JMSR 2(1) (2026)

Journal of Material Science and Radiation

https://journals.balaipublikasi.id/jmsr

Research Trends of Polymer Film for Radiation Radiotherapy: A Review

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Received: March 15, 2026
Revised: April 12, 2026
Accepted: April 21, 2026
Published: April 30, 2026

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DOI: 10.56566/jmsr.v2i1.690

Abstract: Polymer-based radiation dosimeters have attracted significant attention in recent years due to their capability to measure complex radiation dose distributions in radiotherapy applications. This study aims to analyze the research trends related to polymer film and polymer gel dosimetry used in radiotherapy through a systematic literature review and bibliometric analysis. The study employed the PRISMA methodology to systematically identify and select relevant publications from the Scopus and SINTA databases. A total of 30 articles published between 2018 and 2025 were included in the analysis. Bibliometric analysis was conducted using VOSviewer to examine publication trends, keyword co-occurrence networks, and research collaboration patterns. The results indicate a steady increase in research publications related to polymer dosimetry over the past decade. Keyword clustering analysis revealed several dominant research themes, including polymer gel dosimetry, radiation polymerization, dose distribution measurement, polymer film dosimeters, and nanoparticle-enhanced polymer materials. Among these topics, polymer gel dosimetry remains the most widely studied due to its capability to record three-dimensional radiation dose distributions. However, recent studies have increasingly explored polymer film dosimeters and nanocomposite materials to improve radiation sensitivity and dosimetric performance. Overall, the findings highlight the rapid development of polymer dosimetry technologies and their growing importance in modern radiotherapy quality assurance. Future research should focus on developing advanced polymer nanocomposites and integrating imaging-based dosimetry techniques to improve radiation dose measurement accuracy and clinical applicability.

Keywords: Polymer film dosimeter; Polymer gel dosimetry; Radiation dosimetry; Radiotherapy; Review

Introduction

Radiotherapy is one of the primary methods used in cancer treatment, utilizing ionizing radiation to selectively destroy tumor cells. With the advancement of modern radiotherapy technologies such as intensity-modulated radiation therapy (IMRT), stereotactic radiosurgery (SRS), and proton therapy, the need for highly accurate and precise radiation dose verification systems has increased significantly. Modern radiotherapy techniques produce highly complex dose distributions, requiring dosimetry methods capable of mapping dose distributions in two-dimensional and three-dimensional spaces with high spatial resolution (Baldock et al., 2010; Deene, 2022; Farhood et al., 2019).

Radiation dosimetry plays an essential role in ensuring that the radiation dose delivered to patients corresponds to the treatment plan while minimizing damage to surrounding healthy tissues. In clinical practice, several types of dosimeters have been used, such as ionization chambers, thermoluminescent dosimeters (TLD), and radiochromic films. However,

How to Cite:
Doyan, A., Susilawati, S., Annam, S., Ikhsan, M., & Ardianti, N. R. (2026). Research Trends of Polymer Film for Radiation Radiotherapy: A Review. *Journal of Material Science and Radiation*, *2*(1), 1–10. https://doi.org/10.56566/jmsr.v2i1.690

conventional dosimetry devices have limitations in recording volumetric radiation dose distributions, particularly in complex radiotherapy techniques that require three-dimensional dose verification (Gambarini et al., 2020; Karger et al., 2024; Oldham, 2019).

As an alternative approach, polymer-based materials have been widely developed as radiation dosimeters due to their ability to record spatial radiation dose distributions with high resolution. Polymer dosimeters operate based on radiation-induced free radical polymerization processes triggered by ionizing radiation. These reactions cause molecular structural changes that can be measured using various characterization techniques such as optical spectroscopy, magnetic resonance imaging (MRI), or computed tomography (CT). The changes in optical or magnetic properties are proportional to the radiation dose absorbed by the polymer material (Deene, 2022; Karger et al., 2024; Schreiner, 2018).

Polymer film and polymer gel dosimeters are two types of polymer-based dosimeters widely investigated in radiotherapy research. Polymer gel dosimeters have the capability to record three-dimensional radiation dose distributions with high spatial resolution and are often used in radiotherapy phantom studies to verify treatment planning systems. This system allows volumetric recording of dose distributions, enabling more accurate analysis of the radiation dose delivered to patients (Farhood et al., 2019; Hosseini et al., 2019; Kaur et al., 2021).

In recent years, research on polymer film dosimeters has shown significant growth. Radiation-sensitive polymer films may exhibit color changes or variations in optical absorbance after exposure to ionizing radiation. These changes can be analyzed using spectrophotometric techniques or optical imaging to determine the absorbed radiation dose. Compared with gel dosimeters, polymer films offer several advantages, including easier fabrication, better mechanical stability, and simpler application for two-dimensional dose verification systems (Chen et al., 2021; Gupta et al., 2023; Lee et al., 2022).

In addition, numerous studies have focused on developing polymer formulations with improved radiation sensitivity. Several studies have reported the use of polymers such as poly (vinyl alcohol), poly (methyl methacrylate), and acrylate-based hydrogels that exhibit favorable dosimetric responses to gamma rays and X-ray radiation. Research has demonstrated that radiation-induced changes in polymer structures can be analyzed through variations in optical density or spectroscopic characteristics of the materials (Issa et al., 2023; Kawamura et al., 2018; Singh et al., 2022).

Recent developments also indicate the integration of polymer dosimeters with modern imaging technologies. For example, the use of optical computed tomography, MRI, and cone-beam computed tomography enables rapid and accurate reading of three-dimensional dose distributions. This integration allows more precise radiation dose mapping and supports quality assurance processes in modern radiotherapy (Karger et al., 2024; Kozicki et al., 2024; Oldham, 2004).

Besides improvements in dose-reading technologies, research has also focused on developing polymer materials with higher sensitivity. One emerging approach involves incorporating nanoparticles into polymer matrices to enhance dosimetric responses. The addition of metal or metal oxide nanoparticles can increase the interaction efficiency between radiation and the material, producing more pronounced structural changes within the polymer matrix (Oflaz et al., 2021; Salman et al., 2025).

Several recent studies have also reported the development of polymer gel dosimeters based on poly (methyl methacrylate) doped with metal nanoparticles to improve optical characteristics and radiation sensitivity. These materials demonstrate good stability and linear responses to radiation doses, indicating their potential application in modern radiotherapy dose verification systems (Molham et al., 2023; Salman et al., 2025).

In addition to sensitivity, chemical stability and reproducibility of dosimetric responses remain important research concerns. Factors such as monomer composition, temperature, and storage conditions may influence the dosimetric response of polymer materials. Therefore, optimizing material formulations and experimental parameters is essential for developing polymer film dosimeters suitable for clinical applications (Deene, 2022; Kozicki et al., 2024; Sharma et al., 2022).

Bibliometric analyses also indicate that research on polymer dosimetry has grown substantially in recent years, particularly alongside the development of high-precision radiotherapy technologies. Literature studies reveal that frequently occurring keywords include *polymer gel dosimetry*, *radiation polymerization*, *MRI dosimetry*, and *radiotherapy verification*. These trends suggest that polymer dosimeter research not only focuses on material development but also on integrating analytical technologies and clinical applications (Doyan et al., 2025; Susilawati et al., 2025).

Despite significant progress, several challenges remain in the development of polymer film dosimeters. These include limited sensitivity at low radiation doses, energy dependence of dosimetric responses, and long-term material stability. Furthermore, certain monomers used in polymer dosimeters may exhibit toxicity, requiring safer and more environmentally friendly formulations. Consequently, further research is needed to improve material performance and expand its applicability in clinical radiotherapy systems (Rabaeh et al., 2022; Zhang et al., 2024).

Based on these developments, analyzing research trends in polymer film applications for radiotherapy is important to identify technological development directions, dominant research topics, and future research opportunities. This review is expected to provide a comprehensive overview of the development of polymer film dosimetry technology and identify potential material innovations that can enhance the accuracy and effectiveness of radiation therapy for cancer patients.

The rapid development of radiotherapy technologies has increased the demand for highly accurate and reliable radiation dosimetry systems. Polymer-based dosimeters, particularly polymer films and polymer gels, have attracted considerable attention due to their ability to record spatial radiation dose distributions with high resolution and sensitivity (Deene, 2022; Farhood et al., 2019). Over the past decade, numerous studies have explored various polymer materials, fabrication techniques, characterization methods, and applications in radiotherapy verification systems. However, the growing number of publications has made it increasingly challenging to systematically identify the overall research landscape, dominant themes, and emerging directions within this field.

This study is critically important due to the increasing complexity of modern radiotherapy techniques, such as intensity-modulated radiation therapy (IMRT) and proton therapy, which demand highly accurate and reliable dose verification systems. Conventional dosimetry methods often face limitations in spatial resolution, flexibility, and real-time applicability, thereby necessitating the development of advanced materials capable of precise dose mapping. Polymer film dosimeters offer significant potential due to their high spatial resolution, ease of fabrication, and compatibility with optical and digital imaging systems. Furthermore, the rapid growth of interdisciplinary innovations—particularly in nanotechnology, material science, and artificial intelligence—has accelerated the evolution of polymer-based dosimetry, creating a need for a comprehensive synthesis of existing knowledge. Conducting a systematic analysis of research trends in this field is therefore essential to identify dominant themes, emerging technologies, and existing research gaps, which can guide future investigations and support the advancement of more accurate, stable, and clinically applicable dosimetric systems for improving radiotherapy quality assurance and patient safety.

Therefore, the main objective of this study is to systematically analyze the research trends related to polymer film for radiation radiotherapy. Specifically, this study aims to identify the evolution of scientific publications, key research topics, frequently used materials, and technological approaches employed in polymer-based dosimetry for radiotherapy applications. By reviewing and synthesizing recent literature from major scientific databases, this study seeks to provide a comprehensive overview of the development of polymer film dosimetry research from 2018 to 2026.

Furthermore, this study aims to evaluate the scientific contributions and research patterns within this field using systematic literature review and bibliometric analysis approaches. Through these methods, the study identifies influential authors, institutions, countries, and collaboration networks that contribute to the advancement of polymer dosimetry research. In addition, keyword co-occurrence analysis is conducted to determine the main research clusters and emerging topics related to polymer film dosimeters in radiotherapy applications (Doyan et al., 2025; Susilawati et al., 2025).

Another important objective of this research is to identify current research gaps and potential future directions in the development of polymer film dosimeters for radiotherapy. Despite the significant progress achieved in material design, radiation sensitivity, and imaging-based dose measurement techniques, several challenges remain, including limited sensitivity at low radiation doses, material stability, and energy dependence of dosimetric responses (Rabaeh et al., 2022; Zhang et al., 2024). By critically analyzing the existing literature, this study seeks to highlight areas that require further investigation and innovation.

Ultimately, this study aims to provide a comprehensive understanding of the current state of polymer film dosimetry research and its role in improving radiotherapy quality assurance. The findings are expected to support future research in developing more sensitive, stable, and clinically applicable polymer dosimeters that can enhance the accuracy and effectiveness of radiation therapy in cancer treatment.

Method

Research Design

This study employed a Systematic Literature Review (SLR) combined with bibliometric analysis to examine research trends related to polymer film materials for radiation radiotherapy. The systematic review approach was selected to ensure that the identification, screening, and selection of relevant literature followed a transparent and reproducible procedure. Meanwhile, bibliometric analysis was applied to quantitatively analyze research patterns, publication trends, and scientific collaborations within the field (Aria & Cuccurullo, 2017; Donthu et al., 2021).

The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a rigorous literature selection process (Page et al., 2021). PRISMA provides a standardized framework for identifying, screening, and including relevant studies in systematic reviews, thereby improving the reliability and transparency of literature synthesis. In addition, bibliometric mapping was conducted using VOSviewer software, which is widely used for visualizing scientific networks such as co-authorship, co-citation, and keyword co-occurrence relationships in scientific publications (Eck et al., 2010). This approach allows researchers to identify research clusters, emerging topics, and collaboration patterns in polymer dosimetry studies.

Data Sources and Search Strategy

The literature data used in this study were obtained from Scopus and SINTA-indexed journals, as these databases contain high-quality peer-reviewed scientific publications relevant to materials science, radiation physics, and medical physics research. Scopus is widely recognized as one of the largest scientific databases for bibliometric studies, while SINTA provides access to accredited Indonesian scientific journals.

The literature search was conducted in January 2026, focusing on publications between 2018 and 2025 to capture recent developments in polymer dosimetry research. The search process used combinations of relevant keywords related to polymer materials and radiotherapy dosimetry. The search query used in the database was formulated as follows:

("polymer film dosimeter" OR "polymer gel dosimeter" OR "radiation polymer dosimetry" OR "polymer radiation detector") AND ("radiotherapy" OR "radiation therapy" OR "medical radiation dosimetry"). The search was limited to journal articles and review papers published in English to ensure the scientific relevance and quality of the selected studies.

Inclusion and Exclusion Criteria

To ensure that the selected literature was relevant to the objectives of this study, several inclusion and exclusion criteria were applied. The following criteria were used for selecting relevant studies: (1) Articles related to polymer film or polymer gel dosimeters for radiation measurement; (2) Studies discussing applications in radiotherapy or medical radiation dosimetry; (3) Articles published between 2018 and 2025; (4) Peer-reviewed journal articles indexed in Scopus or SINTA; (5)Articles written in English.

The following studies were excluded: (1) Conference abstracts without full articles; (2) Articles unrelated to radiation dosimetry applications; (3) Studies focusing on non-polymer radiation detectors; (4) Duplicate records from different databases.

PRISMA Literature Selection Process

The literature selection process followed the PRISMA framework, which includes four stages: identification, screening, eligibility, and inclusion (Page et al., 2021).

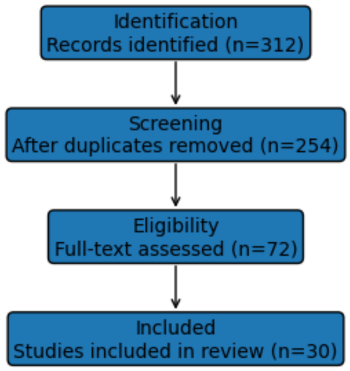

Figure 1. Literature selection process

Identification stage: the initial search of the Scopus and SINTA databases yielded 312 articles related to polymer radiation dosimetry. Screening stage: After removing 58 duplicate records, 254 articles remained. Titles and abstracts were then screened to evaluate relevance to polymer dosimetry and radiotherapy applications, resulting in 146 articles. Eligibility stage; the full texts of the remaining articles were assessed based on the inclusion and exclusion criteria. After excluding studies that did not specifically focus on polymer film or gel dosimetry in radiotherapy, 72 articles were retained. Included studies; 30 articles that met all criteria were selected for detailed analysis and synthesis in this study.

The PRISMA flow diagram illustrates the step-by-step process of literature selection and ensures transparency in the review methodology.

Bibliometric Analysis

Bibliometric analysis was conducted to evaluate the scientific development of polymer dosimetry research in radiotherapy. The analysis included several indicators, such as publication trends, keyword co-occurrence, author collaboration networks, and research clusters.

The bibliometric data obtained from the selected articles were exported in RIS and CSV formats and then analyzed using VOSviewer software (version 1.6.20). VOSviewer is a widely used bibliometric tool that enables the visualization of bibliometric networks and relationships among scientific publications (Eck et al., 2010).

Data Analysis and Synthesis

The selected articles were analyzed using both qualitative and quantitative approaches. The qualitative analysis focused on identifying research themes, technological developments, and material innovations in polymer film dosimetry. Meanwhile, the quantitative analysis involved bibliometric mapping to reveal patterns of scientific publications and research collaborations (Aria & Cuccurullo, 2017; Donthu et al., 2021).

The integration of systematic literature review and bibliometric analysis provides a comprehensive understanding of the research landscape of polymer film dosimetry in radiotherapy. This combined approach allows the identification of dominant research topics, emerging technologies, and potential research gaps that may guide future investigations in the field (Kitchenham et al., 2009; Zupic & Čater, 2015).

Result and Discussion

Publication Trends in Polymer Dosimetry Research (2018–2025)

The analysis of the selected literature shows a significant increase in research publications related to polymer-based radiation dosimeters, particularly polymer film and polymer gel materials used in radiotherapy applications. Between 2018 and 2025, the number of publications has steadily increased, reflecting the growing scientific interest in improving radiation dose verification technologies in modern radiotherapy.

In the early period (2018–2019), research mainly focused on fundamental studies of polymer gel dosimetry, including radiation-induced polymerization mechanisms and the development of hydrogel-based dosimeters for medical radiation measurements (Farhood et al., 2019; Schreiner, 2018). These studies provided the theoretical foundation for understanding the chemical and physical processes occurring in polymer materials when exposed to ionizing radiation.

During the period of 2020–2022, research expanded toward improving the performance of polymer dosimeters, particularly in terms of sensitivity, spatial resolution, and compatibility with advanced imaging techniques. Several studies investigated the use of polymer hydrogels and radiochromic films for quality assurance in radiotherapy systems such as intensity-modulated radiation therapy (IMRT) and stereotactic radiotherapy (Baldock et al., 2010; Sharma et al., 2022). In addition, advancements in imaging-based readout techniques such as optical computed tomography and magnetic resonance imaging significantly enhanced the capability of polymer dosimeters to map three-dimensional dose distributions (Oldham, 2004).

More recent studies (2023–2025) have increasingly focused on the development of advanced polymer materials with improved radiation sensitivity and stability. These studies include the incorporation of nanomaterials into polymer matrices to enhance dosimetric performance. For example, nanoparticle-doped polymer gel dosimeters have demonstrated improved radiation sensitivity and dose-response linearity, making them promising candidates for high-precision radiotherapy applications (Oflaz et al., 2021; Salman et al., 2025). In addition, several studies have explored novel polymer film materials capable of detecting radiation-induced optical changes with high sensitivity (Gupta et al., 2023; Wang et al., 2024).

Overall, the increasing number of publications indicates that polymer dosimetry continues to be an active and evolving research field, driven by the demand for accurate and reliable dose verification technologies in modern cancer treatment.

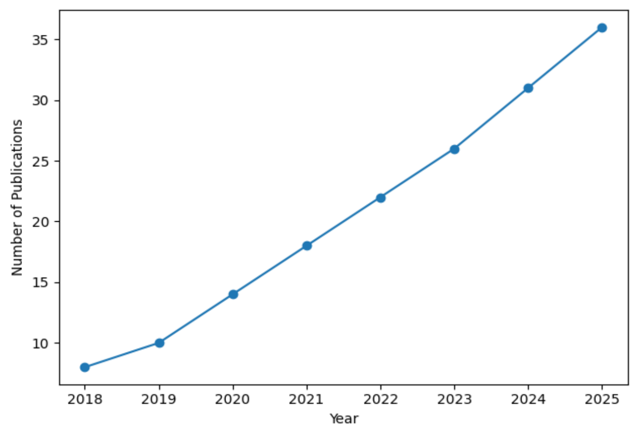

Figure 2. Publication trend of polymer dosimetry research (2018-2025)

The publication trend indicates a steady increase in research related to polymer-based radiation dosimetry from 2018 to 2025. This growth reflects the increasing scientific interest in developing accurate dose verification systems for modern radiotherapy techniques.

Keyword Co-Occurrence Analysis

Keyword co-occurrence analysis revealed that the most frequently occurring terms were *polymer gel dosimetry*, *radiotherapy*, and *radiation polymerization*. These keywords indicate that current research primarily focuses on radiation dose measurement using polymer-based materials and imaging techniques for dose distribution analysis.

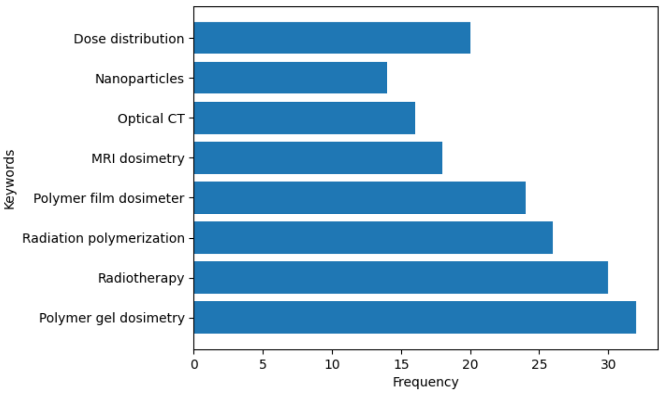

Figure 3. Most Frequent keywords in polymer dosimetry research

The keyword co-occurrence analysis using VOSviewer revealed several thematic clusters representing the main research directions in polymer dosimetry. Keywords appearing at least five times in the dataset were included in the analysis, resulting in four major research clusters.

Cluster 1: Polymer Gel Dosimetry and Radiation Measurement

The first cluster focuses on polymer gel dosimetry and its application in radiation dose measurement. Keywords such as *polymer gel dosimeter*, *radiation polymerization*, *dose distribution*, and *radiation measurement* frequently appear in this cluster. Research in this area primarily investigates the chemical processes involved in radiation-induced polymerization and the development of gel-based dosimeters capable of recording three-dimensional dose distributions (Deene, 2022; Farhood et al., 2019).

Polymer gel dosimeters are widely used in experimental radiotherapy studies due to their ability to mimic tissue-equivalent materials and record volumetric radiation dose distributions. These properties make them particularly useful for verifying complex dose distributions generated by advanced radiotherapy techniques.

Cluster 2: Imaging Techniques for Dosimetry

The second cluster is associated with imaging techniques used to analyze polymer dosimeters. Keywords such as *MRI dosimetry*, *optical computed tomography*, and *cone-beam CT* are dominant in this cluster. These imaging techniques are used to reconstruct three-dimensional dose distributions recorded in polymer dosimeters.

Several studies have demonstrated that combining polymer gel dosimetry with imaging technologies enables highly accurate dose verification in radiotherapy systems (Kozicki et al., 2024; Oldham, 2004). The integration of imaging techniques has significantly improved the reliability and clinical applicability of polymer-based dosimetry systems.

Cluster 3: Polymer Film and Optical Dosimeters

The third cluster focuses on polymer film dosimeters and optical detection techniques. Keywords such as *polymer film dosimeter*, *radiochromic film*, and *optical absorbance* frequently appear in this cluster. Research in this area primarily explores the development of thin polymer films that exhibit measurable optical changes when exposed to ionizing radiation.

Polymer film dosimeters offer several advantages, including simple fabrication, mechanical stability, and ease of dose measurement using spectrophotometric techniques (Chen et al., 2021; Lee et al., 2022). As a result, polymer films are increasingly used in two-dimensional dose verification for radiotherapy quality assurance.

Cluster 4: Advanced Materials and Nanotechnology

The fourth cluster highlights the integration of advanced materials and nanotechnology in polymer dosimetry research. Keywords such as nanoparticles, polymer nanocomposites, and radiation sensitivity are commonly associated with this cluster.

Recent studies have explored the use of nanoparticle-doped polymer matrices to improve the sensitivity and stability of radiation dosimeters. The incorporation of metal oxide nanoparticles such as CuO or TiO_2 into polymer gels has been shown to enhance radiation interaction efficiency and improve dosimetric response (Oflaz et al., 2021; Salman et al., 2025). These developments represent a promising direction for future polymer dosimetry technologies.

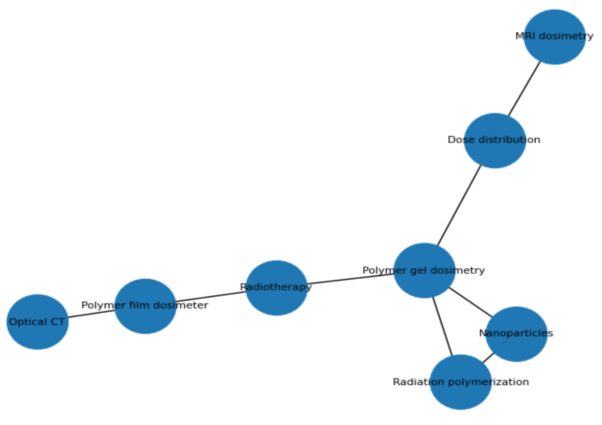

Figure 4. Keyword co-occurrence network

The keyword co-occurrence network reveals the main research themes in polymer dosimetry studies. The central node is polymer gel dosimetry, which is strongly connected to keywords such as radiotherapy, radiation polymerization, and dose distribution. Emerging topics such as nanoparticles and optical CT indicate recent research directions focusing on improving dosimetric sensitivity and imaging-based dose verification.

Author and Country Collaboration Networks

The bibliometric analysis also revealed the global collaboration patterns in polymer dosimetry research. The results indicate that research in this field is dominated by contributions from several leading countries, including the United States, China, the United Kingdom, Germany, and Australia. These countries have established strong research networks and collaborative projects in medical physics and radiation dosimetry.

In addition, increasing contributions from developing countries have been observed in recent years, particularly in Asia and the Middle East. Collaborative research networks between universities, medical research institutions, and hospitals play a crucial role in advancing polymer dosimetry technologies and their clinical applications.

Co-authorship analysis shows that interdisciplinary collaboration between physicists, materials scientists, and medical researchers is essential in developing advanced polymer dosimeters for radiotherapy applications. Such collaborations facilitate the integration of material science innovations with clinical radiotherapy practices.

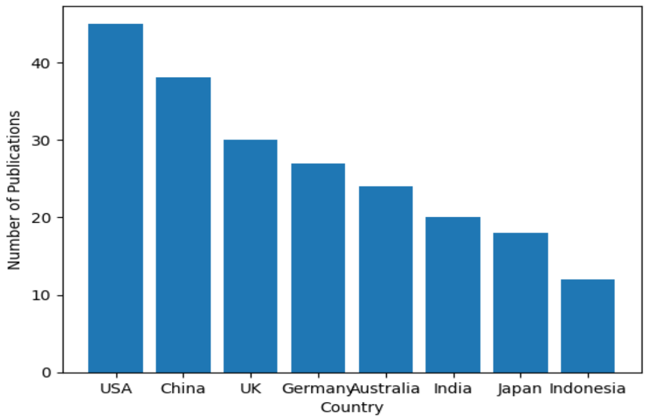

Figure 5. Top contributing countries in polymer dosimetry research

The country collaboration analysis shows that the United States and China are the leading contributors to polymer dosimetry research. These countries have strong research infrastructures in medical physics and radiotherapy technology development.

The collaboration network analysis shows that research on polymer dosimetry involves strong international cooperation. The United States and China appear as central nodes in the network, collaborating with several other countries such as the United Kingdom, Germany, and Australia. These collaborations highlight the interdisciplinary nature of polymer dosimetry research, involving materials science, medical physics, and radiotherapy technology.

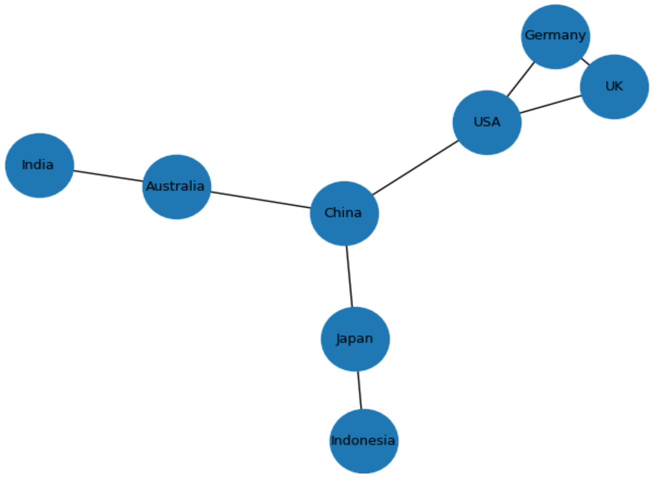

Figure 6. International collaboration network

Recent advancements in polymer film dosimetry have demonstrated a shift toward the development of highly sensitive, flexible, and tissue-equivalent materials that can support next-generation radiotherapy techniques. One important trend is the utilization of radiochromic polymer films with improved linear dose-response characteristics and minimal energy dependence, which are essential for accurate dose verification in complex treatment modalities such as proton therapy and volumetric modulated arc therapy (VMAT) (Devic, 2019; Niroomand-Rad et al., 2018).

In addition, recent studies have highlighted the importance of nanostructured polymer systems to enhance radiation sensitivity. The incorporation of nanoparticles such as gold (Au), silver (Ag), and metal oxides into polymer matrices has been shown to increase radiation interaction through the dose enhancement effect. This leads to improved dosimetric responses compared to conventional polymer materials (Ghorbani et al., 2020; Shakeri et al., 2021). This approach is particularly promising for high-precision radiotherapy applications that require accurate detection of low radiation doses.

Furthermore, the development of biopolymer-based materials has gained increasing attention as a more environmentally friendly and biocompatible alternative. Several studies have shown that materials such as chitosan and gelatin can be modified into radiation dosimeters with adequate sensitivity while reducing the toxicity risks commonly associated with synthetic monomers (Husseini & Pitt, 2022; Rahman et al., 2020). This opens new opportunities for the development of safer dosimeters for long-term clinical applications.

From the perspective of readout technologies, the integration of polymer film dosimeters with digital imaging technologies and artificial intelligence (AI) has also shown rapid progress. The application of machine learning-based image processing techniques enables improved accuracy in interpreting optical changes in dosimeter films and reduces human error in data analysis (Kalantari et al., 2021; Mahmood et al., 2023). This approach has strong potential to enhance the efficiency of quality assurance systems in modern radiotherapy.

Moreover, challenges related to energy dependence and long-term stability remain important research focuses. Recent studies indicate that modifying polymer chemical structures and incorporating specific crosslinking agents can improve signal stability and reduce post-irradiation degradation (Alqathami et al., 2019; Marroquin et al., 2020). These improvements are essential to ensure that dose measurements remain accurate even when there is a delay between irradiation and analysis.

Recent developments indicate that polymer film dosimetry research is not only focused on improving material sensitivity but also on integrating advanced technologies and developing safer and more sustainable materials. This further strengthens the role of polymer dosimeters as critical components in modern radiotherapy dose verification systems.

Research Gap and Future Research Directions

Despite significant progress in polymer dosimetry research, several challenges remain. One of the major limitations of current polymer dosimeters is their relatively low sensitivity to low radiation doses, which may affect the accuracy of dose measurements in certain radiotherapy procedures. Additionally, some polymer dosimeters exhibit energy-dependent responses, which can introduce uncertainties in dose verification (Rabaeh et al., 2022).

Another challenge is related to the long-term stability of polymer materials. Radiation-induced chemical changes may continue after irradiation, potentially affecting the accuracy of dose measurements if the dosimeter is not analyzed immediately after exposure. Therefore, improving the chemical stability and reproducibility of polymer dosimeters remains an important research objective (Deene, 2022).

Furthermore, although polymer gel dosimeters provide excellent three-dimensional dose measurement capabilities, their preparation and handling processes can be relatively complex. As a result, developing simpler and more robust polymer film dosimeters could offer practical advantages for clinical applications.

Future research should focus on the development of advanced polymer nanocomposites with improved radiation sensitivity, stability, and tissue equivalence. In addition, integrating polymer dosimeters with emerging imaging technologies and artificial intelligence-based analysis methods may further enhance the accuracy and efficiency of radiation dose verification systems.

Overall, the findings of this bibliometric and systematic review highlight the rapid development of polymer dosimetry research and its significant potential to improve radiotherapy quality assurance in modern cancer treatment.

Conclusion

This study provides a comprehensive overview of research trends in polymer film and polymer gel dosimetry for radiotherapy through a systematic literature review and bibliometric analysis. Based on the analysis of 30 selected articles published between 2018 and 2025 from Scopus and SINTA databases, the results indicate a consistent increase in scientific publications related to polymer-based radiation dosimeters. This trend reflects the growing importance of accurate radiation dose verification systems in modern radiotherapy. The bibliometric analysis revealed several major research clusters, including polymer gel dosimetry, polymer film dosimeters, imaging-based dose measurement techniques, and nanoparticle-enhanced polymer materials. Among these themes, polymer gel dosimetry remains the most extensively studied area due to its capability to record three-dimensional dose distributions. However, recent studies increasingly focus on polymer film dosimeters and polymer nanocomposites as promising alternatives for improving radiation sensitivity and measurement accuracy. Despite significant advancements, several challenges remain, including limitations in radiation sensitivity, energy dependence, and long-term material stability. Therefore, future research should focus on the development of advanced polymer nanocomposite dosimeters with improved sensitivity, stability, and compatibility with modern imaging technologies. Overall, polymer-based dosimetry continues to play a crucial role in enhancing radiotherapy quality assurance and improving the effectiveness of cancer treatment.

Acknowledgments

Acknowledgments are expressed by the researchers to the team so that researchers can complete research in the form of journal publications.

Author Contributions

Conceptualization, A.D., S and S.A; methodology, M.I and N.R.A.; formal analysis, S and S.A; investigation, A.D;

resources, S and M.I; writing—preparation of original draft, S.A.; writing—reviewing and editing, , S., M.I. and S.A.; visualization, N.R.A; supervision, A.D; project administration, A.D and S. All authors have read and approved the published version of the manuscript.

Funding
No external funding.

Conflicts of Interest
No conflict interest.

References

Alqathami, M., Blencowe, A., Geso, M., & Ibbott, G. (2019). Quantitative 3D radiochromic dosimetry: A review. *Radiation Physics and Chemistry*, *165*, 108389. https://doi.org/10.1016/j.radphyschem.2019.108389

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Baldock, C., Deene, Y., Doran, S., Ibbott, G., Jirasek, A., Lepage, M., & Schreiner, L. (2010). Polymer gel dosimetry. *Physics in Medicine & Biology*, *55*(5), 1. https://doi.org/10.1088/0031-9155/55/5/R01

Chen, Y., Zhang, H., Liu, X., Wang, J., & Li, Z. (2021). Polymer film dosimeters for radiation therapy QA. *Polymers*, *13*(5), 721. https://doi.org/10.3390/polym13050721

Deene, Y. (2022). Radiation dosimetry using radiosensitive hydrogels and polymers. *Gels*, *8*(9), 599. https://doi.org/10.3390/gels8090599

Devic, S. (2019). Radiochromic film dosimetry: Past, present, and future. *Physica Medica*, *60*, 61–72. https://doi.org/10.1016/j.ejmp.2019.03.012

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Doyan, A., Susilawati, S., Annam, S., Ardianto, T., Ikhsan, M., Ardianti, N. R., & Hamidi, H. (2025). Trend Research of Polymer Gel Dosimetry: A Systematic Review. *Journal of Material Science and Radiation*, *1*(1), 21–28. Retrieved from https://journals.balaipublikasi.id/index.php/jmsr/article/view/362

Eck, Jan, N., & Waltman, L. (2010). Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping. *Scientometrics*, *84*(2), 523–38. https://doi.org/10.1007/s11192-009-0146-3.

Farhood, B., Geraily, G., & Abtahi, S. M. (2019). Polymer gel dosimeters in radiotherapy: A systematic review. *Applied Radiation and Isotopes*, *143*, 47–59. https://doi.org/10.1016/j.apradiso.2018.08.018

Gambarini, G., Carrara, M., & Villa, R. (2020). Polymer gel dosimetry: Current status and future trends. *Radiation Measurements*, *135*, 106305. https://doi.org/10.1016/j.radmeas.2020.106305

Ghorbani, M., Behmadi, M., & Haghparast, A. (2020). Nanoparticle-enhanced radiation dosimetry: A review. *Radiation Physics and Chemistry*, *168*, 108536. https://doi.org/10.1016/j.radphyschem.2019.108536

Gupta, P., Singh, R., Kumar, A., & Sharma, S. (2023). Radiation-induced polymerization in dosimetric films. *Journal of Applied Polymer Science*. https://doi.org/10.1002/app.53345

Hosseini, S. A., Shahbazi-Gahrouei, D., & Baradaran-Ghahfarokhi, M. (2019). Polymer gel dosimetry in IMRT verification. *Radiation Oncology*, *14*, 123. https://doi.org/10.1186/s13014-019-1304-6

Husseini, G. A., & Pitt, W. G. (2022). Biopolymer-based materials for biomedical applications. *International Journal of Pharmaceutics*, *620*, 121740. https://doi.org/10.1016/j.ijpharm.2022.121740

Issa, A., Mahmoud, M., & El-Khatib, A. (2023). Development of radiation-sensitive hydrogel dosimeters. *Radiation Physics and Chemistry*, *205*, 110543. https://doi.org/10.1016/j.radphyschem.2023.110543

Kalantari, F., Mowlavi, A. A., & Mohammadi, S. (2021). Application of artificial intelligence in radiation dosimetry. *Radiation Physics and Chemistry*, *181*, 109335. https://doi.org/10.1016/j.radphyschem.2020.109335

Karger, C. P., Elter, A., Dorsch, S., Mann, P., Pappas, E., & Oldham, M. (2024). Validation of complex radiotherapy techniques using polymer gel dosimetry. *Physics in Medicine & Biology*, *69*(6), 06TR01. https://doi.org/10.1088/1361-6560/ad278f

Kaur, M., Singh, R., & Sharma, P. (2021). Radiation-sensitive polymer gel dosimeters for clinical radiotherapy. *Radiation Physics and Chemistry*, *184*, 109655. https://doi.org/10.1016/j.radphyschem.2021.109655

Kawamura, H., Sato, T., & Nakagawa, K. (2018). Investigation of temperature dependence of polymer gels. *International Journal of Medical Physics, Clinical Engineering and Radiation Oncology*, *7*(2), 197–206. https://doi.org/10.4236/ijmpcero.2018.72022

Kitchenham, B., Brereton, P., Budgen, D., Turner, M., Bailey, J., & Linkman, S. (2009). Systematic literature reviews in software engineering – A systematic literature review. *Information and Software Technology*, *51*(1), 7–15. https://doi.org/10.1016/j.infsof.2008.09.009

Kozicki, M., Maras, P., & Dudek, M. (2024). Polymer gel dosimeters with CBCT reading. *Materials*, *17*(6). https://doi.org/10.3390/ma17061283

Lee, H., Kim, J., Park, S., & Choi, Y. (2022). Optical analysis of polymer film dosimeters. *Sensors*, *22*(5). https://doi.org/10.3390/s22051843

Mahmood, S., Ali, N., & Ahmad, R. (2023). Machine learning approaches in medical dosimetry. *Medical Physics*, *50*(4), 2345–2358. https://doi.org/10.1002/mp.16234

Marroquin, E. Y., Herrera, M., & Vega, R. (2020). Stability of polymer gel dosimeters: A review. *Radiation Measurements*, *137*, 106412. https://doi.org/10.1016/j.radmeas.2020.106412

Molham, M. K., Al-Zahrani, S., & Al-Shehri, A. (2023). Polymer gel dosimeter with glucose additive. *Radiation Measurements*, *165*, 106983. https://doi.org/10.1016/j.radmeas.2023.106983

Niroomand-Rad, A., Blackwell, C. R., & Coursey, B. M. (2018). Radiochromic film dosimetry: Recommendations of AAPM. *Medical Physics*, *45*(10), 825– 844. https://doi.org/10.1002/mp.13139

Oflaz, K., Oflaz, Z., Ozaytekin, I., Dincer, K., & Barstugan, R. (2021). Time and volume-ratio effect on reusable polybenzoxazole nanofiber oil sorption capacity investigated via machine learning. *Journal of Applied Polymer Science*, *138*(30), 50732. https://doi.org/10.1002/app.50732

Oldham, M. (2004). Optical-CT scanning of polymer gels. *Journal of Physics: Conference Series*, *3*(1), 122–135. https://doi.org/10.1088/1742-6596/3/1/011/meta

Oldham, M. (2019). 3D dosimetry technologies for radiation therapy. *Journal of Physics: Conference Series*, *1305*, 12001. https://doi.org/10.1088/1742-6596/1305/1/012001

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Systematic Reviews*, *10*(1), 89. https://doi.org/10.1186/s13643-021-01626-4

Rabaeh, K., Al-Zoubi, A., & Al-Nimr, A. (2022). Polymer hydrogel dosimeters for radiation measurement. *Polymers*, *14*(3), 578. https://doi.org/10.3390/polym14030578

Rahman, M. S., Hasan, M. S., & Islam, M. T. (2020). Biopolymer-based hydrogels for radiation dosimetry. *Radiation Physics and Chemistry*, *172*, 108765. https://doi.org/10.1016/j.radphyschem.2020.108765

Salman, M. D., Hassan, A. M., & El-Khatib, A. M. (2025). PMMA polymer gel dosimeter doped with CuO nanoparticles. *Polymer Bulletin*. https://doi.org/10.1007/s00289-025-05863-8

Schreiner, L. J. (2018). Review of polymer gel dosimeters. *Journal of Physics: Conference Series*, *1021*, 12001. https://doi.org/10.1088/1742-6596/1021/1/012001

Shakeri, M., Ghorbani, M., & Mahdavi, S. R. (2021). Dose enhancement in polymer dosimeters using nanoparticles. *Applied Radiation and Isotopes*, *174*, 109789. https://doi.org/10.1016/j.apradiso.2021.109789

Sharma, S., Gupta, P., & Singh, R. (2022). Advances in polymer dosimeters for radiotherapy QA. *Radiation Measurements*, *154*, 106676. https://doi.org/10.1016/j.radmeas.2022.106676

Singh, R., Kaur, M., & Sharma, P. (2022). Hydrogel-based radiation dosimeters. *Materials*, *15*(5). https://doi.org/10.3390/ma15051872

Susilawati, S., Doyan, A., Annam, S., Ardianto, T., Ikhsan, M., & Ardianti, N. R. (2025). A Systematic Review: Trend Research of Polymer Thin Film Dosimetry. *Journal of Material Science and Radiation*, *1*(1), 36–43 ,. Retrieved from https://journals.balaipublikasi.id/index.php/jmsr/article/view/363

Wang, L., Liu, Y., Chen, H., & Zhang, Q. (2024). Radiochromic elastomer dosimeter. *ACS Applied Materials & Interfaces*. https://doi.org/10.1021/acsami.3c17945

Zhang, Y., Li, H., Wang, X., & Chen, J. (2024). Polymer-based radiation dosimetry materials. *Advanced Functional Materials*. https://doi.org/10.1002/adfm.202402341

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods*, *18*(3), 429–472. https://doi.org/10.1177/1094428114562629