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Article

The Evolution of "Partial Breast Irradiation" in Radiation Oncology: A Bibliometric Analysis

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Abstract

Aim: Partial breast irradiation (PBI) has become an important treatment approach for early-stage breast cancer, offering advantages such as shorter treatment duration and reduced radiation exposure to healthy tissue. Despite its increasing clinical use, a comprehensive evaluation of research trends in this field is lacking.

Methods: This bibliometric analysis examines 1,718 publications on PBI from 2005 to 2024, retrieved from Web of Science (WoS). VOSviewer was used to analyze citation networks, keyword trends, and research collaborations, while SPSS was employed for statistical analysis of publication output and citation distributions.

Results: The number of PBI-related publications peaked in 2011, followed by a fluctuating trend. The International Journal of Radiation Oncology Biology Physics published the highest number of studies (38.07%), while Virginia Commonwealth University and William Beaumont University Hospital emerged as the leading institutions. The most cited studies contributed significantly to shaping clinical guidelines on accelerated PBI. Keyword analysis revealed dominant research themes, with "breast cancer," "brachytherapy," and "radiotherapy" being the most frequently used terms.

Conclusion: While PBI remains a key area in breast cancer radiotherapy, its research output has shown fluctuations over time. Further studies are needed to explore long-term clinical outcomes, technological advancements, and international collaborations. This bibliometric analysis provides valuable insights into the evolution of PBI research and serves as a reference for future investigations in radiation oncology.

Keywords: partial breast irradiation, bibliometric analysis, radiation oncology, breast cancer, citation analysis

Introduction

Breast cancer continues to rank among the most common cancers for women around the globe and radiotherapy is an important component in its treatment [1,2]. In the last 20 years, partial breast irradiation (PBI) has emerged as a new technique in radiation oncology which seeks to increase the efficacy of radiation treatment by limiting the dose to normal breast tissues [3,4]. The technique of PBI is more advantageous than WBI in that it gives the patient the opportunity to receive the treatment in an outpatient setting, the treatment is shorter and the side effects are much less, leading to better compliance among patients [5,6].

Although PBI is rapidly being adopted clinically, its evolution in the scientific literature has not been systematically mapped. There have been some bibliometric analyses on PBI, but very few focused solely on its use within radiotherapy for breast cancer [1,2,7]. The impact of radiation as a major component of breast cancer treatment has been studied [8] and the contribution of breast conserving surgery [9], but no comprehensive study has systematically analyzed the publication trends, citation counts, authors, and collaborators in the field of PBI. These components are key to understanding the scientific network around PBI.

A research domain's impact, and scientific progress relies on advanced collaborative analysis [10,11]. In bibliometric studies, the identification of prolific authors and highly cited studies reveals research hotspots while pinpointing regions lacking adequate literature so as to determine gaps in existing literature and inform future research directions [1,2].

This investigation explores the scientific evolution of partial breast irradiation (PBI) through a bibliometric lens, focusing on key trends, influential studies, academic collaborations, and thematic developments over time. The study aims to assess the literature and focus on the scientific productivity, academic collaborations, and salient themes which speaks on the evolution of partial breast irradiation where gaps have been identified in the literature necessary for further exploration.

Radiotherapy has also seen the adoption of partial breast irradiation (PBI) as a novel technique for treatment of early stage breast cancer patients. However, the scientific literature for this specialty field of medicine has historically been rather neglected as science and research in regards to which journals publish articles concerning the topic or which institutions contribute articles most or even which keywords are used and over what time frame has the research interest shifted is not systematically reviewed.

This research offers a comprehensive bibliometric analysis that spans across twenty years, revealing the most impactful studies and researchers of the discipline. By mapping out international academic cooperations, the analysis offers a historical summary of the field including research trends while pinpointing key studies and researchers. The study further attempts to map the emerging gaps and provide pathways for future research, while offering a frame of reference on the development of literature on Partial Breast Irradiation. At last, the analysis contributes strategies regarding the transformation of science in the discipline of radiotherapy of cancer and serves as a valuable reference for researchers and clinicians.

Materials and Methods

Data Collection and Selection

With the help of bibliometric analysis, data was achieved through Core Collection of Web of Science which is one of the databases for peer reviewed publications. The study was focused on research concerning partial breast irradiation (PBI) that was published during the period of January 2005 and December 2024. Using WoS, the keyword "partial breast irradiation" was searched with the topic filter applied. To narrow down the data set, only Radiation Oncology articles in WoS were used.

Title 1	Title 2	Title 3
entry 1	data	data
entry 2	data	data [1]

After the search, 1718 articles were found and then further studies were conducted based on the title, abstract, and keywords of the articles. As a starting point, all records were strepped of any duplicates, keeping only peer reviewed studies after applying the inclusion prerequisites. The selected records comprised publications with important contributions made to the understanding and development of PBI research. After reaching a final dataset, the selection was reviewed by two independent researchers where most disputes were resolved through a discussion in which a decision was made by the most agreed upon option.

Data Extraction and Analysis

For every article selected, information related to the publication was extracted which includes title, authors, publication year, name of journal, impact factor, citations, affiliated country, institution and frequently used keywords. The searched data were incrementally verified by 2 researchers to check for accuracy countering opinions that were not in agreement.

Using VOSviewer, version 1.6.11, developed at Leiden University, Netherlands, citational mappings were created with respect to publication trends, citations, the relations between keywords, and collaborations. The study sought to look at annual publication trends, volume of journal publications, distribution of citations, and also keyword co-occurrence networks that would identify thematic clusters. Collaborations at the institutional and country levels were presented by portraying research partnerships across different institutions and geographical regions.

Statistical Analysis

The summary output, citation patterns, and journal impact measures publication output details were quantized using basic descriptive statistics. SPSS was employed to analyze publication volumes over time, which showed changes in focus toward research. The top 150 keywords were mapped to determine the presence of thematic clusters

and collaboration networks at the institutional and country level were examined to evaluate the integration of research. The connection densities outlined in the secondary analysis of the PBI institutional and international partnership give a picture of how integrated the PBI research community is. The process of data collection and analysis is presented in Figure 1.

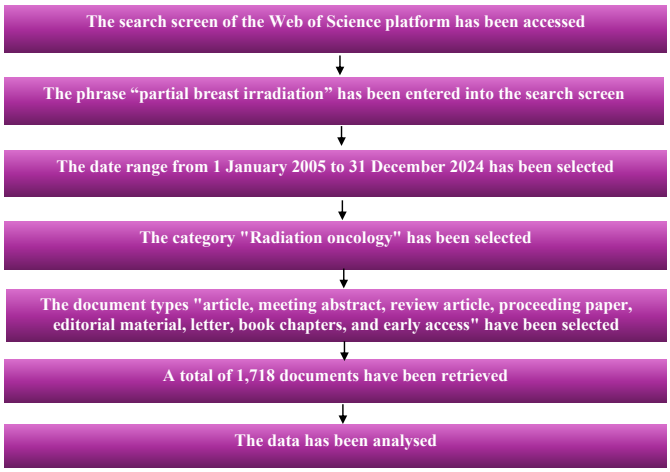


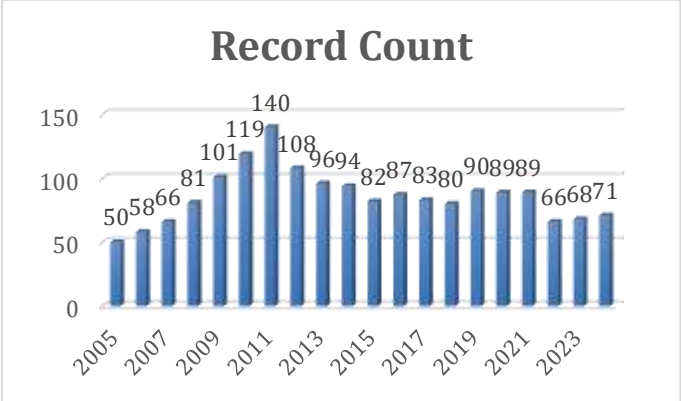
Figure 1. Study selection and bibliometric analysis workflow

Results

1.Analysis of the Distribution of Publications Over the Years

Based on the Web of Science data, the distribution of studies on "partial breast irradiation" between 2005 and 2024 has been analyzed, as illustrated in Graph 1.

In 2005, 50 studies were published, and a steady increase was observed in the following years. By 2009, the number of studies rose to 101, reaching a peak in 2011 with 140 publications. However, from 2012 onward, a downward trend in the number of publications began, decreasing to 96 in 2013 and 94 in 2014. Since 2015, the number of studies has shown a fluctuating pattern, dropping to 83 publications in 2017, followed by an increase to 89 in 2020. However, from 2021 onwards, the number of publications declined again, reaching 66 in 2022. In 2024, a renewed increase was observed, with 71 studies published on the topic.

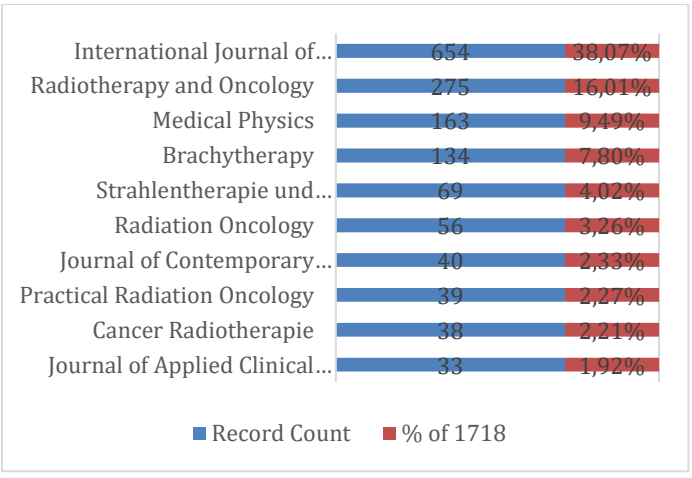


Graph 1. Distribution of publications by year (2005–2024)

2. Journals with the Highest Number of Publications on the Topic

The distribution of journals with the highest number of publications on "partial breast irradiation" in the Web of Science database is presented in Graph 2.

Figure 2 provides an analysis of the journals with the most publications in this field. The *International Journal of Radiation Oncology Biology Physics* stands out with 654 publications, accounting for 38.07% of the total literature, highlighting its significant contribution to the field and its strong academic interest in the topic. Similarly, *Radiotherapy and Oncology* ranks second, contributing 275 publications, which constitute 16.01% of the total, emphasizing its critical role in the international discourse on this subject.In third place, *Medical Physics* has published 163 articles, representing 9.49% of the total, demonstrating a noteworthy contribution to the literature.



Graph 2. Journals publishing articles on partial breast irradiation: Publication counts and percentages

3. Detailed Analysis of the Most Cited Studies: Authors, Titles, Journals, Publication Years, and Citation Counts

The Web of Science database provides detailed information on the most highly cited studies related to *partial breast irradiation*, including author details, publication journals, years of publication, and citation counts, as presented in Table 1.

No	Authors	Paper Name	Journal Name	Year	Citation
1	Smith B.D. et al.	Accelerated Partial Breast Irradiation Consensus Statement From The American Society For Radiation Oncology (Astro)	International Journal of Radiation Oncology Biology Physics	2009	688
2	Csaba, P. et al.	Patient selection for accelerated partial-breast irradiation (APBI) after breast-conserving surgery: Recommendations of the Groupe Europeen de Curietherapie-European Society for Therapeutic Radiology and Oncology (GEC-ESTRO) breast cancer working group based on clinical evidence (2009)	Radiotherapy and Oncology	2010	485
3	Correa, C. et al.	Accelerated Partial Breast Irradiation: Executive summary for the update of an ASTRO Evidence-Based Consensus Statement	Practical Radiation Oncology	2017	470
4	Polgár, C. et al.	Breast-conserving therapy with partial or whole breast irradiation: Ten-year results of the Budapest randomized trial	Radiotherapy and Oncology	2013	292
5	Polgár, C. et al.	Breast-conserving treatment with partial or whole breast irradiation for low-risk invasive breast carcinoma-5-year results of a randomized trial	International Journal of Radiation Oncology Biology Physics	2007	277

Table 1. Most cited publications on partial breast irradiation: Authors, article titles, journals, publication years, and citation counts

Table 1 offers a comprehensive analysis of the most impactful studies in the literature on *partial breast irradiation*. The most highly cited publication in this field is the study by Smith B.D. et al., published in 2009, which has received 688 citations. This study, published in the *International Journal of Radiation Oncology Biology Physics*, presents the American Society for Radiation Oncology (ASTRO) consensus statement on accelerated partial breast irradiation (APBI).

The second most cited study, conducted by Csaba P. et al., was published in 2010 and has accumulated 485 citations. Published in *Radiotherapy and Oncology*, this study outlines the European Curietherapie Group (GEC-ESTRO) recommendations for patient selection for APBI following breast-conserving surgery.

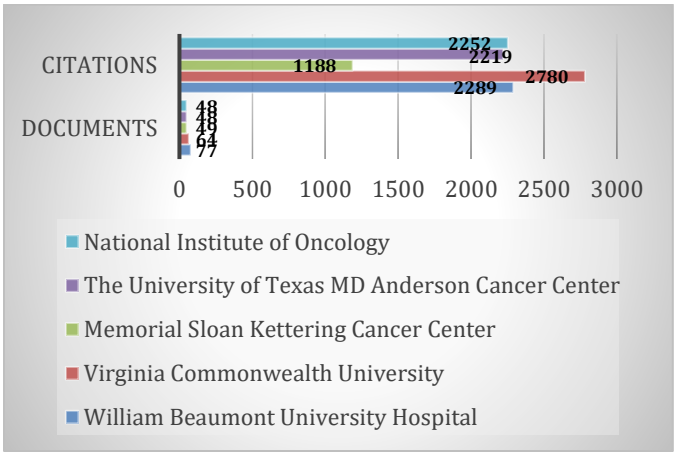
The third most cited publication is a study by Correa C. et al., published in 2017, which has received 470 citations. Published in *Practical Radiation Oncology*, this work presents the updated evidence-based ASTRO consensus statement on accelerated partial breast irradiation.

Other notable studies include two publications by Polgár C. et al., one published in 2013 with 292 citations and another in 2007 with 277 citations. Both studies focus on the long-term outcomes of breast-conserving treatment and irradiation techniques, contributing significantly to the field.

4. Statistical Analysis of Publications from the Most Cited Institutions

The Web of Science database provides a detailed breakdown of institutions affiliated with authors who have published studies on *partial breast irradiation*, including the number of articles produced by these institutions and their citation counts, as presented in Graph 3.

Graph 3 highlights the institutions with the highest citation impact in the field of *partial breast irradiation* and presents their publication statistics. Among these institutions, Virginia Commonwealth University stands out, having produced 64 publications that have received 2,780 citations, demonstrating its significant influence in the field.



Graph 3. Most cited institutions and publication distributions based on Web of Science data

Another prominent institution is William Beaumont University Hospital, which has contributed 77 publications that have received 2,289 citations, further emphasizing its academic importance. Additionally, the National Institute of Oncology has published 48 studies, which have accumulated 2,252 citations, underscoring its strong scientific impact.

Furthermore, The University of Texas MD Anderson Cancer Center has contributed 48 publications, garnering a total of 2,219 citations. Similarly, Memorial Sloan Kettering Cancer Center has 49 publications with 1,188 citations, marking it as another key institution in this research domain.

These data indicate that these institutions are not only highly productive in terms of research output but also have a significant impact on the scientific literature in the field of *partial breast irradiation*.

5. Trends in Keyword Usage

The bibliometric analysis was conducted using VOSviewer software, with a minimum threshold of five occurrences set for keyword selection. This threshold ensured that only keywords that appeared at least five times were included in the analysis, allowing the study to focus on frequently used and scientifically relevant terms. Although a total of 1,198 different keywords were identified, only 92 met the threshold criteria and were included in the analysis. This methodology ensured that the study concentrated on the relationships between selected keywords rather than an exhaustive keyword list.

The analysis results identified the most frequently used and highly interconnected keywords in the research domain. Additionally, a network of 696 keyword links was detected, leading to the identification of 10 distinct clusters. These findings enable a detailed examination of the relationships between keywords in the field. Such an analysis contributes to a deeper understanding of the research domain's terminology while also identifying critical concepts for future studies.

Figure 2 presents the most frequently used keywords in academic publications on *partial breast irradiation* and their occurrence frequencies. According to the data, the most frequently used keyword is "breast cancer", appearing 337 times. This highlights that the primary focus of the research area remains breast cancer and underscores the critical role of this term in the literature.

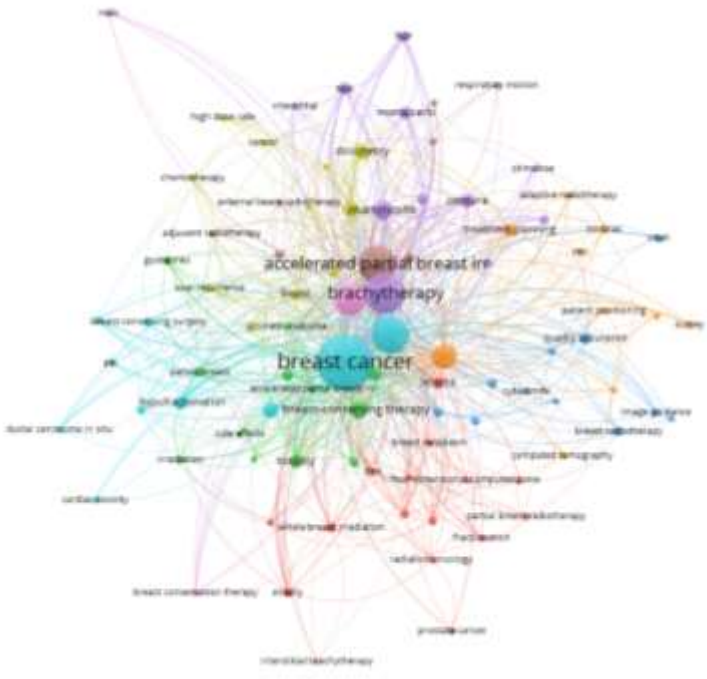


Figure 2. Keyword co-occurrence network and frequency of keyword use

The second most frequently used keyword, "brachytherapy", appears 178 times, reflecting the strong academic interest in brachytherapy methods for breast cancer. The terms "accelerated partial breast irradiation" (154 times) and "partial breast irradiation" (145 times) emphasize the interrelation between partial breast irradiation and its accelerated application and its significance in the literature. These findings suggest a growing interest in radiation techniques in breast cancer treatment.

Other noteworthy keywords include "APBI" (107 times) and "radiotherapy" (66 times), indicating that research has extensively explored radiotherapy techniques and their subfields. Notably, the frequent appearance of "APBI" highlights the importance of accelerated partial irradiation approaches in the field.

This keyword analysis provides valuable insights into the evolution of research themes, emerging trends, and the conceptual structure of the field, offering guidance for future studies in partial breast irradiation.

6. Institutional Collaboration Analysis

The affiliations of authors publishing studies on *partial breast irradiation* and the collaboration networks between these institutions have been analyzed. The results are visually presented in Figure 3.



Figure 3. Bibliometric visualization of institutional collaboration networks

In the collaboration analysis conducted using VOSviewer software, colors distinguish thematic or regional groups, while the connections between institutions represent collaborative relationships. The thickness of these connections indicates the intensity of collaboration. Such visualizations reveal the impact of institutions on research activities in the field of *partial breast irradiation* and contribute to identifying strong partnerships as well as potential collaboration opportunities.

The University of Texas MD Anderson Cancer Center, with 79 connections, emerges as one of the most central institutions in the collaboration network. This indicates that the institution has an extensive collaborative network and has developed strong relationships with other institutions in *partial breast irradiation* research. Virginia Commonwealth University follows with 59 connections, while Memorial Sloan Kettering Cancer Center has 52 connections, highlighting its active engagement in research collaborations. Additionally, William Beaumont University Hospital (50 connections) and Brown University (41 connections) are among the significant institutions in the network.

Overall, the observed connections and clustering structures in the network indicate that studies on *partial breast irradiation* are conducted with intensive institutional collaborations. This type of analysis allows for the evaluation of inter-institutional collaboration potential, providing strategic guidance for expanding research networks and identifying new partnership opportunities.

7. Author Collaboration Analysis

Studies on *partial breast irradiation* in the Web of Science database were analyzed, and collaboration networks among authors were examined. The findings from this analysis are presented in Figure 4.

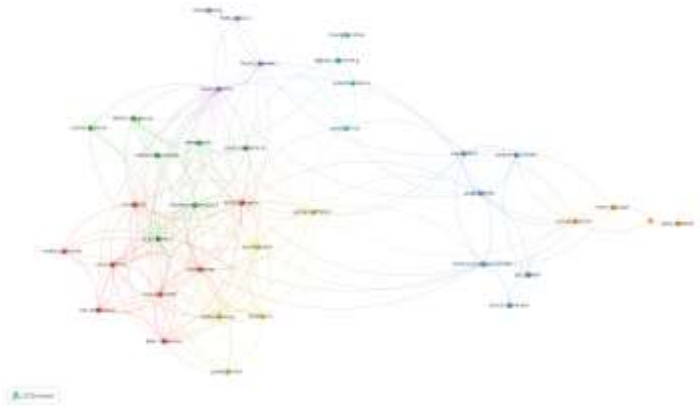


Figure 4. Bibliometric map of author collaboration

Figure 4 analyzes the bibliographic connections among authors who have published at least 10 studies in the field. A total of 7,049 authors were evaluated, but only 83 authors met the threshold for inclusion. The criterion of having published at least 10 studies was set to ensure that the analysis included noteworthy contributors who have demonstrated a sufficient level of productivity in the field. This threshold enhances the reliability and significance of the results by focusing solely on active and influential researchers.

The visualization presents collaboration networks and bibliographic connections among researchers working in the field of *partial breast irradiation*. Each author is represented by a circle, where the size of the circle reflects the author's impact on the literature, and the lines indicate the strength of their collaboration links.

- Douglas W. Arthur and Chirag Shah are at the center of the red cluster, standing out as key contributors in this field. This cluster also includes Michelle Wallace and Martin Keisch, who demonstrate strong collaboration ties.
- The green cluster, led by Simona Shaitelman and Benjamin D. Smith, represents an intensely collaborative group. This cluster also maintains connections with other clusters, highlighting its significant role in the field's literature.
- In the blue cluster, Alphonse G. Taghian and Simon N. Powell are the leading figures, while Celine Bourgie and Imran Zober also contribute to the network. This cluster is characterized by an extensive collaboration network that strengthens the field’s research output.
- The yellow cluster, centered around Catheryn Yashar, includes fewer authors and focuses on a specific sub-theme within *partial breast irradiation*.

- The orange cluster, with Frederik Wenz and Michael Lotter as central figures, plays a major role in the research network.

Overall, the different color-coded clusters reflect groups of authors who share thematic or methodological similarities. These collaboration networks provide valuable insights into the dynamics of research in this field.

8. Country-Based Citation Analysis

The citations of studies on *partial breast irradiation* have been analyzed based on Web of Science (WoS) data, providing a detailed evaluation of citation distribution across countries. The results of this analysis are visually presented in Figure 5, illustrating the geographical density and interconnections of citations.

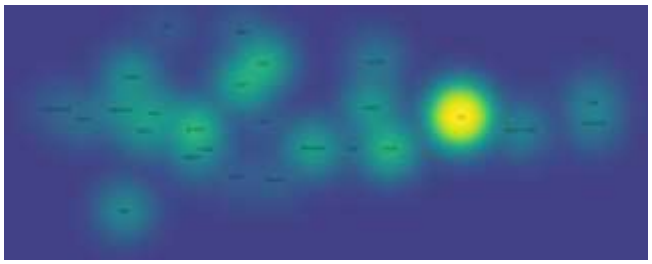


Figure 5. Country-level distribution of citations

Figure 5 presents a detailed visualization of the geographical distribution of citations and international academic collaboration networks based on articles published in the Web of Science (WoS) database. The analysis included only countries that have published at least five studies, out of which 26 countries were selected for evaluation from a total of 50 eligible countries.

A total of seven distinct clusters were identified, with each cluster representing a specific research focus or collaboration network. The visualization reveals the distribution of citations across different countries and academic collaborations at an international level in *partial breast irradiation* research.

- The United States (USA) stands out as the brightest node in the network, clearly indicating its leading role in this field.
- In Europe, the United Kingdom, Germany, France, and Italy emerge as key centers, both individually and through strong collaborative networks.
- In Asia, China, Japan, and South Korea play a significant role, particularly through their connections with the USA and European countries in global scientific collaborations.
- Canada, Australia, and Brazil are also notable contributors, representing key research hubs outside North America and Europe.
- Other countries with lower citation densities but still making significant contributions include Switzerland, Spain, the Netherlands, and Israel, reflecting regional and thematic collaborations within the field.

The findings from Figure 5 emphasize the geographical concentration of scientific contributions, highlighting countries that significantly impact the literature on *partial breast irradiation*. Notably, Turkey is not included in this visualization, indicating a lack of substantial contributions in this research area from the country.

Discussion

This study provides a comprehensive bibliometric analysis of partial breast irradiation (PBI) research, mapping its scientific evolution, key contributors, and research trends over the past two decades. The findings align with previous bibliometric studies in breast cancer radiation therapy [1,2], yet offer a focused perspective on PBI, an area that has seen significant clinical adoption but limited systematic analysis in the literature.

The increasing role of PBI in breast cancer treatment is well-documented in the literature. However, most bibliometric analyses have focused on general radiotherapy trends rather than specifically addressing PBI [1,2]. Compared to whole breast irradiation (WBI), PBI has shown benefits such as reduced treatment time, fewer side effects, and improved patient compliance [3,6]. The meta-analyses conducted by Shah et al. and Shumway et al. support these findings, showing that PBI provides comparable oncological outcomes with better tolerability [5,8]. Despite these advantages, our study identifies fluctuations in research activity over time, particularly after 2011, suggesting that while clinical interest remains, scientific output has varied. This pattern is consistent with the findings of Franco et al. and Jia et al., who noted similar shifts in breast cancer radiotherapy research trends [1,2].

Our results indicate that PBI-related publications peaked in 2011 but have since followed a fluctuating trend. This is in contrast to broader breast cancer radiotherapy research, which has shown steadier growth over the years [7]. The most highly cited study in our analysis, Smith et al. [3], which provides the ASTRO consensus statement on accelerated PBI, remains a foundational reference in the field. These findings mirror Goldberg et al. [6], who also identified these works as pivotal in shaping PBI research and clinical practice.

The International Journal of Radiation Oncology Biology Physics emerged as the leading journal in PBI research, contributing 38.07% of total publications. This dominance aligns with findings in general breast cancer radiotherapy studies [1].The presence of Radiotherapy and Oncology (16.01%) and Medical Physics (9.49%) as key journals also corresponds with broader radiation oncology bibliometric analyses [2].

In terms of institutional impact, our findings highlight Virginia Commonwealth University and William Beaumont University Hospital as the most influential institutions, producing high-impact publications with significant citation counts. This is consistent with previous bibliometric studies, which identify these institutions as leaders in breast cancer radiotherapy research [1,2].Furthermore, The University of Texas MD Anderson Cancer Center and Memorial Sloan Kettering Cancer Center continue to be major contributors, emphasizing the role of highly specialized cancer centers in advancing PBI research.

Our study highlights strong inter-institutional and international collaborations in PBI research. The University of Texas MD Anderson Cancer Center emerged as a central institution in global research networks, similar to previous studies in broader breast cancer radiation therapy research [1,2]. The United States leads in scientific output, while European institutions, particularly in the UK, Germany, France, and Italy, play significant roles in shaping the field. Asian countries, including China, Japan, and South Korea, are increasing their research contributions, reflecting a growing global interest in PBI. These findings are consistent with Shumway et al. [8], who also noted increasing global collaboration in breast cancer radiotherapy research.

The keyword analysis reveals that "breast cancer," "brachytherapy," "accelerated partial breast irradiation (APBI)," and "radiotherapy" are the most frequently used terms, reflecting the central themes in PBI research. This aligns with the keyword trends identified in previous bibliometric studies on breast cancer radiotherapy [1,2]. However, our findings suggest that while APBI remains a dominant focus, newer research areas such as advanced imaging techniques and adaptive radiotherapy have not yet gained significant traction in PBI research.

While PBI research remains a significant area within breast cancer radiotherapy, its publication trends indicate fluctuating interest over the years. The continued dominance of highly cited studies from the late 2000s and early 2010s suggests that while clinical implementation has progressed, new groundbreaking research in PBI may be limited. This contrasts with the findings in general breast cancer radiotherapy research, where novel technologies and techniques have driven continuous publication growth [2,7].

Given the documented benefits of PBI, future research should explore:

- The integration of PBI with emerging radiotherapy technologies, such as artificial intelligence-driven treatment planning and adaptive radiotherapy.
- Long-term oncological and quality-of-life outcomes of PBI, addressing gaps in follow-up data.
- Comparative effectiveness studies between different PBI techniques, such as brachytherapy vs. external beam radiotherapy.

Limitations

This study is limited by its reliance on the Web of Science (WoS) database, which may exclude relevant research indexed in other databases such as Scopus, PubMed, or Google Scholar. Additionally, while bibliometric analysis provides insights into publication trends and citation patterns, it does not assess the clinical efficacy, methodological quality, or real-world impact of the studies analyzed, which would require a more detailed systematic review.

Conclusion

This study provides a comprehensive bibliometric analysis of PBI research, identifying key contributors, research trends, and gaps in the literature. While PBI remains an important focus in breast cancer radiotherapy, its research output has shown fluctuations over time, necessitating renewed scientific efforts to explore its long-term efficacy, integration with modern radiotherapy technologies, and global research collaboration opportunities. The findings complement previous bibliometric analyses in breast cancer radiotherapy [1,2] and highlight the need for further targeted research to advance PBI as a standard treatment option for early-stage breast cancer patients.

Patents

Not applicable.

Supplementary Materials

No supplementary materials have been provided with this manuscript.

Ethics

Ethical approval was not required for this bibliometric study, as it was based exclusively on bibliographic records retrieved from the Web of Science database and did not involve human participants, animals, or identifiable personal health information.

Author Contributions

Burcu Saglam Alan: Conceptualization, methodology, formal analysis, investigation, data curation, visualization, writing—original draft preparation, and writing—review and editing. The author has read and approved the final version of the manuscript.

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Institutional Review Board Statement

Not applicable. This study involved the bibliometric analysis of published scientific literature and did not include human participants or animal experiments.

Informed Consent Statement

Not applicable. No human participants were recruited, and no individual patient data were collected or analyzed.

Data Availability Statement

The bibliographic data analyzed in this study were retrieved from the Web of Science Core Collection for publications indexed between 2005 and 2024. The dataset was analyzed using VOSviewer and SPSS. Access to the underlying bibliographic records is subject to the database's subscription and licensing conditions. Availability of the processed dataset from the corresponding author has not been specified.

Acknowledgments

No acknowledgments were specified in the submitted manuscript.

Conflicts of Interest

The author's conflict-of-interest declaration has not been provided.

Abbreviations

Abbreviation	Full Term
PBI	Partial Breast Irradiation
APBI	Accelerated Partial Breast Irradiation
WBI	Whole Breast Irradiation
WoS	Web of Science
SPSS	Statistical Package for the Social Sciences
ASTRO	American Society for Radiation Oncology
GEC-ESTRO	Groupe Européen de Curiethérapie–European Society for Radiotherapy and Oncology
VOSviewer	Visualization of Similarities Viewer

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