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Mobile applications for patients undergoing assisted reproduction: A systematic review of the gap between clinical research and practice

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ABSTRACT

Objective: To evaluate mobile applications available for patients undergoing assisted reproduction and assess the extent of their clinical validation.**Methods:** A systematic search was conducted in the Apple App Store and Google Play between September 1, 2023 and September 30, 2023 to identify mobile applications related to assisted reproduction. Apps were evaluated using the mobile app rating scale (MARS). In parallel, a literature search of PubMed, Scopus, Embase, and Web of Science was performed to identify clinical studies related to mobile applications in assisted reproduction. Clinical validation status and MARS scores were recorded, and findings were synthesized to highlight the gap between commercially available apps and research-based evidence.**Results:** From 1 143 apps screened, 11 met the inclusion criteria. Mean MARS score across apps was 3.63, with Leeaf scoring the highest (4.60). However, only one application (Embie) was supported by published research. The literature research identified 13 relevant studies, mostly randomized controlled trials, cohort studies, or usability studies. While research-based apps demonstrated clinical utility (*e.g.*, MediEmo, PreLiFe, Patient Journey App), most were unavailable on app stores. This revealed a disconnect between research-backed applications and those accessible to patients.**Conclusions:** Although several mobile apps for assisted reproduction demonstrate high usability and quality, few are clinically validated. The lack of integration between research and practice highlights the need for stronger collaboration between researchers, developers, and policymakers to ensure that patients access safe and effective tools.**KEYWORDS:** Mobile application; mHealth apps; Digital health tools; *In vitro* fertilization; Assisted reproduction; Infertility; User experience; Usability assessment

1. Introduction

Assisted reproductive technologies (ART) encompass a variety of medical procedures used primarily to address infertility. These

Key Points

Question: What is the gap between mobile applications available for assisted reproduction and clinical research supporting their use?**Findings:** This systematic review identified 11 mobile apps in app stores, with an average quality score of 3.63 on the mobile app rating scale. Only one app, Embie, had published clinical research to support its use. Meanwhile, 13 studies described research-based applications, but most of these were not available to patients in commercial app stores.**Meaning:** Although mobile applications have the potential to improve patient support during assisted reproduction, most tools lack clinical validation, which highlights to make evidence-based apps more accessible in routine practice.

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include *in vitro* fertilization (IVF), intracytoplasmic sperm injection (ICSI), cryopreservation of gametes or embryos, frozen embryo transfer, and the use of fertility medications[1]. ART has transformed reproductive medicine, offering hope and solutions for individuals and couples struggling with infertility. However, the journey through ART can be complex and emotional, with strict timing requirements and the constant anxiety of potential treatment failure[2]. In response to these challenges, the integration of telemedicine and mobile health (mHealth) applications has emerged as a promising development in patient care. Telemedicine enhances care by enabling remote consultations, reducing the need for frequent clinic visits, and providing timely access to specialist advice - particularly in the post-COVID-19 era[3]. Mobile application development for ART patients is characterized by the growing incorporation of digital tools that support patient care, education, and treatment outcomes. These apps provide functionalities such as medication tracking, appointment reminders, communication with healthcare providers, and access to emotional support and educational resources. By offering personalized and accessible care, these tools play a critical role in easing the complexities and stress of the ART journey.

However, despite advancements in mobile applications for ART, challenges remain in ensuring their scientific validation and integration into clinical practice. Many fertility-related apps lack clinical validation, even though they are marketed to patients as tools for managing complex ART protocols. This discrepancy highlights a critical gap in the development of mHealth tools for fertility care: while the technology exists to support patients, there is insufficient evidence to demonstrate the effectiveness of most fertility apps in improving treatment outcomes. The ease and cost-effectiveness of mobile app development, combined with the lack of stringent regulatory oversight in app stores, have resulted in an influx of apps on the market[4]. While this has allowed many companies to enter the healthcare sector, it has also introduced challenges in ensuring the reliability and effectiveness of these tools.

Research authenticating the quality of reproductive health apps remains limited, and as a result, users may encounter low-quality applications[5]. The absence of stringent regulatory barriers has led to inconsistent standards and security levels among these apps[6]. This lack of oversight may expose patients or healthcare providers to apps that do not meet necessary standards, potentially compromising their health and well-being. For instance, Zwingerman *et al* found that only about 17.9% of the apps they reviewed contained adequate information or features for patients, highlighting the limited clinical relevance of many of these tools[5].

In this review, we address the gap between clinical research and the practical use of mobile applications in ART. We assess whether these apps are supported by research and if clinically validated applications are accessible to patients. To explore this, we identified ART-related apps available on the Apple App Store and Google

Play, using the mobile app rating scale (MARS), a validated instrument for evaluating mobile app quality[7,8]. Additionally, we reviewed published studies to assess the presence of clinical research supporting these apps. By synthesizing insights from both scientific literature and the available mobile apps, this review seeks to bridge the gap between clinical evidence and the features offered by these tools, highlighting areas for improvement to enhance patient outcomes and care.

Given the goal of mapping the existing literature, summarizing evidence, and identifying gaps between commercially available mobile applications and clinically validated tools, a systematic review methodology was determined to be the most appropriate approach for this study.

2. Methods

2.1. Registration

The protocol was registered in the International prospective register of systematic reviews (PROSPERO) on 01/05/2024 under the registration number CRD42024502234.

2.2. Search strategy

2.2.1. Mobile applications

For the selection of mobile apps, a comprehensive search strategy was implemented on the Apple App Store and Google Play from September 1, 2023 to September 30, 2023. The search terms encompassed a wide range of topics related to fertility, reproductive health, and assisted reproduction. The suggested keywords included: fertility, IVF, *in-vitro* fertilization, ovulation, support fertility, assisted reproduction, embryo, reproductive health, fertility clinic, obstetrics & gynecology, ob-gyn, infertility, embryo transfer, reproductive medicine, ovum pick up, and preimplantation genetic testing. The search was conducted by two research members using both Android phones and iPhones to ensure comprehensive coverage.

The search was limited to apps available in English and those listed in the major app stores, which may have introduced language and platform biases. Additionally, apps that were updated infrequently or had poor user ratings may not have appeared prominently in search results, potentially leading to the exclusion of some relevant tools. To mitigate this bias, manual searches were conducted to identify lesser-known apps that might not rank highly in initial search results.

2.2.2. Published studies

A comprehensive literature search was performed on PubMed, Scopus, Embase, and Web of Science using keywords and phrases such as fertility, infertility, reproductive health, reproductive

medicine, fertility clinic, obstetrics and gynecology, ovulation, embryo transfer, *in-vitro* fertilization, support fertility, assisted reproduction, ovum pick up, preimplantation genetic testing, mobile application, smartphone application, mobile health, and mHealth. Additionally, grey literature (such as conference proceedings or unpublished reports) was not included in the search, which could have resulted in the omission of valuable insights on emerging mobile applications that have not yet undergone formal peer review. To account for these limitations, we supplemented the database search with manual searches of reference lists from key papers to identify any additional relevant studies.

2.3. Eligibility criteria for selection

2.3.1. Mobile applications

Inclusion criteria for mobile applications were apps in English related to assisted reproduction, fertility tracking, or IVF support; apps available on the Apple App Store or Google Play during the search period; and apps providing functionalities such as medication tracking, appointment reminders, educational resources, and emotional support.

Exclusion criteria included non-English language apps; apps not updated since September 1, 2021; apps intended primarily for healthcare professionals; apps designed exclusively for pregnancy or menstrual tracking without a focus on ART; apps focused on general lifestyle factors rather than reproductive health; apps lacking essential features for assisting reproductive health; and apps not relevant to the study's focus.

2.3.2. Published studies

The search included studies published no later than September 30, 2023. Inclusion criteria for published studies were studies discussing the development, testing, or evaluation of mobile applications in the context of assisted reproduction, including observational studies or clinical trials published in English.

Exclusion criteria included studies not involving human participants; studies not specifically addressing mobile applications in ART; opinion pieces or editorials; and studies without a focus on the clinical validation or efficacy of the apps.

2.4. Data extraction of published studies and mobile applications

Data extraction was performed independently by three reviewers to ensure accuracy and consistency. Regarding information extracted from selected mobile applications, we reported app name, developer, target patient groups, and price.

For published studies, data extracted included app name, country, type of publication, study design, target patient group, app functions, and key findings related to mobile applications in ART. Discussion was used to resolve disagreements between team members.

2.5. Evaluation of included mobile apps using MARS

We used MARS tool to evaluate the included mobile apps. The MARS was selected for this study because it is a widely accepted and validated tool designed specifically to evaluate the quality of mHealth applications. MARS is particularly suited to evaluating fertility and ART apps because it assesses key dimensions that are critical for the success of such applications: engagement, functionality, aesthetics, and information quality. Each of these categories provides a comprehensive view of the app's overall utility and user experience. In addition, MARS has been extensively used in the literature for evaluating health-related mobile apps, making it a reliable and well-documented choice for this study.

Two team members underwent preparation by watching a training video, followed by testing each app for a minimum of 10 minutes to ensure a comprehensive assessment and minimize biases. Member-related errors such as exhaustion, experience, and familiarity can impact the assessment procedure. To mitigate these potential issues, assessments were conducted when raters were psychologically prepared, and breaks were taken if a rater experienced exhaustion to ensure accurate evaluations.

For systematic evaluation, MARS scores were determined by computing the score of each dimension. The overall score was then calculated as the mean of these dimension scores. The overall scores and dimension scores were summarized to report the range for each app.

2.6. Synthesis of the results

The presence or absence of clinical validation for each app was documented, focusing on the gaps between research and practice. Additionally, the MARS scores were summarized to address the quality of each app. To interpret the quality scores, the standard 5-point MARS rating scale was used: 1 = Inadequate, 2 = Poor, 3 = Acceptable, 4 = Good, and 5 = Excellent. For this review, an app with a mean score of 4.0 or higher was considered to be of 'Good' quality, while a score below 3.0 was considered 'Poor'. This quantitative analysis was supplemented by a qualitative review of the key findings from the included studies, highlighting the extent to which the apps' features and functionalities are supported by empirical evidence. The results were synthesized to provide a summary of the findings, emphasizing the disparity between the practical use of mobile applications in assisted reproduction and their clinical validation.

3. Results

3.1. Search results

3.1.1. Mobile applications

Table 1 presents the search results from two leading app stores,

Table 1. Search strategy and results of mobile applications from two leading app stores.

App stores	Query	Results
Google Play	Fertility OR IVF OR “ <i>in-vitro</i> fertilization” OR ovulation OR “support fertility” OR “assisted reproduction” OR “embryo” OR “reproductive health” OR “fertility clinic” OR “obstetrics & gynecology” OR “ob-gyn” OR infertility OR “embryo transfer” OR “reproductive medicine” OR “ovum pick up” OR “preimplantation genetic testing”	371
Apple App Store	Fertility OR IVF OR “ <i>in-vitro</i> fertilization” OR ovulation OR “support fertility” OR “assisted reproduction” OR “embryo” OR “reproductive health” OR “fertility clinic” OR “obstetrics & gynecology” OR “ob-gyn” OR infertility OR “embryo transfer” OR “reproductive medicine” OR “ovum pick up” OR “preimplantation genetic testing”	716

Google Play and the Apple App Store, highlighting applications related to fertility. The search strategy aimed to encompass a wide range of apps addressing fertility treatments and reproductive health. Google Play found 371 relevant apps, indicating a moderate presence of fertility-focused applications in its catalogue. This suggests that while Google Play offers a targeted selection of fertility and reproductive health apps, the options may be somewhat limited. In contrast, the Apple App Store identified 716 relevant applications, demonstrating a more extensive selection and variety of fertility-

related apps. This broader availability could be attributed to the Apple App Store's larger user base and more diverse range of app offerings.

Figure 1 illustrates the preferred reporting items for systematic reviews and meta-analyses (PRISMA) flowchart summarizing the selection process, from the initial search to the final inclusion of mobile apps. The systematic review involved several rigorous stages. Initially, a comprehensive search was conducted on the Apple App Store ($n=716$) and Google Play ($n=371$), supplemented by a manual search ($n=56$), resulting in a total of 1 143 mobile applications. After removing duplicates ($n=612$), 531 unique mobile applications remained. These were screened for relevance, leading to the exclusion of 67 irrelevant apps. Further eligibility assessment excluded 438 apps that were either not available in English ($n=9$) or lacked essential reproductive health features ($n=429$). This left 26 apps for detailed evaluation, of which 15 were excluded for various reasons: not updated since September 1, 2021 ($n=7$), intended only for healthcare professionals ($n=1$), inability to sign in ($n=5$), or containing redundant content ($n=2$). Ultimately, 11 mobile applications met all the inclusion criteria and were included in the final systematic review.

3.1.2. Published studies

Table 2 summarizes the search results from four major databases -PubMed, EMBASE, Scopus, and Web of Science - focusing on literature related to fertility and mobile applications. The search strategy was designed to capture a comprehensive range of studies on

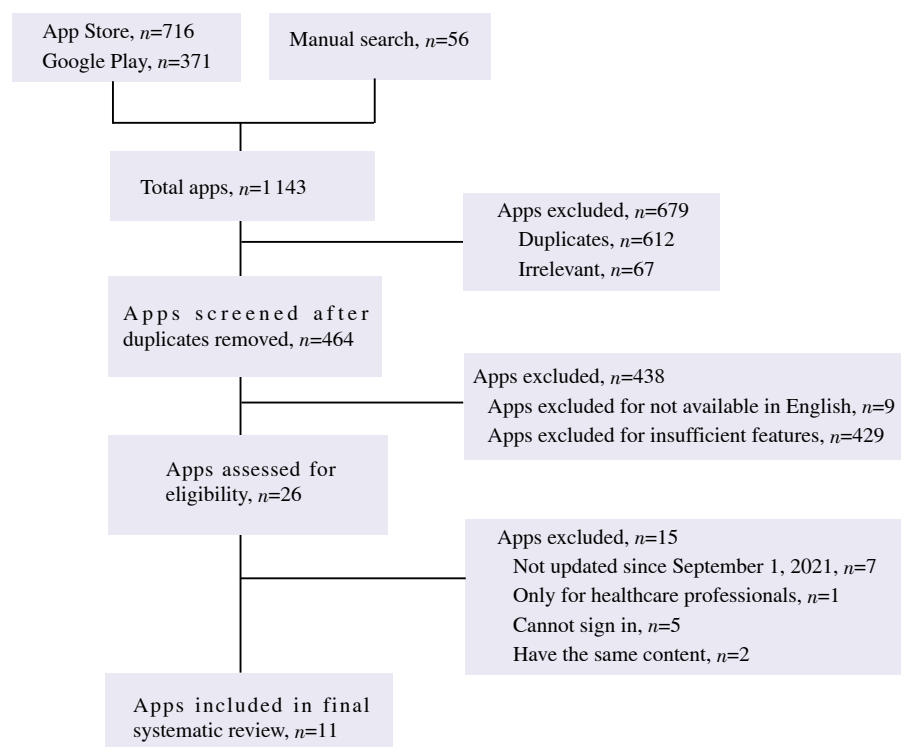
**Figure 1.** Flowchart summarizing the selection process from the initial search to the final inclusion of mobile apps.

Table 2. Search strategy and results of the published studies from four major databases.

Databases	Query	Results
PubMed		
#1	Fertility OR Infertility OR “Reproductive health” OR “Reproductive medicine” OR “Fertility clinic” OR “Obstetrics and gynecology” OR Ovulation OR “Embryo transfer” OR “ <i>In-vitro</i> fertilization” OR “Support fertility” OR “Assisted reproduction” OR “Ovum pick up” OR “Preimplantation genetic testing”	611 236
#2	“Mobile application” OR “smart phone application” OR “mobile health” OR mHealth	77 027
#3	#1 AND #2	1 439
EMBASE		
#1	Fertility OR Infertility OR “Reproductive health” OR “Reproductive medicine” OR “Fertility clinic” OR “Obstetrics and gynecology” OR Ovulation OR “Embryo transfer” OR “ <i>In-vitro</i> fertilization” OR “Support fertility” OR “Assisted reproduction” OR “Ovum pick up” OR “Preimplantation genetic testing”	930 290
#2	“Mobile application” OR “smart phone application” OR “mobile health” OR mHealth	38 040
#3	#1 AND #2	1 042
Scopus		
#1	Fertility OR Infertility OR “Reproductive health” OR “Reproductive medicine” OR “Fertility clinic” OR “Obstetrics and gynecology” OR Ovulation OR “Embryo transfer” OR “ <i>In-vitro</i> fertilization” OR “Support fertility” OR “Assisted reproduction” OR “Ovum pick up” OR “Preimplantation genetic testing”	2 502 902
#2	“Mobile application” OR “smart phone application” OR “mobile health” OR mHealth	240 514
#3	#1 AND #2 AND	9 660
Web of Science		
#1	Fertility OR Infertility OR “Reproductive health” OR “Reproductive medicine” OR “Fertility clinic” OR “Obstetrics and gynecology” OR Ovulation OR “Embryo transfer” OR “ <i>In-vitro</i> fertilization” OR “Support fertility” OR “Assisted reproduction” OR “Ovum pick up” OR “Preimplantation genetic testing”	468 484
#2	“Mobile application” OR “smart phone application” OR “mobile health” OR mHealth	20 077
#3	#1 AND #2 AND #3	291

fertility treatments, reproductive health, and mHealth technologies.

PubMed identified 1 439 relevant studies, benefiting from its strong focus on clinical research. EMBASE, which had the highest number of fertility-related results (930 290), yielded slightly fewer relevant studies (1 042) when combined with mobile health terms, indicating fewer integrated studies in this area. Scopus provided the largest pool of fertility-related studies (2.5 million) and the highest number of combined results (9 660), likely due to its broad multidisciplinary coverage. Web of Science, while yielding fewer results overall, indicated a more limited focus on the intersection of fertility and mobile health technologies, with only 291 relevant studies.

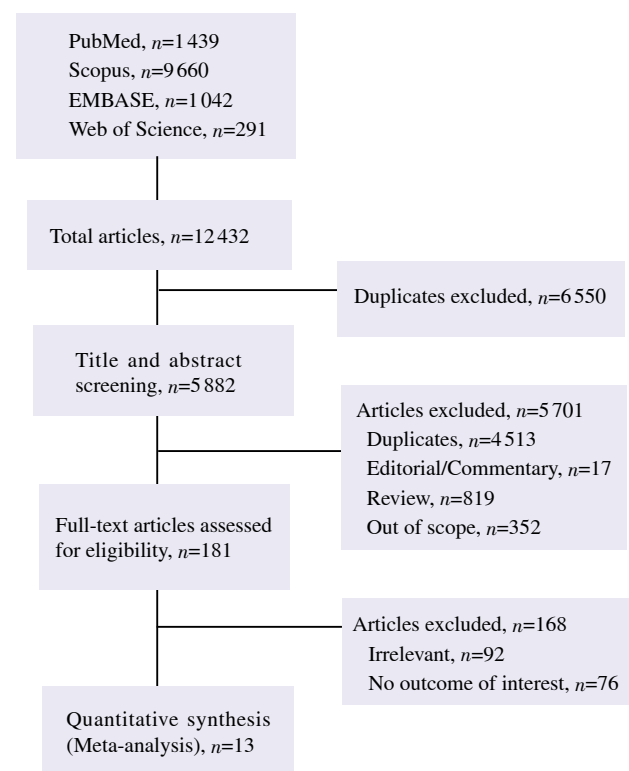
Figure 2 presents the PRISMA flowchart summarizing the selection process from the initial search to the final inclusion of studies. After removing duplicates ($n=6\,550$), 5 882 unique articles remained for title and abstract screening. This phase excluded 5 701 articles for various reasons, such as being duplicates ($n=4\,513$), ethical/commentary pieces ($n=17$), reviews ($n=819$), or being out of scope ($n=352$). Subsequently, 181 full-text articles were assessed for eligibility, with 168 articles excluded for irrelevance ($n=92$) or not having the outcome of interest ($n=76$). In the end, 13 studies were included in the systematic review.

3.2. Characteristics of the included mobile apps and studies

3.2.1. Mobile applications

Table 3 provides a detailed overview of mobile applications designed to support patients undergoing fertility treatments, focusing on aspects such as target group, developer, category, study availability, and pricing. Most of the apps are specifically tailored for

patients, offering a variety of features, including reminders, tracking, and educational content, with some apps like Tilly: Fertility & IVF Support also addressing mental health. ART Compass stands out as it is designed for both patients and clinicians, emphasizing its broader applicability within clinical settings.

**Figure 2.** Flowchart summarizing the selection process from the initial search to the final inclusion of studies.

A significant observation from Table 3 is that only Embie: IVF & IUI Tracker has studies available to validate its effectiveness, highlighting a potential gap between clinical research and the practical application of these tools. This lack of clinical validation in most apps suggests that while these tools may offer valuable features, there is a need for more research to ensure they provide reliable and evidence-based support. In terms of pricing, the apps offer a range of models, from free versions with optional upgrades to more premium subscription services. For instance, Bonzun IVF provides a one-time upgrade for a relatively low cost, while Tilly: Fertility & IVF Support charges a higher fee for a three-month upgrade, reflecting different strategies within the market. The diversity in developers, ranging from specialized fertility-focused companies to broader health information providers, illustrates the varying levels of expertise and focus areas on the fertility app market. This variation likely contributes to the differences in functionality, usability, and effectiveness of the apps, underscoring the importance of further research to validate these tools and ensure they meet the needs of patients effectively.

3.2.2. Published studies

Table 4 highlights a variety of mobile applications developed for patients undergoing fertility treatments, detailing studies conducted on these apps, their target users, functions, and current availability. Notably, Embie and Patient Journey App have studies available to validate their effectiveness. However, the main language of Patient Journey App is not in English. They included studies span across different countries and research designs, reflecting a global interest in integrating mobile technology into fertility care. A key

observation from Table 4 is the range of app functionalities, which are tailored to meet the specific needs of fertility patients. Common features include medication management, tracking fertility cycles, providing educational content, and offering mental health support through mindfulness exercises or cognitive-behavioral strategies. For example, MediEmo focuses on both medication management and emotional support, while MoMiFer is dedicated to mindfulness practices for couples dealing with infertility. This diversity in functions underscores the multifaceted approach required to address the complex physical and emotional challenges associated with fertility treatments.

In terms of the current status of these apps, there is a noticeable variation in their availability. While some apps like Embie and Patient Journey App are accessible on major platforms like the Apple App Store and Google Play, others, such as MindfulSpot and FertiStrong, are no longer available. This inconsistency highlights a potential gap in the longevity and sustainability of fertility-related mobile apps, which could be due to various factors, including lack of updates, changes in developer focus, or insufficient funding. Additionally, the inclusion of multiple studies on apps like PreLiFe demonstrates ongoing interest in refining and validating these tools through research, though the fact that many of these apps remain unavailable to users suggests a disconnect between research and real-world application.

3.3. Quality assessment of the included mobile apps

Table 5 presents the MARS assessment results for the 11 included mobile apps, provided by two raters, which were assessed across

Table 3. Characteristics of the included mobile applications.

Reference	App name	Target group	Developer	Category	Studies available	Price
[9]	Imine IVF	Patient	BabySentry Ltd.	Reminder, Tracking	No	72 500 VND (US \$2.99)
[10]	Bonzun IVF	Patient	Bonzun Health Information AB	Reminder, Tracking, Education	No	Free for normal purchase, 109 000 VND (US \$4.5) for one time upgrade
[11]	Embie: IVF & IUI Tracker	Patient	Embie Clinic, Ltd	Reminder, Tracking, Education	Yes	229 000 VND/month (US \$9.45)
[12]	eIVF Patient	Patient	PracticeHwy.com	Reminder	No	Free
[13]	Tilly: Fertility & IVF Support	Patient	Tilly TTC AB	Reminder, Education, Mental health	No	1 139 000 VND (US \$47) for 3 months
[14]	Ferona: IVF Tracker & Support	Patient	FertilityAI Lab	Reminder, Tracking, Education	No	Free
[15]	Hope Cycle Tracker	Patient	Hope Applications GmbH	Reminder, Tracking, Education	No	799 000 VND (US \$33) for one time upgrade
[16]	Apricity Fertility Companion	Patient	Apricity	Reminder, Tracking, Education	No	Free
[17]	Salve	Patient	Salve Technologies Limited	Reminder, Education	No	Free
[18]	Leeaf	Patient	Cognitive IVF	Reminder, Education	No	Free
[19]	ART Compass	Patient & Clinician	Fertility Guidance Technologies	Reminder, Education	No	Free

Table 4. Characteristics of the included studies.

Ref.	Mobile App	Study	Country	Type of publication	Study design	Target user	App functions	Main findings	Current status
[20]	MediEmo	Robertson <i>et al</i> (2022)	United Kingdom	Article	Mixed methods of research (development and implementation)	IVF/ICSI or IUI patients	-Medication management: medication timeline, messaging. -Mood management: emotional tracking, coping support. -Functional support: frequently asked questions, symptom checker.	MediEmo demonstrates feasibility in both managing patient medication diaries and providing emotional support.	- Available on Appstore or Google Play. - Last update version is 5 years ago.
[21]	MindfulSpot	Monteiro <i>et al</i> (2016)	Portugal	Abstract	Development study	Infertile patients	Audio and written texts for practicing mindfulness.	MindfulSpot provides valuable insights into the emotional impact of infertility.	Not available on Appstore or Google Play
[22]	PreLiFe	Boedt <i>et al</i> (2019)	Belgium	Article	Protocol of RCT	Dutch speaking infertile patients	-Advice and skill training on physical activity, diet and mindfulness-based stress reduction. -Monitoring and tracking the patient lifestyle.	PreLiFe demonstrates the importance of mobile preconception lifestyle support for couples undergoing IVF.	Not available on Appstore or Google Play
[23]	PreLiFe	Boedt <i>et al</i> (2021)	Belgium	Article	Development study	Dutch speaking infertile patients	-Advice and skill training on physical activity, diet and mindfulness-based stress reduction. -Monitoring and tracking the patient lifestyle.	PreLiFe is designed for use by both partners of IVF couples, providing advice and skills training in physical activity, diet, and mindfulness-based stress reduction.	Not available on Appstore or Google Play
[24]	PreLiFe	Boedt <i>et al</i> (2023)	Belgium	Article	RCT	Dutch speaking infertile patients	-Advice and skill training on physical activity, diet and mindfulness-based stress reduction. -Monitoring and tracking the patient lifestyle.	While the acceptability of PreLiFe was positive, minimal to no impact on other reproductive or lifestyle outcomes was observed.	Not available on Appstore or Google Play
[25]	MoMiFer	Boedt <i>et al</i> (2022)	Belgium	Article	RCT	Dutch speaking infertile patients	-Mindfulness exercises accompanied with talking heads. -Information regarding mindfulness and infertility.	MoMiFer offers mindfulness exercises and information tailored for couples experiencing infertility.	Not available on Appstore or Google Play
[26]	FertiStrong	Domar <i>et al</i> (2023)	USA	Article	Randomized control pilot study	Infertile patients	Cognitive-behavioral coping strategies and relaxations.	FertiStrong, aimed at men experiencing infertility, has the potential to reduce psychological distress.	No longer available on Appstore or Google Play
[27]	Infotility	Kruglova <i>et al</i> (2021)	Canada	Article	Development and usability study	Infertile patients	Information to fertility patients including medical, psychosocial, lifestyle, and legal information.	Infotility is designed, developed, and evaluated to offer information and support for both men and women undergoing fertility treatment.	No longer available on Appstore or Google Play
[28]	Infotility	Miner <i>et al</i> (2022)	Canada	Article	Prospective cohort study	Infertile patients	Information to fertility patients including medical, psychosocial, lifestyle, and legal information.	Infotility demonstrates feasibility in addressing the psychosocial and informational needs of fertility patients.	No longer available on Appstore or Google Play
[29]	Iran Mobile App	Langarizadeh <i>et al</i> (2022)	Iran	Article	Quantitative research	Iran infertile patients	Educational content about nutrition: obesity, overweight, lifestyle.	The Iran mobile app is a nutrition educational application that holds significant potential for supporting women with infertility, tailored to the cultural conditions and characteristics of each community.	Not available on Appstore and Google Play

Table 4. Continued.

Ref.	Mobile App	Study	Country	Type of publication	Study design	Target user	App functions	Main findings	Current status
[30]	Embie	Raanani <i>et al</i> (2023)	Israel	Abstract	Retrospective analysis	Infertile patients	-Cycle protocol tracking and monitoring. -Eggs retrieved, embryo transfer and pregnancy results. -Educational articles. -Community support.	Mobile applications for fertility treatment have the potential to significantly enhance ART outcomes and improve the overall experience for patients.	Available on Appstore and Google Play
[31]	MyFertiCoach	Smeenk <i>et al</i> (2022)	Netherlands	Abstract	Cohort study	Fertility patients	Online lifestyle coaching: weight, nutrition, exercise, stress, smoking, alcohol and drug consumption.	MyFertiCoach, designed for fertility patients, exhibited high adherence rates, particularly when compared to other healthcare apps.	Not available on Appstore and Google Play
[32]	Patient Journey App	Timmers <i>et al</i> (2021)	Netherlands	Article	RCT	IVF/ICSI patients	-Instruction (video and text) for medication usage and side effects. -Quiz to assess patient knowledge. -Medication reminders.	Patient Journey App offers timely information and enhances patient satisfaction by providing a deeper understanding of the steps and procedures involved in IVF treatment.	Available on Appstore and Google Play

Ref.: Reference; IVF: *in vitro* fertilization; ICSI: intracytoplasmic sperm injection; IUI: intrauterine insemination; RCT: randomized controlled trial; ART: assisted reproductive technologies.

Table 5. Mobile app rating scale (MARS) assessment results of the 11 included mobile apps.

Reference	App	Engagement	Functionality	Aesthetics	Information	App quality mean score
[9]	Imine IVF	2.40	3.00	1.67	3.08	2.54
[10]	Bonzun IVF	3.40	4.00	3.84	3.50	3.68
[11]	Embie: IVF & IUI Tracker	3.70	4.00	4.00	3.92	3.90
[12]	eIVF Patient	2.80	2.88	2.33	3.38	2.85
[13]	Tilly: Fertility & IVF Support	3.90	3.50	4.00	3.92	3.83
[14]	Feronia: IVF Tracker & Support	3.50	3.63	4.67	4.08	3.97
[15]	Hope Cycle Tracker	4.30	4.13	5.00	4.08	4.38
[16]	Apricity Fertility Companio	3.50	3.00	4.17	3.84	3.63
[17]	Salve	2.90	2.63	3.17	3.75	3.11
[18]	Leeaf	4.10	4.63	5.00	4.67	4.60
[19]	ART Compass	3.03	4.00	2.84	3.85	3.43
	Mean	3.41	3.58	3.70	3.82	3.63

The standard 5-point MARS rating scale is used: 1 = Inadequate, 2 = Poor, 3 = Acceptable, 4 = Good, and 5 = Excellent.

four subscales: engagement, functionality, aesthetic, and information. Each subscale received a mean score based on evaluations from two raters, and an overall app quality mean score was calculated by averaging the scores from these subscales. The overall quality of the apps was rated as average, with a mean MARS score of 3.63 (SD=0.62). Engagement received a mean rating of 3.41 (SD=0.58), while functionality scored a mean of 3.58 (SD=0.63). Aesthetics achieved a mean score of 3.70 (SD=1.08). The strongest dimension was information quality, with a mean score of 3.82 (SD=0.42). Leeaf has the highest overall MARS score with 4.60. In contrast, Imine IVF has the lowest score with only 2.54. Moreover, only Embie has clinical research among these apps, receiving an overall score of 3.90, which is above average.

4. Discussion

4.1. Main findings

This systematic review evaluated the gap between clinical research and practice in the context of mobile applications for patients undergoing assisted reproduction. Combining both the included mobile apps and clinical studies, our findings revealed a significant disconnect between research and practice, with many apps lacking evidence-based support and studies not translating into accessible patient tools.

Applications such as MediEmo, MoMiFer, and PreLiFe are underpinned by rigorous scientific research, often involving randomized controlled trials (RCTs) or cohort studies. These apps are

developed with a foundation in evidence-based practices, specifically designed to address the medical or psychological needs of fertility patients. Despite their strong clinical backing, many of these apps remain inaccessible to the general public. For instance, although PreLiFe and MoMiFer have demonstrated efficacy in clinical environments, they are not available on mainstream platforms like the Apple App Store or Google Play, which significantly limits their reach and potential impact on a broader population. The absence of these clinically validated apps from the market could be due to various factors, including insufficient commercialization strategies, funding constraints, or challenges in scaling the technology beyond the research phase.

Conversely, commercial apps with high MARS scores, such as Leeaf (4.60), Hope Cycle Tracker (4.38), and Feronia (3.97), excel in metrics such as user engagement, functionality, aesthetics, and information quality. These applications are designed to be intuitive and user-friendly, often prioritizing features that enhance user experience rather than clinical efficacy. The review showed that while these apps perform well in terms of user satisfaction, they lack the clinical validation necessary to demonstrate effectiveness in improving fertility outcomes. This discrepancy suggests that while these apps may be popular and widely utilized, their actual impact on fertility treatment success remains uncertain[33].

In the application market, all of the selected apps are developed by businesses and companies, with only the Embie app having undergone research to verify its performance[30]. These apps offer a variety of features, such as medication reminders to help users track schedules and dosages, monitoring tools for menstrual cycles, ovulation, and basal body temperature, and the ability to connect with other patients for support. Reminders are the most widely used feature, present in all 11 selected apps, and are crucial for improving adherence to assisted reproduction treatments by reducing the risk of forgetting or overlooking important tasks - an objective central to most available applications.

Each of the applications in the market focuses on improving a specific feature. Embie[11] and Feronia[14] excel in providing detailed cycle tracking and personalized reminders, while Bonzun IVF[10] and Tilly[13] emphasize emotional and mental health support, integrating features like meditation guides and community forums. Apricity[16] goes a step further by offering telemedicine consultations, enabling users to connect directly with fertility experts through the app, making it a comprehensive fertility management tool. Salve[17] and eIVF[12] are particularly notable for their integration with clinical systems, allowing communication between patients and healthcare providers, which is crucial for managing complex treatment protocols. ART Compass, though more specialized, offers advanced features tailored to both ART professionals and patients, including detailed procedural tracking and management[19]. Additionally, features such as detailed medication instructions and messaging are

less prevalent; instructions, in particular, appear only in Leeaf[18]. This lack of instructional features in most apps could pose significant challenges, as they provide essential guidance on reproductive healthcare. Besides, many of these tools are developed based on user needs and general health principles rather than being rooted in rigorous clinical research. Consequently, while user reviews and evidence often suggest that these apps are helpful, there is limited formal research to substantiate their efficacy in improving fertility outcomes.

In the academic context, research on mobile apps for IVF patients highlights a diverse array of functionalities, such as medication management, emotional support, mindfulness practices, lifestyle guidance, and informational resources. Many of the apps highlighted in Table 4 are supported by rigorous research studies, ranging from development and usability studies to prospective cohort studies and RCTs. This research-driven approach underscores the importance of evidence-based practice in the development of mobile health solutions. Notably, apps such as MediEmo and Patient Journey App stand out for their medication management and information support[20,32]. These features play an important role in helping patients adhere to their medication. Regarding emotional support, MediEmo and FertiStrong can help patients manage the emotional challenges associated with infertility and fertility treatment[20,26]. MindfulSpot and MoMiFer focus on mindfulness exercises, audio, and written texts for practicing mindfulness[21,25]. These features promote relaxation and stress reduction for IVF patients. Furthermore, lifestyle guidance, as evidenced in apps like PreLiFe and MyFertiCoach, provides users with advice, physical activity, diet, weight management, nutrition, exercise, and other lifestyle factors[24,31]. These features support patients in adopting healthy habits and optimizing their overall well-being to enhance their chances of success with IVF treatment. Additionally, the informational resources, such as psychosocial and legal aspects of fertility are available in apps such as Infotility and Iran Mobile App[28,29]. These apps serve as valuable education, providing patients with evidence-based information, practical tips, and resources to empower them to make informed decisions about their treatment and care. A wide range of mobile application functionalities indicates the multifaceted needs of IVF patients and a desire to provide comprehensive support through digital platforms. However, a significant limitation observed is the limited availability of some apps on major app platforms such as the Apple App Store or Google Play. For instance, apps like MindfulSpot and MoMiFer offer valuable mindfulness exercises and emotional support, yet their absence from app platforms restricts their accessibility to a broader audience. In addition, many apps are single language, which restricts the wider use of international patients. As a result, efforts to increase the accessibility of these IVF-specific apps on popular platforms are imperative.

There is a clear demand for providing psychosocial support through mobile apps, with features such as emotional tracking and mindfulness exercises. Apps such as MoMiFer, MediEmo, FertiStrong, and MindfulSpot are typical examples of this trend by adding the function of the emotional and psychological well-being of individuals undergoing fertility treatment. Particularly, MediEmo offers emotional tracking by applying the emotional reaction list from the daily record keeping form[20]. The app distinguishes negative emotions (anxious, tense, nervous) and positive emotions (confident, positive). Patients will rate the score from 0 to 3 to express their feelings. The app reported an increase in negative emotions after oocyte retrieval. Similarly, FertiStrong integrates cognitive-behavioral coping strategies and relaxation techniques aimed at reducing psychological distress among male patients experiencing infertility. The app contains 50 situations that can be the most stressful for the male partner of an infertile couple, including pregnancy loss, relationship survival, mind/body, and emotions[26]. The solutions include strategies, half of which are directed to treat the distress of the male partner and half of which are suggestions on how the male partner could better support the coping of his female partner. However, the hospital anxiety and depression scale was not significantly different after using the app[21]. Moreover, MindfulSpot emphasizes mindfulness exercises *via* audio and texts. However, the development and efficacy of this app remained unclear. Additionally, MoMiFer is an app that concentrates on the function of mindfulness exercises to reduce emotional distress of infertile patients[25]. The emotional distress and fertility-related quality of life (FertiQoL) were assessed to investigate the effects of this app on patients.

The gap between research and practical application in ART mobile apps is driven by several factors. First, the predominant focus on academic publication and research outcomes may prioritize scholarly contributions over the practical implementation[34]. Second, the complex landscape of healthcare systems, regulatory requirements, and commercial considerations may pose barriers to the widespread adoption and availability of apps. Third, the commercialization of research-backed apps faces significant barriers, as researchers often lack the resources to transition from academia to the app marketplace[35]. Developers, on the other hand, may prioritize user engagement over clinical evidence to meet consumer demand. Finally, limited resources, funding constraints, and sustainability issues may hinder the long-term viability of these apps beyond the research phase[35]. For example, MediEmo is a well-developed app, it is also available for users, but the last update was 5 years ago, which may not be appropriate for current usage. As a result, despite the promising outcomes demonstrated in research studies, many IVF-focused apps fail to transition from the idea to the hands of patients. To close this gap, we recommend increased collaboration between researchers and technology companies to ensure that

validated apps reach patients. Policymakers should also impose stricter requirements for mobile apps, mandating clinical testing for those marketed as medical tools in ART. By bridging this divide, researchers, developers, and healthcare providers can ensure that the innovative solutions generated through research efforts are effectively integrated into clinical practice, ultimately enhancing the quality of care and experience for IVF patients.

4.2. Contribution of the study

The disconnect between research and practice identified in our review aligns with broader trends in digital health, where innovations frequently outpace the establishment of rigorous evidence[36]. This review sheds light on the significant gaps between research and practical application, underscoring the critical need for evidence-based digital health solutions. The consequences of this gap are substantial. For patients, using apps without clinical validation can result in misinformation, inappropriate self-management, and ultimately, poor health outcomes[37,38]. Such apps risk providing inaccurate or misleading guidance, which may cause emotional distress, wasted time, and reduced chances of conception. Moreover, users may place undue trust in these apps, assuming that their advice is scientifically grounded. Without proper clinical validation, however, the information provided may not be evidence-based, leading to decisions that are ineffective or even harmful to fertility treatments. For healthcare providers, the lack of reliable, evidence-based digital tools complicates the integration of these technologies into standard care practices. Bridging this gap is essential to ensuring patients have access to safe and effective tools that are grounded in solid clinical evidence.

Additionally, the failure to bring clinically validated apps to market represents a significant missed opportunity. The challenges in commercializing such apps slow down healthcare innovation. When effective, evidence-based apps fail to reach patients, it diminishes the incentive to invest in similar technologies, potentially slowing the integration of digital health tools into fertility care and limiting improvements in patient outcomes. Clinically proven apps, which have demonstrated benefits through trials, could significantly enhance fertility experiences. For instance, an app designed to alleviate stress and improve mental well-being during IVF could not only enhance the patient experience but also boost success rates. When these apps remain unavailable, their positive impact on patients is lost. Furthermore, the resources invested in their development and testing are wasted when they fail to transition into practical use, potentially discouraging further innovation in the field. Beyond benefiting patients, ART mobile applications have the potential to significantly enhance the daily operations of healthcare providers by streamlining workflows, improving data flow, and supporting effective communication between patients and providers.

Integrating these apps into existing healthcare systems would not only help patients manage their treatment but also reduce the administrative workload for clinicians. For instance, ART apps that track medication adherence, ovulation cycles, and patient symptoms in real time could automatically update electronic health record systems, enabling providers to monitor patient progress remotely without the need for constant in-person appointments[39]. In terms of data flow, these apps that collect daily logs on patient symptoms, hormonal levels, and medication adherence can transmit this data directly to clinicians, who can then adjust treatment protocols based on real-time insights[40]. Additionally, ART apps can enhance communication between patients and providers by offering secure messaging features and push notifications for appointment reminders, test results, and treatment adjustments[41]. This not only reduces the workload associated with manual data entry and routine check-ups but also allows healthcare providers to focus on more complex cases that require personalized attention, ultimately improving both patient satisfaction and clinical outcomes.

4.3. Strengths and limitations

This review's strength lies in its dual focus on both the clinical research and practical application of mobile apps in the field of assisted reproduction. By examining how these apps are utilized in real-world settings, the review provides valuable insights into their potential benefits for patients undergoing fertility treatments.

Despite its strengths, this review has several limitations. The primary limitation is the reliance on available data, which may not fully capture the entirety of the digital health landscape in assisted reproduction. Some apps, particularly newer or less popular ones, or the apps which are not in English, may have been overlooked, leading to a potential bias in the selection of apps analyzed. Additionally, the review is limited by the quality and scope of the studies including some of which may not have been comprehensive in their evaluation of app effectiveness. Finally, the fast-evolving nature of the digital health market means that the findings of this review could quickly become outdated as new apps are developed and existing ones are updated.

While MARS is an established tool for evaluating mobile health apps, it does have limitations. One key limitation is that MARS relies on subjective ratings by reviewers, which can introduce variability in the scoring process depending on the rater's level of expertise or familiarity with the app's content. Furthermore, MARS does not assess the clinical effectiveness or real-world outcomes of the apps, which is a critical factor for mobile applications targeting ART patients. Although MARS provides a comprehensive evaluation of app quality, it does not include a direct measure of the app's impact on patient health outcomes, which could limit its utility for apps that claim to have a therapeutic or clinical benefit.

Furthermore, as is characteristic of the systematic review methodology, this study did not involve a formal critical appraisal or risk of bias assessment of the included studies. The primary objective was to map the extent of the available evidence rather than to synthesize and weigh its quality, which is a limitation to consider when interpreting the findings.

4.4. Future direction

Mobile applications hold significant promise in supporting ART patients, but several barriers prevent research-based apps from transitioning effectively into public use. To overcome these barriers, a collaborative and solution-oriented approach is needed. Partnerships between academic institutions, tech companies, and venture capital firms could provide the necessary funding and expertise to move research-based apps from concept to market[42]. Academia can contribute clinical research and validation, while tech companies offer the infrastructure and marketing expertise required for large-scale deployment. Government grants and private investment could further support commercialization efforts, ensuring that validated apps reach a broad audience. Streamlining regulatory approval processes is another key solution[3]. Regulatory bodies could introduce expedited pathways for low-risk mHealth apps, particularly those that have been validated in academic settings. This would ensure that apps meet safety and efficacy standards without being subjected to the full regulatory processes required for medical devices. Furthermore, to ensure mHealth apps are more readily integrated into clinical workflows, healthcare providers must be involved in the development process[43]. This would help ensure that the apps are compatible with existing clinical systems. Healthcare providers should also be trained to recommend these tools effectively, ensuring that patients understand how to integrate them into their ART treatment plans.

The global regulatory landscape for mHealth apps is fragmented, with significant differences in how various countries regulate digital health tools. For example, in the European Union, apps that provide medical advice or impact patient treatment decisions must obtain an European Conformity (CE) mark, indicating compliance with health, safety, and environmental standards[44]. The regulatory landscape in the United States follows a risk-based approach under the Food and Drug Administration (FDA). The FDA requires regulatory approval for apps that meet certain criteria, such as those that function as medical devices or make specific treatment recommendations[45]. Other regions, such as Asia and Africa, have less developed regulatory frameworks for mHealth apps[46]. In developing countries, regulatory gaps may also hinder the availability of apps that meet international safety standards, as there is no formal requirement for clinical validation before release[47]. The inconsistencies in global regulatory frameworks create challenges for both developers and

users of ART apps. Developers may struggle to navigate the varied regulatory requirements in different markets, while patients face uncertainty about the quality and safety of the apps they use. Given the fragmented nature of mHealth app regulation, policymakers must take an active role in bridging the gap between clinical research and practical application. There should be a move toward developing a common set of guidelines for ART apps. Such standards would include clear requirements for clinical validation to ensure that all fertility apps, regardless of their country of origin, adhere to the same quality benchmarks. A harmonized approach to regulating mHealth apps, particularly in the area of fertility and reproductive health, would ensure that patients around the world have access to safe and clinically validated tools.

As mHealth apps become more prevalent in fertility treatment, ethical considerations are increasingly important[48]. These apps collect sensitive data, including information on hormonal levels, sexual activity, and medication adherence. Beyond privacy, app security is a critical concern. Apps must be protected against cybersecurity threats, including unauthorized access and data breaches. Regular security audits and updates should be a standard practice for fertility apps, given the sensitive nature of the information they handle. Additionally, developers have an ethical responsibility to ensure that their apps provide accurate and up-to-date clinical information. In ART, inaccurate data can lead to treatment failures and emotional distress for patients[49]. Developers should collaborate with healthcare professionals to ensure that app recommendations are evidence-based and regularly updated to reflect the latest clinical guidelines. Establishing advisory boards of clinicians and fertility experts would help maintain the accuracy and relevance of the content provided to users.

Patient adherence also remains a persistent issue[50]. Even when apps are clinically validated, users often download them but fail to engage consistently over time. This can be attributed to factors such as app complexity, lack of personalization, or insufficient guidance from healthcare providers. To improve adherence to ART mobile apps, developers should prioritize personalization and ease of use. Features like tailored reminders, progress tracking, and motivational feedback aligned with individual treatment plans can make the experience more engaging and supportive. Additionally, older adults, who are often less familiar with mobile apps, require simplified interfaces, larger fonts, and intuitive navigation[51]. Offering tutorials and ensuring compatibility with assistive technologies like screen readers can enhance accessibility. Healthcare providers also play a vital role by recommending and supporting app use, while social features like caregiver access can further increase engagement and confidence. Collaboration between developers, healthcare providers, and older adults is essential to creating solutions tailored to their needs.

To successfully transition mHealth apps from research to public use, it is critical to address the challenges of commercialization,

regulation, clinical integration, and patient adherence. Additionally, addressing ethical concerns related to data privacy, security, and clinical accuracy will ensure that these tools offer safe, reliable, and effective support for patients undergoing ART. Future research should aim to bridge the gap between clinical research and practical application by developing and validating mobile apps informed by robust clinical studies. Additionally, additional research is needed to assess the effectiveness, user satisfaction, and long-term impact of these apps on patient outcomes. Collaborative efforts between researchers, developers, and regulatory bodies may help the transition from research to practice, ensuring that evidence-based apps can be rapidly and effectively brought to market.

4.5. Conclusions

In conclusion, this systematic review highlights a significant gap between clinical research and practice in the field of mobile applications for assisted reproduction. While many apps are available to patients, few are supported by robust clinical evidence, and even fewer research-backed apps make it to market. Closing this gap is essential for ensuring that patients have access to safe, effective, and evidence-based digital tools that can truly enhance their fertility treatment experience.

Conflict of interest statement

The authors declare no conflict of interest.

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Authors' contributions

The study concept was developed by Huy Phuong Tran, Thuy Thi-Thanh Tran, Tuyet Thi-Diem Hoang, Hang Thi Phan, Nam Nhat Nguyen, and Le-Giang Tran. The intellectual content was defined by Huy Phuong Tran, Le-Giang Tran, and Van-Toi Vo. The investigation of published studies was conducted by Huy Phuong Tran, Minh-Triet Ho, Dang-Quang Tran, and Nam Nhat Nguyen. Minh-Triet Ho and Dang-Quang Tran evaluated the mobile applications. The interpretation of the review was handled by Huy Phuong Tran, Minh-Triet Ho, and Dang-Quang Tran. Finally, the manuscript writing was carried out by Minh-Triet Ho, Dang-Quang Tran, Huy Phuong Tran, and Le-Giang Tran.

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