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Global Trends of Artificial Intelligence for Diabetic Wound Care: A Bibliometric Analysis

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Abstract

This study provides a comprehensive bibliometric analysis of the application of artificial intelligence (AI) in diabetic wound care, focusing on trends, key contributors, and research themes. Using data collected from the Scopus database, the research employs citation analysis and co-occurrence mapping to examine the growth and evolution of the field. The results reveal a substantial increase in research activity from 2019 to 2023, with a marked rise in the number of publications and citations related to AI-driven solutions for diabetic wound management. Asian countries, particularly India and China, are identified as leading contributors in this domain, showcasing their significant role in advancing AI applications in healthcare. Through the use of VOSviewer software, the study identifies three primary research themes: AI for Automated Detection of Diabetic Foot Ulcers (DFUs) & Diabetic Retinopathy (DR), AI in Diabetic Foot Ulcers (DFUs) Diagnosis & Healing, and Diabetic Foot Ulcers (DFUs) Classification in Medical Imaging. The analysis highlights the growing importance of AI in improving the accuracy and efficiency of wound care, thus offering potential improvements in patient outcomes. This study provides valuable insights into the current landscape of AI in diabetic wound care and lays the foundation for future innovations in this crucial area of healthcare.

Keywords: Artificial intelligence, Bibliometric analysis, Diabetic foot ulcers, Diabetic wound, VOSviewer.

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1. Introduction

Diabetes mellitus is a complex systemic disease that often leads to severe complications, with non-healing wounds, such as diabetic foot ulcers (DFU), being among the most critical [1]. These chronic wounds pose significant risks to patients, including prolonged suffering, increased morbidity, amputations, and even mortality in severe cases. Effective and timely diagnosis and treatment are essential to prevent these outcomes and improve patients' quality of life. However, managing diabetic wounds remains a challenge due to their multifactorial nature, requiring innovative solutions to enhance care and outcomes [2].

In recent years, the rapid advancement of artificial intelligence (AI) has opened new possibilities in the diagnosis and treatment of diabetic wounds [3]. AI has demonstrated potential in improving diagnostic accuracy, predicting wound progression, and optimizing personalized treatment plans. Despite the growing body of research in this area, there is still a lack of comprehensive studies that analyze the trends, key contributors, and collaborations shaping this emerging field. This gap highlights the importance of focused bibliometric analyses to better understand the current landscape of AI applications in diabetic wound care and to guide future research in leveraging AI technology for more effective and efficient wound management.

While various studies have explored the application of AI in diabetic wound care, comprehensive bibliometric reviews that track the evolution of this research field are still scarce. Bibliometric studies have been carried out in related fields, such as diabetic retinopathy (DR), but no thorough analysis exists for AI applications in diabetic wounds. For instance, Poly et al. [4] examined AI in DR research from 2012 to 2022, systematically cataloging academic literature, identifying publication trends, key authors, institutions, and collaborations. Similarly, Zhang et al. [5] analyzed global scientific trends in the application of nanomaterials for diabetic wound healing from 2011 to 2021, summarizing current research characteristics and identifying emerging trends and future directions. Thus, this study aims to fill this gap by conducting a comprehensive bibliometric analysis of global literature on the application of AI in diabetic wound care.

This bibliometric study provides an overview of the current trends, key topics, and bibliometric characteristics within AI and DR, offering crucial insights and directions for future research in this rapidly evolving field. It also highlights the potential of AI tools to improve DR management and patient outcomes, as well as pinpointing research gaps that warrant further exploration. This analysis not only offers insights into publication trends and the influence of leading researchers but will also highlight the main research themes and future directions in this field. By exploring the developments and applications of AI in diabetic wound management, this study is expected to serve as a foundational resource for researchers and healthcare practitioners, driving the advancement of more effective AI-based solutions for diagnosing and treating diabetic wounds.

Building upon this, the bibliometric analysis will address three key research questions (RQs): 1) Who are the most productive authors, key source titles, leading countries, and highly cited documents in the field of AI for diabetic wounds? 2) What are the primary research themes in AI for diabetic wounds? 3) What are the future research directions for AI in diabetic wound care? This study aims to provide a comprehensive resource that will guide future investigations, helping to shape the development of AI-driven solutions to enhance the diagnosis, management, and treatment of diabetic wounds.

2. Methods

2.1. Data Collection

This study employed bibliometric and content analysis to provide a comprehensive overview of global publication trends related to ship collisions while identifying gaps that warrant further exploration. The bibliometric approach is especially valuable for its ability to quantitatively evaluate research performance, offering an objective measure of academic interest and influence in this field. Techniques such as citation analysis and co-occurrence mapping were employed to systematically chart publication networks and identify key trends. Citation analysis highlights the impact of specific articles, authors, and journals, whereas co-occurrence mapping uncovers emerging themes and potential directions for future research based on authors' keywords. Together, these methods minimize researcher bias and deliver a clear, data-driven perspective on the research landscape [6].

The bibliometric analysis was conducted on October 23, 2024, using the Scopus database, chosen for its extensive coverage of citations and abstracts across disciplines, particularly in STEM (Science, Technology, Engineering, and Mathematics) [7, 8]. Scopus provides a comprehensive overview of global scientific research output and is widely acknowledged as a fundamental resource within the academic community [9]. Its rigorous indexing standards ensure the inclusion of only high-quality, peer-reviewed journals, enhancing the credibility and reliability of the research. Additionally, Scopus is a commonly utilized platform for bibliometric studies due to its robust dataset and reliability [7, 10, 11]. By leveraging Scopus as the sole database, this study aligns with international best practices, further solidifying its methodological foundation.

We utilized a keyword-based search strategy guided by our research questions to identify relevant documents on wound diabetic and artificial intelligence. To ensure a targeted retrieval of documents, we specifically focused on the TITLE field in Scopus. This approach reduced the likelihood of including unrelated studies that might have surfaced if broader fields were searched. The search employed a combination of three (3) core keywords: “wound”, “diabetic” and “artificial intelligence” reflecting the main focus of the bibliometric research topic. To enhance the search comprehensiveness, we expanded these terms by including synonyms, related terms, and associated keywords, as detailed in Table 1. This strategy ensured a thorough and precise identification of pertinent studies within the scope of our analysis.

Table 1.
Keyword-based Search Strategy.

No.	Main Keywords	Synonyms/Related Terms/Associated Keywords
1	Wound	injury OR injuries OR ulcer OR lesion OR sore
2	Diabetic	diabetic OR diabetes OR hyperglycemia OR "glucose control" OR "diabetes mellitus" OR "diabetic patient"
3	Artificial Intelligence	"machine learning" OR "computational intelligence" OR "intelligent system" OR ai OR "deep learning" OR "support vector machine" OR "random forest" OR "logistic regression" OR "supervised machine learning" OR "unsupervised machine learning" OR "transfer learning" OR "neural network"

Based on the keywords and their expanded terms listed in Table 1, we constructed the following search query for the Scopus database:

(TITLE (wound OR injury OR injuries OR ulcer OR lesion OR sore) AND TITLE (diabetes* OR diabetic OR hyperglycemia OR "glucose control" OR "diabetes mellitus" OR "diabetic patient") AND TITLE ("artificial intelligence" OR "Machine Learning" OR "Computational Intelligence" OR "Intelligent System" OR ai OR "deep learning" OR "support vector machine" OR "random forest" OR "logistic regression" OR "supervised machine learning" OR "unsupervised machine learning" OR "transfer learning" OR "neural network"))

The final search in Scopus yielded 182 documents based on the selected keywords. Before initiating the analysis, we performed data cleaning and harmonization essential steps in bibliometric research to ensure the accuracy and reliability of the data [12]. Notably, we did not apply any specific criteria to filter the retrieved documents, ensuring that the dataset remained comprehensive and inclusive. This process focused particularly on refining and standardizing keywords. Using the Thesaurus function in VOSviewer, we addressed inconsistencies such as convolutional neural network, convolutional neural network (cnn) and convolutional neural networks, diabetic foot ulcer, diabetic foot ulcers, diabetic foot ulcer (dfu) and diabetic foot ulcers (dfu), diabetic retinopathy and diabetic retinopathy (dr). Therefore, we need to harmonize the dataset first to ensure accurate co-occurrence analysis in this study. The workflow began with downloading the Scopus data in .csv format, selecting the relevant files, and meticulously editing key columns. Clustering functions were employed to group similar terms, facilitating keyword refinement. The thesaurus function was instrumental in standardizing variations of keywords, ensuring uniformity across the dataset. This thorough preparation established a robust foundation for analyzing co-occurrence patterns and identifying trends in the subsequent stages of the study.

2.2. Data Analysis

This study employs bibliometric methods, integrating citation and co-occurrence analysis, to comprehensively address the research question. Citation analysis evaluates the impact of documents, sources, authors, and affiliations through citation counts, which helps to identify influential contributions and emerging trends, as discussed by Ellahham [3]. Concurrently, co-occurrence analysis was conducted to map key topics, trends, and future research directions based on author keywords, revealing interrelationships among various research components. Following the framework proposed by Donthu et al. [13] we used MS Excel and Publish or Perish to calculate frequencies, percentages, and measures of publication impact and performance based on selected metrics. For co-occurrence analysis, VOSviewer [14] was essential in visualizing bibliometric networks, allowing for an in-depth exploration of structural connections within the research field. Combined, these approaches offer a nuanced understanding of the intellectual landscape within this area of study.

3. Results

3.1. Publication Trends

The bibliometric analysis of publication and citation trends for the topic of AI in diabetic wound reveals significant growth from 1998 to 2025. After an initial period of minimal activity, interest began to emerge in 2013, driven by a few landmark studies that generated high citations despite low publication numbers. A substantial surge occurred between 2019 and 2023, with publications increasing from 7 to 41 annually and citations peaking in 2020–2021 with over 500 citations. In 2024, the number of publications reached its highest at 53 articles, although citations slightly declined, likely due to the time required for newer studies to gain recognition. This trend highlights the increasing acknowledgment of AI's role in managing diabetic wounds as a critical research area, with vast potential for further advancements, particularly through the integration of cutting-edge technologies like machine learning to improve patient care outcomes.

Table 2.
Publication and Citation by Year.

Year	TP	TC
1998	1	0
1999	0	0
2000	0	0
2001	0	0
2002	0	0
2003	0	0
2004	0	0
2005	0	0
2006	0	0
2007	0	0
2008	0	0
2009	0	0
2010	0	0
2011	0	0
2012	0	0
2013	1	63
2014	0	0
2015	0	0
2016	1	28
2017	1	156
2018	1	5
2019	7	135
2020	11	514
2021	19	551
2022	45	494
2023	41	238
2024	53	65
2025	1	0
Total	182	2249

Note: TP=total number of publications; TC=total citations.

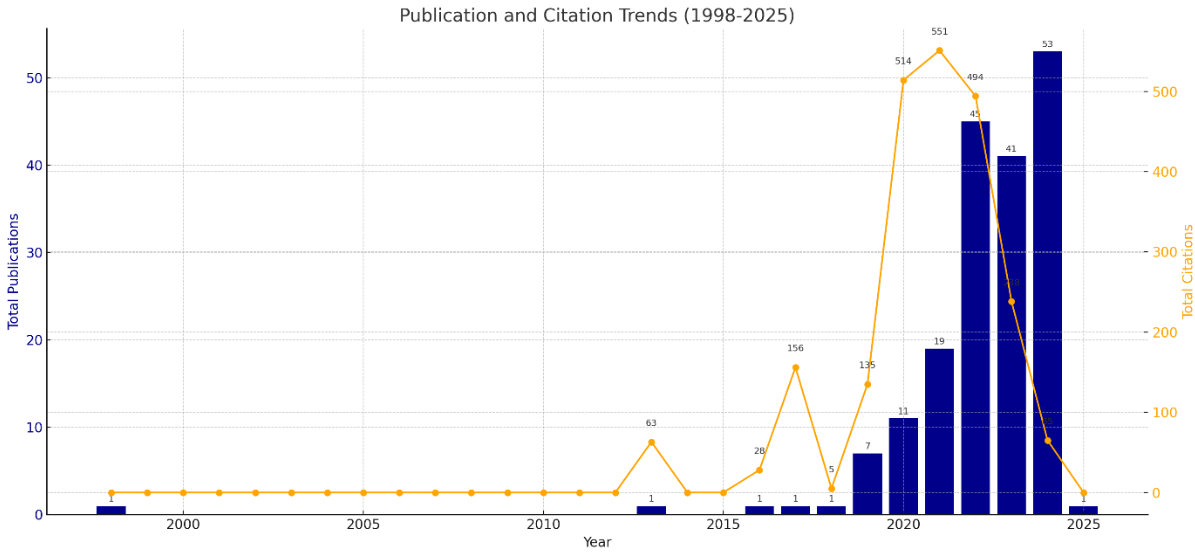

Figure 1.
Total Publications and Citations by Year

3.2. Most Productive and Influential Authors

The bibliometric data on the top 10 authors researching AI in diabetic wounds reveals a global and collaborative research landscape with notable patterns. Gupta, S. from India stands out as the most prolific author with 4 publications and 85 citations, while Alzubaidi, L. from Australia and Fadhel, M.A. from Iraq, despite having fewer publications (3 each), achieve the highest impact with 144 citations, indicating landmark studies driving the field forward. Indian researchers dominate the list with three contributors, reflecting India's growing emphasis on healthcare AI, while France appears as a regional hub with two authors contributing consistently. Interestingly, while some authors achieve high citation counts, others, like Stock and

Biswas [15] and Vanneste et al. [16] with lower citation numbers, represent emerging voices in the field, showcasing a blend of foundational and developing research contributions. This pattern of geographic diversity, high-impact studies, and emerging authors illustrates a maturing field with significant global collaboration and opportunities for interdisciplinary advancements.

Table 3.
Top 10 Authors with at least 3 Publications.

Full Name	Current Affiliation	Country	TP	TC
Gupta, et al. [17]	Graphic Era Deemed to be University	India	4	85
Alzubaidi, et al. [18]	Queensland University of Technology	Australia	3	144
Vanneste, et al. [16]	Mawlana Bhashani Science and Technology University, Department of Information and Communication Technology	Bangladesh	3	10
Bashi, et al. [19]	Manchester Metropolitan University, Department of Mathematics and Computer Science	United Kingdom	3	113
Vanneste, et al. [16]	Siksha O Anusandhan (Deemed to be University)	India	3	46
Vanneste, et al. [16]	Université des Mascareignes, Sciences de L'Education et Informatique Appliquée	Mauritius	3	13
Toofanee, et al. [20]	Université de Limoges, Limoges, FranceUniversité de Bretagne-Sud Campus de Vannes	France	3	13
Alzubaidi, et al. [21]	University of Sumer	Iraq	3	144
Goel, et al. [22]	University of Petroleum and Energy Studies	India	3	77
Toofanee, et al. [20]	3iL Ingénieurs, Limoges, FranceXLIM Institut de Recherche	France	3	13

Note: TP=total number of publications; TC=total citations

3.3. Most Productive and Influential Countries

The data highlights Asia's dominance in AI in diabetic wound research, led by India (62 publications, 526 citations) and China (42 publications, 651 citations), with China achieving a higher impact. The United States ranks third globally with 22 publications and 291 citations, reflecting consistent contributions. Europe and Oceania, represented by the United Kingdom (10 publications, 215 citations) and Australia (7 publications, 275 citations), demonstrate high impact despite lower output. Emerging players like Saudi Arabia, Iraq, Pakistan, and Egypt show growing engagement, with Egypt standing out in Africa with 185 citations from 6 publications. This pattern underscores Asia's leadership and the increasing global participation in this vital research area.

Table 4.
Top 10 Countries with at least 6 Publications.

Country	Continent	TP	TC
India	Asia	62	526
China	Asia	42	651
United States	North America	22	291
United Kingdom	Europe	10	215
Saudi Arabia	Asia	8	183
Australia	Oceania	7	275
Iraq	Asia	7	194
Pakistan	Asia	7	63
Egypt	Africa	6	185
Bangladesh	Asia	6	19

Note: TP=total number of publications; TC=total citations.

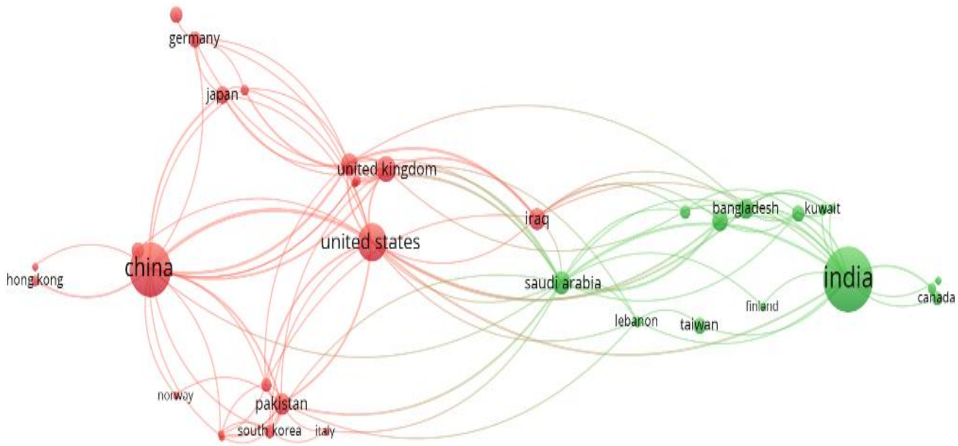

Figure 2.
Countries' Collaboration Network.

The co-authorship analysis reveals distinct patterns of countries' collaboration networks within Cluster 1 (red) and Cluster 2 (green). Cluster 1, led by China (42 documents, 651 citations) and the United States (22 documents, 291 citations), represents a global collaboration network among scientifically advanced nations such as the United Kingdom, Australia, and Germany, reflecting their strong academic ties and shared leadership in high-impact research. This cluster also includes emerging contributors like Iraq, Pakistan, and South Korea, which show growing integration into this global network, albeit with lower total link strengths. In contrast, Cluster 2 is centered around India (62 documents, 526 citations), the dominant player, and features regional collaborations with countries like Saudi Arabia (183 citations), Egypt (185 citations), and Bangladesh. These countries display strong localized cooperation, with relatively higher link strengths among regional neighbors like Malaysia, Lebanon, and the United Arab Emirates. Overall, Cluster 1 illustrates global partnerships with a focus on established research hubs, while Cluster 2 emphasizes regional interconnectivity and collaboration driven by India as the key influencer.

3.4. Most Active Source Titles

Table 5 shows that Springer Verlag leads in publications with contributions from Lecture Notes in Computer Science (8, Q2) and Multimedia Tools and Applications (4, Q1), reflecting a focus on computational and technological applications. Elsevier Ltd follows with high-impact Q1 journals like Computers in Biology and Medicine (4, 388 citations) and multidisciplinary outlets like Heliyon. IEEE Access (6, Q1) highlights IEEE's role in cutting-edge AI research, while Frontiers Media S.A. and John Wiley and Sons Inc. focus on specialized healthcare with Q1 journals like Frontiers in Endocrinology and International Wound Journal. In terms of quartiles, Q1 journals dominate the list, accounting for the majority of publications and citations, highlighting the field's alignment with high-impact, peer-reviewed platforms. Meanwhile, Q2 journals, though fewer, provide essential contributions to niche and emerging areas, such as diagnostics and wound-specific care.

Table 5.
Most Active source titles.

Source Title	**Publisher**	**TP**	**TC**	**Quartile**
Lecture Notes In Computer Science	Springer Verlag	8	201	Q2
IEEE Access	IEEE	6	98	Q1
Computers In Biology And Medicine	Elsevier Ltd	4	388	Q1
Frontiers In Endocrinology	Frontiers Media S.A.	4	41	Q1
International Journal of Lower Extremity Wounds	SAGE Publications Inc.	4	10	Q2
International Wound Journal	John Wiley and Sons, Inc	4	79	Q1
Multimedia Tools And Applications	Springer Verlag	4	166	Q1
Diagnostics	Multidisciplinary Digital Publishing Institute (MDPI)	3	39	Q2
Heliyon	Elsevier Ltd.	3	2	Q1

Note: TP=total number of publications; TC=total citations

3.5. Highly Cited Documents

Table 6 indicates that the top ten highly cited documents collectively highlight the transformative role of deep learning, particularly convolutional neural networks (CNNs), in advancing diagnostics and treatment for diabetic complications, particularly diabetic retinopathy (DR) and diabetic foot ulcers (DFUs). Zago et al. [23] and Alyoubi et al. [24] lead the field with CNN-based approaches for lesion detection and classification in DR, achieving exceptional annual citations of 4875 and

5300, respectively. Yang et al. [25] further advance lesion grading through multi-stage CNNs, while Sudha and Ganeshbabu [26] and Sugeno et al. [27] explore simpler methods leveraging VGG-19 architecture and transfer learning for DR severity grading. Beyond retinopathy, Alzubaidi et al. [18] and Yap et al. [28] focus on DFUs, introducing novel architectures like DFU_QUTNet and evaluating deep learning for ulcer detection. Singh et al. [29] broaden the scope by integrating artificial neural networks with genetic markers for DFU risk assessment, highlighting the intersection of AI and genomics. Pan et al. [30] and Gupta et al. [17] emphasize multi-label classification and transfer learning for retinal lesion detection in DR. Together, these studies underscore the dominant trend of leveraging AI-driven solutions, particularly deep learning, to enhance medical imaging, lesion-specific analysis, and risk assessment for precision diabetes management.

Table 6.
Top 10 highly cited papers.

No.	Author(s)	Title	TC	C/Y
1	Zago, et al. [23]	"Diabetic retinopathy detection using red lesion localization and convolutional neural networks"	195	4875
2	Alyoubi, et al. [24]	"Diabetic retinopathy fundus image classification and lesions localization system using deep learning"	159	5300
3	Yang, et al. [25]	"Lesion detection and grading of diabetic retinopathy via two-stage deep convolutional neural networks"	156	2229
4	Alzubaidi, et al. [18]	"DFU_QUTNet: diabetic foot ulcer classification using novel deep convolutional neural network"	122	3050
5	Yap, et al. [28]	"Deep learning in diabetic foot ulcers detection: A comprehensive evaluation"	90	3000
6	Sudha and Ganeshbabu [26]	"A convolutional neural network classifier VGG-19 architecture for lesion detection and grading in diabetic retinopathy based on deep learning"	68	2267
7	Sugeno, et al. [27]	"Simple methods for the lesion detection and severity grading of diabetic retinopathy by image processing and transfer learning"	65	2167
8	Singh, et al. [29]	"Association of toll-like receptor 4 polymorphisms with diabetic foot ulcers and application of artificial neural network in DFU risk assessment in type 2 diabetes patients"	63	573
9	Pan, et al. [30]	"Multi-label classification of retinal lesions in diabetic retinopathy for automatic analysis of fundus fluorescein angiography based on deep learning"	55	1375
10	Gupta, et al. [17]	"Classification of lesions in retinal fundus images for diabetic retinopathy using transfer learning"	54	1080

Note: TC = total citations; C/Y = total citations per year.

3.6. The Most Frequent Keywords in AI for Diabetic Wound Publications

Keywords describe an article's topic, central idea, or critical topic of a particular research field [31]. After cleaning the keywords, out of a total of 452 keywords, we merged 9 keywords that were unstandardized but had similar meanings, along with keywords that had a co-occurrence frequency below three, resulting in 36 keywords. Thus, all keywords were mapped, as seen in Figures 3 and 4. The circles (nodes) represent specific keywords or topics, and the size of the circles (nodes) indicates the number of co-occurrences, while the link size shows the number of networks.

In the cluster analysis based on co-occurrence keywords (Table 7), the most frequent terms are "dfu" (with 75 occurrences), followed by "deep learning" (52 occurrences), "cnn" (35 occurrences), "machine learning" (34 occurrences), and "diabetic retinopathy (dr)" with 28 occurrences. These keywords highlight the central themes of diabetic foot ulcer (DFU) detection and treatment using deep learning, CNN, and machine learning techniques. These keywords are grouped into specific themes, or clusters, based on their relatedness. Figure 3 shows three (3) clusters of AI in Diabetic Wound publications, each marked by red, green, and blue dotted circles, representing different thematic areas within the research.

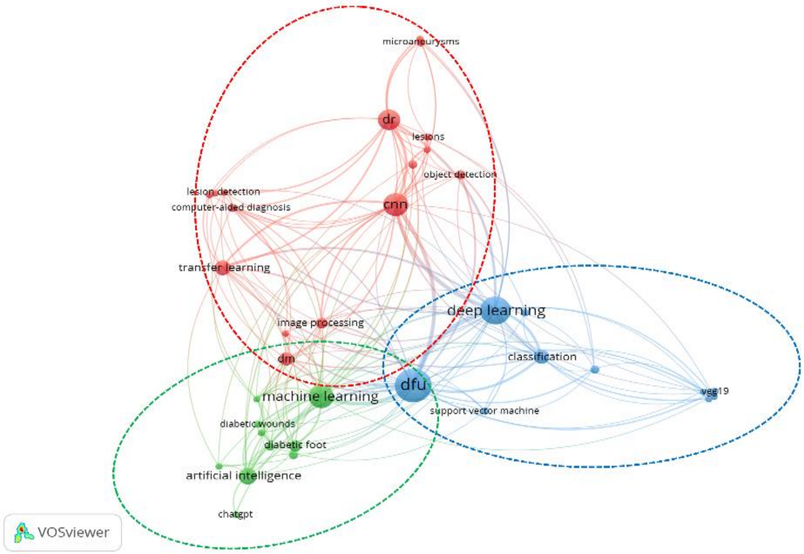

Figure 3.
Thematic Cluster of AI in Diabetic Wound Publications.

The visualization overlay on the VOSviewer mapping results (Figure 4) shows the publication trend of keywords based on the year of appearance. The lighter the color of the link and circle, the more recent the publication. Keywords from recent publications, such as dfu, machine learning, diagnosis, wound healing, artificial neural network and chatgpt are particularly notable. Many of these recent keywords are concentrated in cluster 1, highlighted by the red dotted circle, indicating their significant presence in recent research**.**

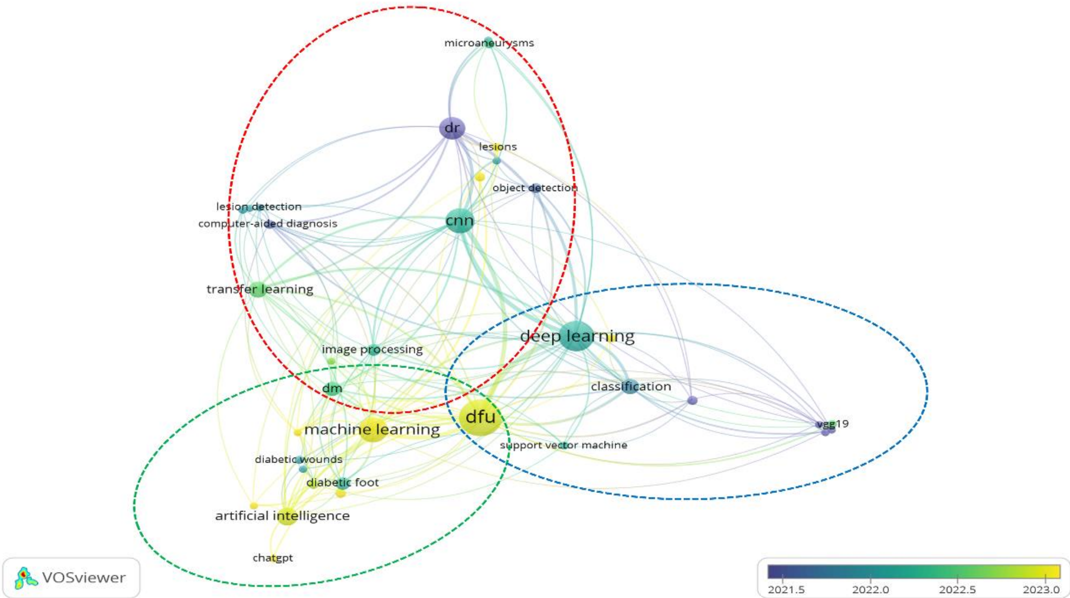

Figure 4.
Trends of AI in Diabetic Wound Publications by Year.

Table 7.
Cluster Analysis Based on Co-Occurrence Keywords

Cluster	Keywords	Occurrences	Theme
Cluster 1	cnn dr transfer learning dm image processing object detection bioinformatics computer-aided diagnosis microaneurysms image classification lesions fundus image hemorrhage lesion detection medical image processing neural networks	35 28 15 12 8 6 5 5 5 4 4 3 3 3 3 3	AI for Automated Detection of Diabetic Foot Ulcers (DFUs) & Diabetic Retinopathy (DR)
Cluster 2	machine learning artificial intelligence diabetic foot foot ulcer wound healing diabetic wounds amputation artificial neural network chatgpt diagnosis	34 18 9 5 5 4 3 3 3 3	AI in Diabetic Foot Ulcers (DFUs) Diagnosis and Healing
Cluster 3	dfu deep learning classification accuracy medical imaging support vector machine vgg19 inception v3 knn vgg16	75 52 13 5 4 4 4 3 3 3	Diabetic Foot Ulcers (DFUs) Classification in Medical Imaging

4. Discussion

This study employed bibliometric analysis to comprehensively explore the development, current status, and future directions of AI in diabetic wound publications. By examining a substantial set of 182 documents, the study mapped the intellectual landscape of the field, identified key contributors, highlighted dominant trends, and outlined significant themes. This section aims to further interpret the findings, discuss their implications for the field, and clarify their relevance for future research. To achieve this, we addressed three primary research questions, each analyzed through distinct thematic lenses.

Regarding the first RQ related to the trend of publications, the bibliometric analysis of AI in wound diabetic shows significant growth from 1998 to 2025. This trend reflects the growing recognition of AI's potential in diabetic wound care, as researchers and healthcare professionals increasingly turn to AI technologies to address the challenges associated with managing diabetic wounds. With advancements in machine learning, deep learning, and data analytics, AI can offer more accurate predictions, personalized treatment plans, and automated monitoring systems, ultimately enhancing patient outcomes. Gupta, S. from India is the most prolific, while Alzubaidi et al. [18] from Australia and Fahimnia et al. [7] from Iraq have the highest impact. Indian researchers lead the list, reflecting India’s growing focus on healthcare AI. The presence of both high-impact authors and emerging contributors like Stock and Biswas [15]. shows a mix of established and developing research, highlighting global collaboration and opportunities for interdisciplinary advancements in the field. In terms of countries, the data reveals Asia’s clear dominance in AI for wound diabetic research, with India and China leading in both publications and citations. In general, Asia leads this field, but global participation is expanding, signaling growing interest and collaboration in this important research area. The highly cited documents emphasize the key role of deep learning, particularly CNNs, in improving diagnostics and treatment for diabetic complications like retinopathy (DR) and foot ulcers (DFUs), with leading studies by Zago et al. [23] and Alyoubi et al. [24] focused on lesion detection and classification.

To answer the second RQ, the research focus on AI for diabetic wounds was mapped into three (3) main research themes by using cluster analysis through VOSviewer. Cluster 1 (red), labeled as “AI for Automated Detection of Diabetic Foot Ulcers (DFUs),” focuses on the transformative application of artificial intelligence (AI) in the detection and management of diabetic foot ulcers (DFUs). This theme underscores the integration of cutting-edge technologies, such as deep neural networks, convolutional neural networks (CNNs), and object recognition, to accurately analyze the location and size of DFUs through advanced image analysis. Research in this field also emphasizes the use of transfer learning and computer-aided diagnosis (CAD) systems, which combine bioinformatics with neural networks to significantly enhance the accuracy and efficiency of wound detection [32]. Similarly, Rao et al. [33] developed an innovative model that not only detects DFUs but also precisely locates their position on the feet of diabetic patients. Thus, this cluster highlights the growing importance of AI technologies in improving the detection and management of diabetes-related complications, with a particular emphasis on advanced medical imaging and automated diagnostic systems that streamline the process for better patient outcomes.

The research topic represented by Cluster 2 (green), titled "AI in Diabetic Foot Ulcers (DFUs) Diagnosis and Healing," delves into the application of artificial intelligence (AI) and machine learning (ML) techniques for diagnosing and treating diabetic foot ulcers (DFUs). This theme underscores the complexity of DFU wound healing, which presents significant medical, economic, and social challenges. Early identification and diagnosis of patients with high-risk profiles are crucial for providing timely and effective treatment, ultimately leading to more favorable health outcomes [34]. The research highlights the critical role of DFU duration, illness perception, and biochemical markers as predictors of healing in chronic conditions. Additionally, another study within this cluster focuses on identifying CTSH as a biomarker for diagnosing and treating diabetic foot ulcers, as well as developing more effective therapies for wound healing through the integration of bioinformatics and machine learning technologies [35].

Cluster 3 (blue) is labeled as “AI for Classification of Diabetic Foot Ulcers (DFUs),” which focuses on applying deep learning techniques to classify diabetic foot ulcers through medical imaging. This theme highlights various classification methods, such as minimum distance, spectral angle mapper, spectral information divergence, and support vector machine, for tissue mapping and identifying the most effective classification approach to differentiate between normal and pathological tissue related to diabetic foot ulcers [36]. Similarly, another study within this cluster proposed a deep learning framework to automatically distinguish healthy skin from DFU lesions based on plantar thermograms. Infrared thermography is used to document the pathogenic factors causing superficial temperature changes in the foot, offering a non-invasive method to monitor DFUs [37].

The third research question (RQ) regarding future research directions was addressed based on three research themes. First, Enhancement of Identification Function: Future research should incorporate additional relevant information based on existing wound classifications, such as comparing wounds before and after treatment, as well as wound range data. This aims to provide more detailed records for healthcare professionals. Second, Integration with Electronic Medical Records (EMRs): Research should integrate wound classification data with electronic medical records to improve disease evaluation quality and enrich existing data. Third, Model Refinement: Continuous improvements should be made to detection models, such as Convolutional Neural Networks (CNNs), to enhance ulcer detection accuracy by collecting more diverse data and refining model architectures. Fourth, Development of Web Application Capabilities: Expanding the capabilities of web applications to offer clinical insights, such as risk assessments based on ulcer characteristics, treatment recommendations, and referrals to specialists, would be beneficial. Fifth, Further Investigation of the CTSH Gene's Function and Molecular Mechanisms: Future research should focus on validating the function and molecular mechanisms of the CTSH gene to gain deeper insights into diabetic wound healing. Although CTSH has been identified as a potential diagnostic and prognostic biomarker, further research is needed to confirm the results from data analysis in larger clinical samples and to better understand its regulatory mechanisms and function. Sixth, Use of Broader Data Sets: Generally, previous studies used only a single case with a low number of training pixels, limiting the generalization of their findings. Future research could involve more cases to enhance the validity and reliability of the results. By using a larger and more diverse dataset, future studies can develop more robust models and generalize findings more effectively.

5. Conclusion

This bibliometric study offers a comprehensive analysis of global trends in the application of Artificial Intelligence (AI) for diabetic wounds. By employing both citation and co-occurrence analyses, the study reveals a remarkable surge in research activity, particularly between 2019 and 2023, when both publications and citations reached their peak. The findings underscore the prominent role of Asian countries, especially China and India, in driving advancements in AI technologies for diabetic wound management, alongside notable contributions from European and Oceanian nations. Emerging countries such as Saudi Arabia, Egypt, and Pakistan are also increasingly participating in the research network, signaling the growing global interest in this area. The co-authorship analysis further unveils a dynamic global collaboration network, where established research hubs are forging strong ties with emerging regions, facilitating both global and regional partnerships. Cluster analysis identifies several key research themes, including the use of AI for the automatic detection of diabetic foot ulcers (DFUs), DFU classification, and the development of healing diagnostic techniques. Each theme highlights the advanced applications of AI in image analysis and diagnosis, with the potential to significantly improve patient care outcomes.

While this bibliometric analysis offers valuable insights into the rapidly growing body of research, several limitations should be acknowledged that may influence the comprehensiveness and accuracy of the findings. First, the study relies solely on the Scopus database for data collection, which, although comprehensive in the STEM fields, may not capture all relevant literature on diabetic wound care and AI applications. This limitation could result in the omission of important publications not indexed in Scopus. Second, the study uses only the TITLE field in the document search. While this approach may enhance accuracy in identifying highly relevant studies and improve search efficiency, it also risks overlooking some pertinent research. Article titles often do not fully reflect the scope of the study, and variations in terminology across titles can lead to incomplete search results. Consequently, the findings may not be entirely representative, and a more comprehensive approach, incorporating the abstract and keywords fields, would likely yield a more complete and relevant literature review. Third, the use of methods such as citation analysis and co-occurrence mapping may not provide a comprehensive understanding of the context and value of the identified research. This is because these methods are quantitative in nature and do not account for the qualitative aspects of the studies, such as the depth of their contributions, the significance of their findings, or the nuances of their methodologies.

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