. This design can improve patient comfort, enhance adherence to treatment, and mitigate the psychological burden associated with injections [24].

A survey conducted among the Jordanian public indicated that 28.5% of respondents reported experiencing needle phobia, while 43.5% expressed varying degrees of fear toward injections [21]. The study also revealed that the public demonstrated greater familiarity with and preference for MNs compared to traditional needles, underscoring their potential to reduce needle-related anxiety and gain patient acceptance in clinical settings.

Pharmacists should also be informed about the wide range of MN applications. This technology has been evaluated for managing chronic conditions, including hypertension, cancer, and rheumatoid arthritis [25-27], as well as for acute issues such as pain relief, vaccination, and inflammation [28, 29]. Although more than half of the surveyed pharmacists (52%) were unsure about the suitability of MNs for chronic disease management, evidence from the literature demonstrates that MNs can effectively deliver medications for long-term conditions [30].

The results of this study highlight the substantial potential of microneedles (MNs) to influence a wide range of clinical scenarios. Nearly half of the pharmacists surveyed anticipated that MN implementation could enhance patient engagement and adherence to prescribed treatments, suggesting a generally positive perception of this innovative delivery system. Given that medication adherence—patients following prescribed regimens—directly affects treatment outcomes [31], the minimally invasive and virtually painless nature of MN administration may offer a valuable means to improve compliance. Furthermore, reducing dosing frequency or extending intervals between applications has been shown to further support adherence [32]. Long-acting MN patches, designed for application every few days or weeks, may therefore help patients maintain more consistent therapy schedules [17]. These features collectively contribute to enhancing the overall patient experience and improving clinical outcomes, highlighting the promise of MN technology within pharmacy practice.

Research into patient-friendly drug delivery methods remains an active focus, particularly for systems that simplify administration [33]. MNs have emerged as a pioneering technology in this field, attracting significant interest though not yet fully commercialized [34]. They have demonstrated the ability to deliver a broad spectrum of pharmaceuticals, including both hydrophilic and hydrophobic molecules, high- and low-dose medications, prescription drugs, and over-the-counter products [35]. In this study, almost 40% of pharmacists indicated that age does not restrict MN use, reflecting the versatility of this technology across patient populations. Indeed, European pediatric drug legislation emphasizes the need for minimally invasive, painless, and age-appropriate delivery systems [36]. The small size of MN arrays has allowed for the successful administration of insulin in children [37], as well as other medications such as methotrexate and antirheumatic drugs [38, 39].

MNs are also applicable to adult and geriatric populations, supporting treatments including cancer therapy, vaccines, NSAIDs, and local anesthetics [24, 40]. This demonstrates that MNs can be effectively adapted for patients of all age groups. However, certain precautions are necessary for pediatric use, such as ensuring complete patch application and maintaining an appropriately compact design.

Pharmacists serve a pivotal role in patient care, providing both medication dispensing and crucial counseling [41, 42]. Education on novel technologies is essential for fostering informed professionals who can guide patient acceptance and safe use of innovations like MNs [43, 44]. MNs, as a minimally invasive delivery option, have the potential to improve treatment experiences and encourage better adherence.

The most frequently reported benefits of MNs compared to conventional transdermal approaches include rapid healing at the application site, ease of administration, and a nearly painless delivery of drugs. In this study, 43.7% of pharmacists highlighted accelerated healing, while 41.1% emphasized simplicity of use. MNs can be self-administered, eliminating the need for healthcare professionals or specialized facilities, which adds practical convenience.

Since their inception in 1998, MNs have been the focus of extensive research investigating materials, molecular payloads, device designs, clinical applications, and future prospects [45-47]. Despite this growing body of evidence, no MN-based pharmaceutical products are commercially available in Jordan.

For MNs to transition from research to clinical practice and commercial use, several issues must be addressed. MNs penetrate the stratum corneum to deliver molecules to the viable epidermis, which could allow entry of exogenous substances or microorganisms [27]. Proper patient education, including instructions to clean or sterilize the application site, can reduce this risk. It is also notable that MNs generally pose a lower risk of microbial contamination compared with conventional hypodermic needles [48].

Conclusion

Although microneedles (MNs) have yet to reach the commercial market, the results of this study indicate that pharmacists possess a notable level of understanding of this innovative drug delivery technology. Nonetheless, certain gaps in knowledge remain, highlighting the need for targeted educational efforts. MNs have demonstrated a unique ability to painlessly breach the skin's outermost layer, enabling efficient delivery of a wide range of therapeutic agents. Their applications extend across diverse clinical contexts, including acute and chronic conditions, hormone therapies, vaccine administration, and usage across different age groups. Therefore, it is essential to strengthen pharmacist education on MN technology to prepare them for its potential integration into routine clinical practice.

Successful adoption of MNs in healthcare will require a comprehensive approach, encompassing regulatory development, standardized manufacturing practices, structured pharmacist training, and effective patient education strategies. Pharmacists are well-positioned to lead this integration, ensuring the safe and effective utilization of MN-based therapies. They can provide critical guidance on proper administration, drug delivery mechanisms, storage requirements, labeling interpretation, and adherence to expiry dates. By equipping pharmacists with this knowledge, MN technology could revolutionize drug delivery practices and substantially improve patient care outcomes.

What is already known about this topic?

Microneedle technology represents a cutting-edge area in drug delivery research. Existing studies have demonstrated its versatility and effectiveness for both transdermal and intradermal delivery of therapeutic agents. Initially introduced primarily as a cosmetic tool—commonly known as "dermaroller" devices—MN technology has since evolved to encompass broader medical and pharmaceutical applications.

What does this article add?

MN technology has attracted growing interest for delivering vaccines and therapeutic agents via transdermal or intradermal routes. Despite this potential, regulatory approval is still pending, and MN-based products are not yet available in the pharmaceutical market, limiting their use by pharmacists. This study provides an evaluation of Jordanian pharmacists' knowledge, attitudes, and practices regarding MNs, highlighting areas for improvement. The findings offer valuable insights for experts in the field, helping to address knowledge gaps, foster pharmacist awareness, and support the future development and clinical integration of this technology.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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