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Trend Research of Polymer Gel Dosimetry: A Systematic Review

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Abstract: Polymer gel dosimeters are fabricated from radiation sensitive chemicals which, upon irradiation, polymerize as a function of the absorbed radiation dose. These dosimeters, which uniquely record the radiation dose distribution in three-dimensions (3D), have specific advantages when compared to one-dimensional dosimeters, such as ion chambers, and two-dimensional dosimeters, such as film. This research aims to identify and analyze research trends of Polymer gel dosimeters. This research method is descriptive and analytical. The data used in this research was obtained from documents indexed by Google Scholar from 2016-2025 using Publish or Perish and Dimension.ai. Research procedures use PRISMA guidelines. The data identified and analyzed are the type of publication, publication source, and the title of research Polymer gel dosimeters that is widely cited. The data analysis method uses bibliometric analysis assisted by VOS viewer software. The results of the analysis show that research trend indexed by Google Scholar from 2016 to 2025 has experienced ups and down. There are many documents in the form of articles, chapters, proceeding, and edited books that discuss research about Polymer gel dosimeters. Key words that are often used in research about it are Magnetic Resonance Imaging, MRI, Monte carlo simulation, Characterization, Fricke gel, Polymerization, etc.

Keywords: Dosimetry; Polymer gel; Radiation.

Introduction

Polymer gel dosimeters are fabricated from radiation sensitive chemicals which, upon irradiation, polymerize as a function of the absorbed radiation dose. These dosimeters, which uniquely record the radiation dose distribution in three-dimensions (3D), have specific advantages when compared to one-dimensional dosimeters, such as ion chambers, and two dimensional dosimeters, such as film. These advantages are particularly significant in dosimetry situations where steep dose gradients exist such as in intensity-modulated radiation therapy (IMRT) and stereotactic radiosurgery. Furthermore, polymer gel dosimeters have also specific advantages in brachy therapy dosimetry. Potential applications also exist in low-energy x-ray, high-linear energy transfer (LET) and proton therapy, radionuclide and boron capture neutron

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therapy dosimetries. These 3D dosimeters are radiologically soft-tissue equivalent with properties that may be modified depending on the application (Baldock et al., 2010; Farhood et al., 2019; McAuley, 2006). Polymer gel dosimetry is usually used in the field of radiotherapy.

The purpose of radiotherapy is to cover the tumor tissue homogeneously with an adequate dose while minimizing the dose to the surrounding normal tissue (Mann et al., 2016; Tanha et al., 2014). At present, applied techniques in radiation oncology can deliver a dose distribution with high conformity and precision to the treatment target volume (Novotny et al., 2001). It is noteworthy that any error or inaccuracy in dose delivery during irradiation in these modern techniques can result in either an insufficient dose to the tumor tissue or a high dose to the adjacent vital organs. Hence, the determination of the three-dimensional (3D) dose distribution in a tissue-equivalent material, before radiotherapy, can decrease any possible error (Abtahi et al., 2016). To verify the dose distributions resulting from modern radiotherapy techniques, a dosimeter is needed to accurately measure 3D dose distributions with high spatial resolution (Hilts et al., 2000). In clinical radiotherapy, the use of gel dosimeters can help in the high-resolution and precise verification of 3D dose distributions obtained by treatment planning facilities, while most current dosimeters measure the dose in one or two dimensions only (such as thermoluminescent dosimeters, ionization chamber–based dosimeters, and radiographic film–based dosimeters) (Senden et al., 2006). Polymer gel dosimeters are constructed from chemical materials that are sensitive to radiation and are polymerized as a function of the absorbed dose on irradiation (Abtahi et al., 2014). Radiation induces structural changes in the different polymer gel dosimeters that can affect their properties, such as variation in the proton nuclear magnetic resonance relaxation times, mass density, opacity, and elasticity (Senden et al., 2006). These characteristics can be read out by magnetic resonance imaging (MRI), x-ray computed tomography (CT), optical scanning, and ultrasonography. Gel dosimetry has advantageous properties that can simplify radiotherapy dosimetry, particularly in conditions in which conventional dosimeters cannot be used (Farhood et al., 2019). These characteristics consist of the capability of measuring complex 3D dose distributions; radiological tissue equivalence; radiation direction independency; high spatial resolution; integration of dose during a treatment; etc (Abtahi et al., 2014; Abtahi et al., 2016). In addition, gel dosimeters are relatively safe to fabricate and handle, although there are some toxic components, such as acrylamide, that must be applied with appropriate protection (Ibbott, 2004). The applications of gel dosimeters include basic dosimetry such as depth dose, penumbra, and wedge profiles in different types of beams; dose distributions from various imaging procedures; dose distribution from different radiotherapy techniques, such as conformal therapy, intensity-modulated radiotherapy (IMRT), and stereotactic radiosurgery; dose distributions around various brachytherapy sources; and assessment of tissue heterogeneities such as bone and air.

Therefore, this research wants to know the research trend of the Polymer gel dosimeters. It is hoped this research can become a reference in developing further research related to Polymer gel dosimeters.

Method

This research method is descriptive and analytical, which aims to understand and describe research trends in the Polymer gel dosimeters. The data used in this study was obtained from information sources indexed by Google Scholar using analytical tools such as Publish or Perish and Dimension.ai.

In this research, an analysis was carried out on 1,000 documents that had been indexed by Google Scholar between 2016 and 2025. The Google Scholar database was chosen as a place to search for documents because Google Scholar applies consistent standards in selecting documents to be included in its index, and Google Scholar displays more documents than the top databases. Others, especially research in the field of education (Hallinger & Chatpinyakoop, 2019; Hallinger & Nguyen, 2020; Zawacki-Richter et al., 2019). To filter data that has been collected via Publish or Perish, researchers used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Result and Discussion

This research aims to describe research trends on the Polymer gel dosimeters conducted from 2016 to 2025. Figure 1 shows that the trend in research on the Polymer gel dosimeters from 2016 to 2025 experiencing ups and downs.

The most publications occurred in 2022, namely 32 publications and continued to decline thereafter. This proves that research about Polymer gel dosimeters is starting to be rarely done. Below are also table 1 presented research of Polymer gel dosimeters based on the type of publication.

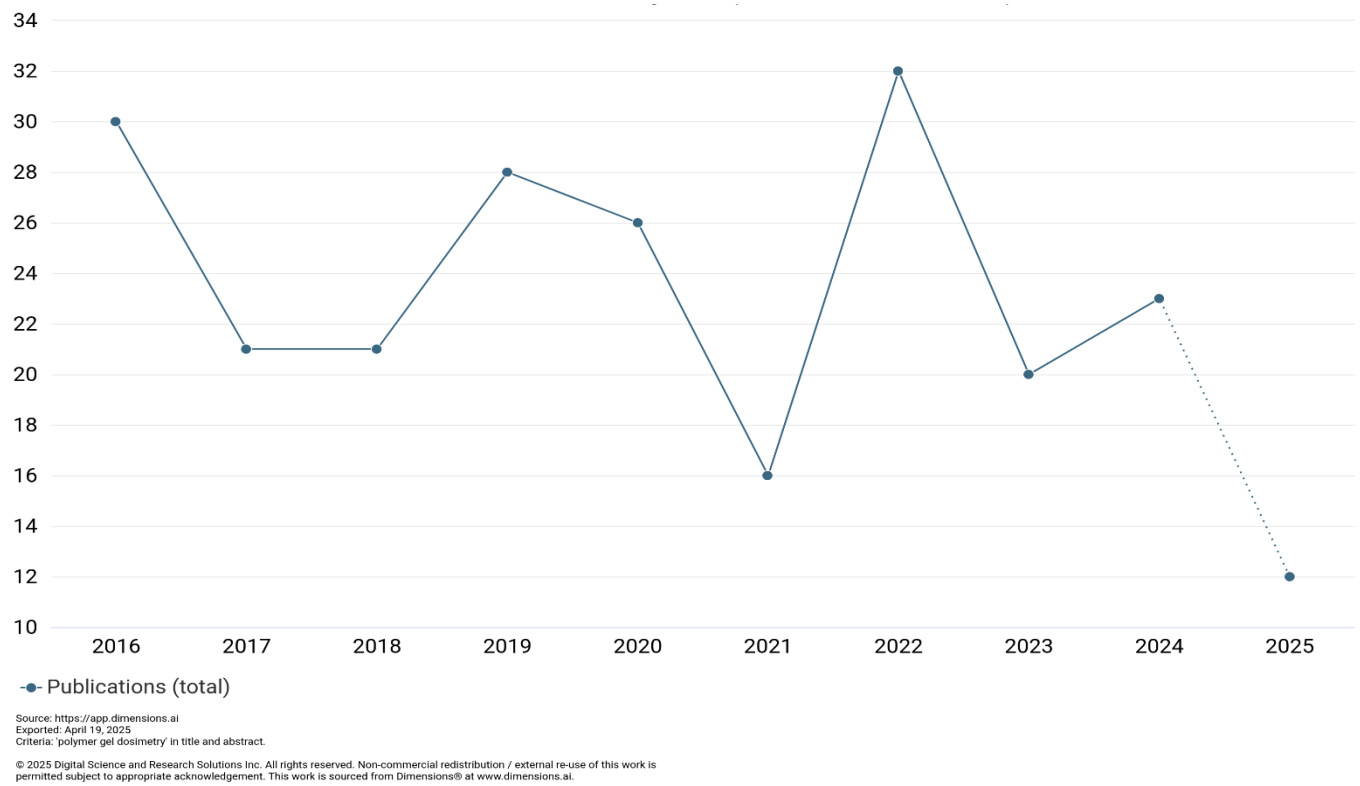

Figure 1. Research trends in Polymer gel dosimeters

Table 1. Trends in Polymer gel dosimeters Research Based on Publication Types

Publication Type	Publications
Article	675
Chapter	27
Proceeding	11
Edited Book	1

Based on Table 1, it is known that research Polymer gel dosimeters from 2065 to 2025 contained in 4 types of publications. In the form of articles there were 675 documents, edited books only 1 document, chapter as many as 27 documents and also 11 documents from proceeding. Research trends Polymer gel dosimeters in article form is the type of publication that contains the most research compared to other types of publications. Meanwhile, the type of publication contains the least amount of research results is a edited book. Research conducted by Oltarzhevskyi (2019) states that an article is a complete factual essay of a certain length created for publication in online or print media (via newspapers, magazines or bulletins) and aims to convey ideas and facts that can convince and educate. These articles are usually published in scientific journals both in print and online (Suseno & Fauziah, 2020).

Below are also table 2 presented top sources title trends in research on Polymer gel dosimeters which are often cited by other researchers related to this matter.

Table 2 shows that the most widely published source of research trends on the Polymer gel dosimeters is the Medical Physics, namely 133 publications with 2,440 citations and an average citation of 18.35. *Medical Physics* publishes original, high-impact research in physics, imaging science, radiation therapy and engineering in medicine that advances patient diagnostic information and therapeutic outcomes. The journal was established in 1974 and is currently published monthly. Below are also table 3 presented top article title trends in research on Polymer gel dosimeters which are often cited by other researchers related to this matter.

Table 3 shows that research on the Polymer gel dosimeters that is widely cited by other researchers is about "A systematic review of clinical applications of polymer gel dosimeters in radiotherapy" which is 17.33 (Farhood et al., 2019). Then the research entitled "Three-dimensional radiation dosimetry using polymer gel and solid radiochromic polymer: From basics to clinical applications" was cited 12.13 times (Watanabe et al., 2017). Research by Karger et al. (2024) entitled "Validation of complex radiotherapy techniques using

polymer gel dosimetry" is also widely cited by other researchers, namely 12.00 per year.

Table 2. Top Sources Title Trend of Polymer gel dosimeters Research in 2016-2025

Name	Publications	Citations	Citations Mean
Medical Physics	133	2,440	18.35
Journal of Physics Conference Series	119	830	6.97
Physics in Medicine and Biology	106	5,643	53.24
Radiotherapy and Oncology	22	244	11.09
Radiation Physics and Chemistry	22	254	11.55
Physics Medica	22	226	10.27
Applied Radiation and Isotopes	20	512	25.60
Journal of Applied Clinical Medical Physics	15	218	14.53

This research data is comparable to data on the increasing trend of research on the Polymer gel dosimeters from 2016 to 2025. This means that in that year, research related to it was continuously cited by other researchers. In the articles researched and written by these researchers, there are many terms/keywords related to Polymer gel dosimeters. Below are presented the most popular keywords related to Polymer gel dosimeters.

Table 3. Top Citations on Trend of Polymer gel dosimeters Research in 2016-2025

Cites/year	Year	Author	Title
17.33	2019	Bagher Farhood, Ghazale Geraily, Seyed Mohammad Mahdi Abtahi	A systematic review of clinical applications of polymer gel dosimeters in radiotherapy
12.13	2017	Y Watanabe, L Warmington, N Gopishankar	Three-dimensional radiation dosimetry using polymer gel and solid radiochromic polymer: From basics to clinical applications
12.00	2024	Christian P Karger, Alina Elter, Stefan Dorsch, Philipp Mann, Evangelos Pappas and Mark Oldham	Validation of complex radiotherapy techniques using polymer gel dosimetry
7.88	2017	Marek Kozicki, Malwina Jaszczak, Piotr Maras, Mariusz Dudek and Marian Cłapa	On the development of a VIPARnd radiotherapy 3D polymer gel dosimeter
4.38	2017	Evan Maynard, Michelle Hilts, Emily Heath, Andrew Jirasek	Evaluation of accuracy and precision in polymer gel dosimetry

Table 4 shows that the keywords that often appear related to research on the the Polymer gel dosimeters are magnetic resonance image, 11 times with a level of 3.98. Table 4 also shows that MRI is also one of the keyword that appears frequently in research trends on the Polymer gel dosimeters, namely 14 times with a relevance of 2.75.

Table 4. Keywords on Trend of Polymer gel dosimeters Research in 2016-2025

Terms	Occurrences	Relevance
Magnetic Resonance Imaging	11	3.98
MRI	14	2.75
Monte carlo simulation	14	1.81
Characterization	19	0.73
Fricke gel	7	1.02
Polymerization	22	1.37

Below are the visualization is accomplished by generating a landscape map, which offers a visual representation of subjects related to scientific studies. The outcomes of bibliometric mapping for the co-word network in articles related to the topic Polymer gel dosimeters are illustrated in Figure 2.

Figure 2 shows the results of bibliometric keyword mapping on research trends on the Polymer gel dosimeters. In Figure 2 there are 36 keyword items that are often used in research on the Polymer gel dosimeters from 2016 to 2025. Figure 2 also contains 5 clusters, where the first cluster is colored red and consists of 13 keyword items, namely application, dose distribution, monte carlo situation, etc. The second cluster in green consists of 7 keyword items, namely comparison, dosimeter, radiation, etc. The third cluster in blue consists of 6 keyword items, namely characterization, MRI, radiotherapy, etc. The fourth yellow cluster consists of 6 keyword items, namely development,

Fricke gel, sensitivity, etc. And the fifth cluster consists 4 items, namely dose response, radiation therapy, etc.

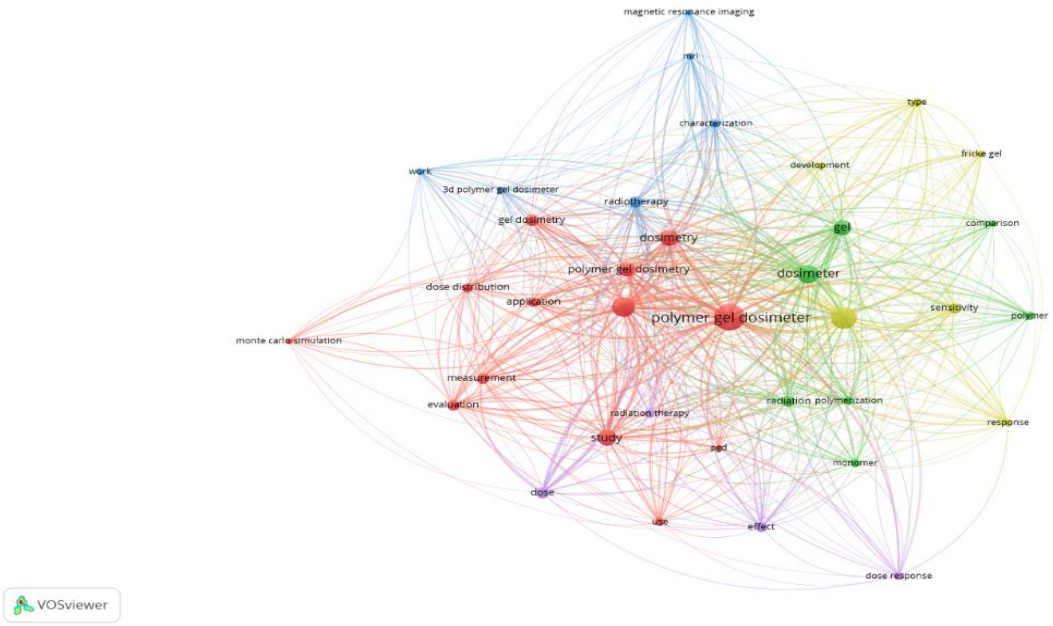

Figure 2. Network visualization on trend Polymer gel dosimeters research

Figure 2 above also shows that network visualization shows the network between the terms being visualized. Keywords classified into four clusters are arranged in a color chart showing the divisions/clusters that are connected to each other. The results of this analysis can be used to determine keyword research trends in the last year. This analysis shows several keywords that are often used in research on the Polymer gel dosimeters. The more keywords that appear, the wider the visualization displayed. Below are also presented keywords regarding the Polymer gel dosimeters based on overlay visualization.

Figure 3 shows the trend of keywords related to Polymer gel dosimeters in Google Scholar indexed journals from 2016 to 2025. Trends in the themes of writing articles related to Polymer gel dosimeter from the oldest to the newest year are marked with purple, blue themes, turquoise, dark green, light green and yellow. In the picture below you can see that magnetic resonance imaging, MRI, etc. This shows that these keywords were widely used by researchers in 2019. In 2020, the keywords that frequently appeared were Fricke gel, radiotherapy, dosimeter, etc.

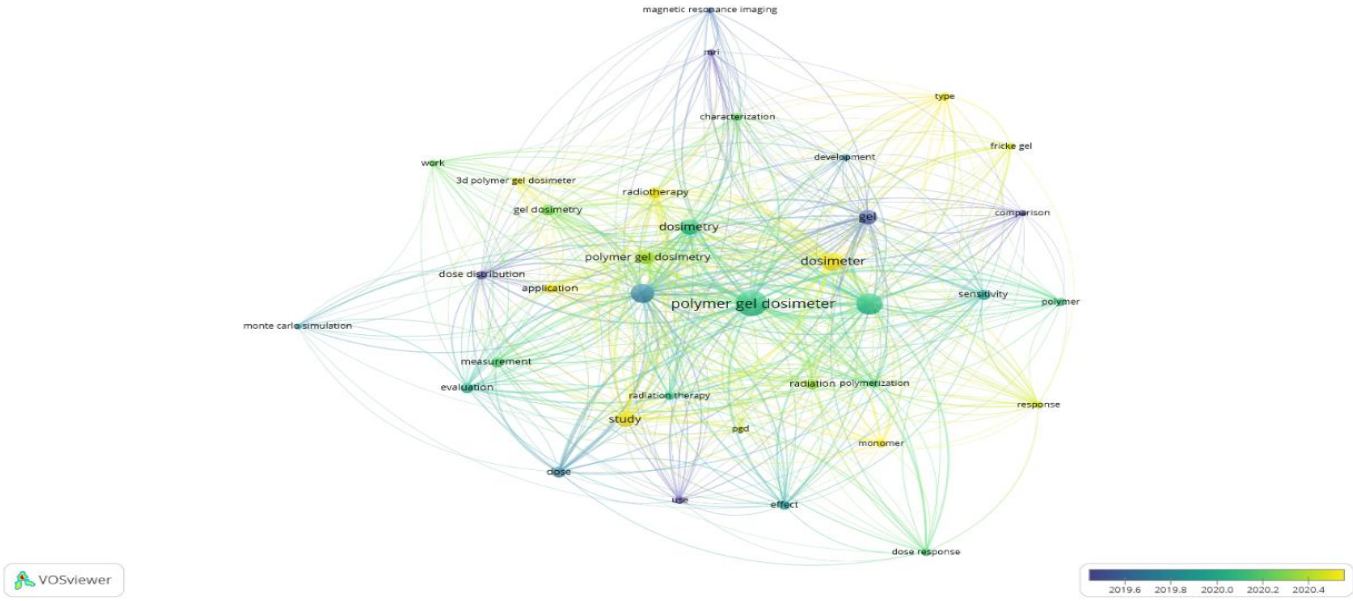

Figure 3. Overlay visualization on trend Polymer gel dosimeters research

Research on Polymer gel dosimeters is one area of research that has developed rapidly in recent years. The following also presents keywords for Polymer gel dosimeters research based on density visualization.

Figure 4 shows density visualization. The density of research themes is shown in bright yellow. The brighter the colors of a theme, the more research is done. The fainter the color means the theme is rarely researched (Kaur et al., 2022; Liao et al., 2018). Faintly colored themes such as monte carlo simulation, dose response, dose distribution are dimly colored keywords. This shows that these keywords can be used as a reference for further research. Doyan et al. (2023) and Bahtiar et al. (2023) stated that yellow indicates keywords that are currently and frequently used in research, like polymer gel, dosimetry, etc.

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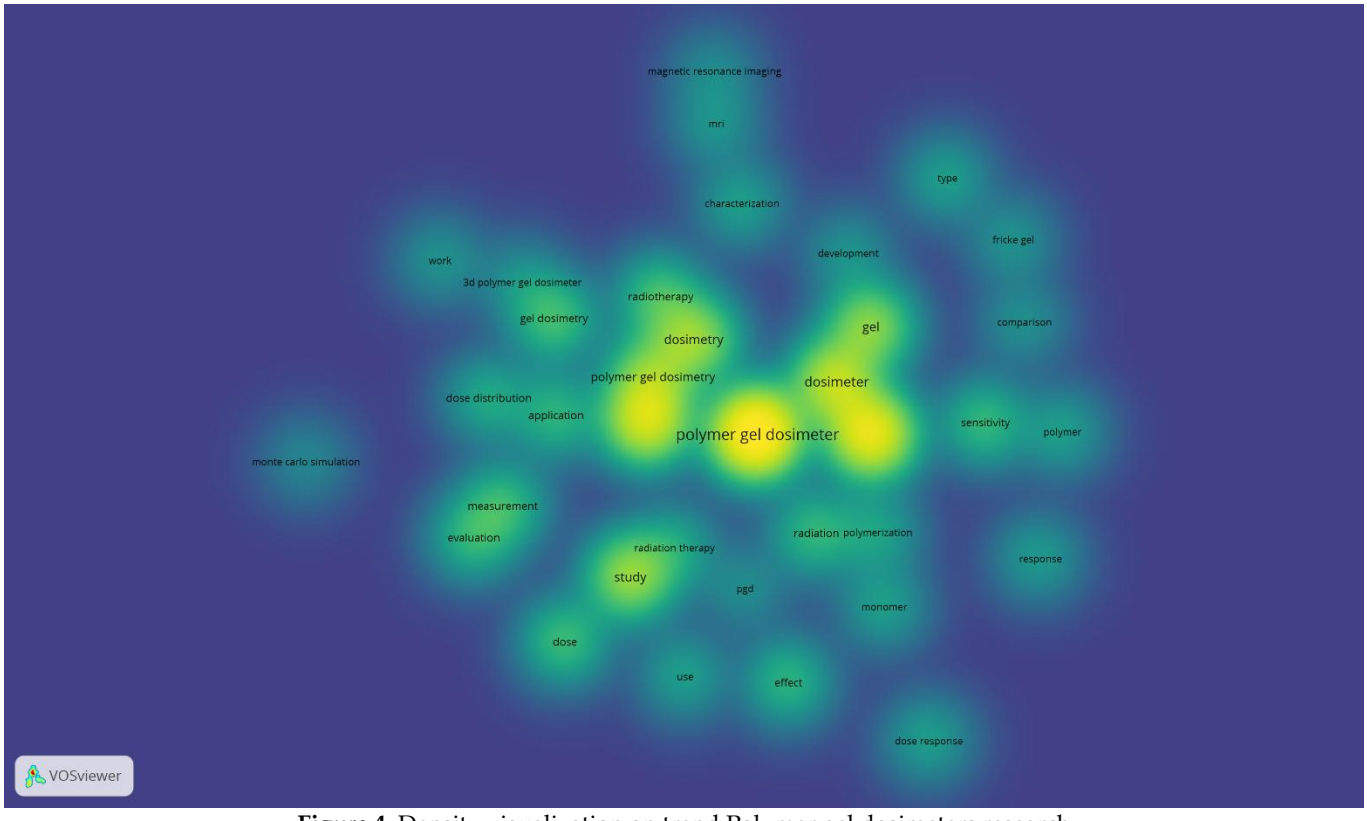

Figure 4. Density visualization on trend Polymer gel dosimeters research

Overall, the ultimate goal of polymer gel dosimetry is to verify radiation dose distributions in 3D. The major challenge in gel dosimetry is to achieve a spatial and dose accuracy and precision that satisfy the requirements for 3D dose verification of radiation treatments that are performed in the radiation hospital. As there exists no other experimental 3D dosimeter that can serve as a 'gold standard', a measure for both the spatial and dose accuracy is difficult to define. In addition, as a 3D dosimeter, gel dosimeters have to accomplish specific dosimetric requirements in terms of stability, spatial integrity, temperature insensitivity, dose rate and energy independence and tissue equivalence.

Research in the field of polymer gel dosimetry covers many different aspects. Several studies have been conducted on the chemistry of the polymer gel and different gel compositions have been proposed. A better understanding of the physical and chemical interactions within the polymer gel dosimeter can help in optimizing the composition to obtain a gel that fulfills the dosimetric criteria and achieves high dose sensitivity. Research in the field of gel dosimetry includes also the development and optimization of quantitative scan techniques. The most promising scan techniques are magnetic resonance imaging and x-ray and optical computerized tomography. For different scan techniques, different optimal gel dosimeters can be found. Optimal gel systems for magnetic resonance imaging display a significant change in NMR relaxation time or magnetization transfer. For x-ray CT, the dose sensitivity is determined by the density change.

Conclusion

Research on trends in the polymer gel dosimetry has urgency high because it is very useful in the health sector, especially radiotherapy. The research trend on the polymer gel dosimetry indexed by Google Scholar from 2016 to 2025 has experienced ups and downs. There are many documents in the form of articles, chapters, proceeding and edited books that discuss research into the polymer gel dosimetry. Key words that are often used in research about it are Magnetic Resonance Imaging, MRI, Monte carlo simulation, Characterization, Fricke gel, Polymerization, etc.

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References

Abtahi, S., Aghamiri, S., Khalafi, H., & Rahmani, F. (2014). An investigation into the potential applicability of gel dosimeters for dosimetry in boron neutron capture therapy. *Int. J. Radiat. Res*, *12*, 149. Retrieved from https://shorturl.asia/az8Rf

Abtahi, S. M., Aghamiri, S. M. R., & Khalafi, H. (2014). Optical and MRI investigations of an optimized acrylamide-based polymer gel dosimeter. *Journal of Radioanalytical and Nuclear Chemistry*, *300*, 287–301. https://doi.org/10.1007/s10967-014-2983-7

Abtahi, S. M., Zahmatkesh, M. H., & Khalafi, H. (2016). Investigation of an improved MAA-based polymer gel for thermal neutron dosimetry. *Journal of Radioanalytical and Nuclear Chemistry*, *307*, 855–868. https://doi.org/10.1007/s10967-015-4469-7

Bahtiar, B., Yusuf, Y., Doyan, A., & Ibrahim, I. (2023). Trend of Technology Pedagogical Content Knowledge (TPACK) Research in 2012-2022: Contribution to Science Learning of 21st Century. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 39–47. https://doi.org/10.29303/jppipa.v9i5.3685

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

Doyan, A., Susilawati, Purwoko, A. A., Ibrahim, Ahzan, S., Gummah, S., Bahtiar, & Ikhsan, M. (2023). Trend Synthesis Thin Film Research as Electronic Device (A Review). *Jurnal Penelitian Pendidikan IPA*, *9*(11), 1155–1164. https://doi.org/10.29303/jppipa.v9i11.5764

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

Hallinger, P., & Chatpinyakoop, C. (2019). A Bibliometric Review of Research on Higher Education for Sustainable Development, 1998–2018. *Sustainability*, *11*(8), 2401. https://doi.org/10.3390/su11082401

Hallinger, P., & Nguyen, V.-T. (2020). Mapping the Landscape and Structure of Research on Education for Sustainable Development: A Bibliometric

Review. *Sustainability*, *12*(5), 1947. https://doi.org/10.3390/su12051947

Hilts, M., Audet, C., Duzenli, C., & Jirasek, A. (2000). Polymer gel dosimetry using x-ray computed tomography: a feasibilitystudy4. *Physics in Medicine & Biology*, *45*(9), 2559. https://doi.org/10.1088/0031-9155/45/9/309

Ibbott, G. S. (2004). Applications of gel dosimetry. *Journal of Physics*, *3*(1), 58. https://doi.org/10.1088/1742-6596/3/1/007

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, S., Kumar, R., Kaur, R., Singh, S., Rani, S., & Kaur, A. (2022). Piezoelectric materials in sensors: Bibliometric and visualization analysis. *Materials Today: Proceedings*, *65*, 3780–3786. https://doi.org/10.1016/j.matpr.2022.06.484

Liao, H., Tang, M., Luo, L., Li, C., Chiclana, F., & Zeng, X.-J. (2018). A Bibliometric Analysis and Visualization of Medical Big Data Research. *Sustainability*, *10*(2), 166. https://doi.org/10.3390/su10010166

Mann, P., Witte, M., Moser, T., Lang, C., Runz, A., Johnen, W., & Karger, C. P. (2016). 3D dosimetric validation of motion compensation concepts in radiotherapy using an anthropomorphic dynamic lung phantom. *Physics in Medicine & Biology*, *62*(2), 573. https://doi.org/10.1088/1361-6560/aa51b1

McAuley, K. B. (2006). Fundamentals of polymer gel dosimeters. *Journal of Physics: Conference Series*, *56*(1), 35. https://doi.org/10.1088/1742-6596/56/1/004

Novotny, J., Spevacek, V., Dvorak, P., Novotny, J., & Cechak, T. (2001). Energy and dose rate dependence of BANG-2 polymer-gel dosimeter. *Medical Physics*, *28*(11), 2379–2386. https://doi.org/10.1118/1.1414307

Oltarzhevskyi, D. O. (2019). Typology of contemporary corporate communication channels. *Corporate Communications: An International Journal*, *24*(4), 608–622. https://doi.org/10.1108/CCIJ-04-2019-0046

Senden, R. J., Jean, P., McAuley, K. B., & Schreiner, L. J. (2006). Polymer gel dosimeters with reduced toxicity: a preliminary investigation of the NMR and optical dose–response using different monomers. *Physics in Medicine & Biology*, *51*(14), 3301–3314. https://doi.org/10.1088/0031-9155/51/14/001

Suseno, B. A., & Fauziah, E. (2020). Improving Penginyongan Literacy in Digital Era Through E-Paper Magazine of Ancas Banyumasan. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3807680

Tanha, K., Mahdavi, S. R., & Geraily, G. (2014). Comparison of CCC and ETAR dose calculation algorithms in pituitary adenoma radiation treatment planning; Monte Carlo evaluation. *Journal of Radiotherapy in Practice*, *13*(4), 447–455. https://doi.org/10.1017/S1460396914000211

Watanabe, Y., Warmington, L., & Gopishankar, N. (2017). Three-dimensional radiation dosimetry using polymer gel and solid radiochromic polymer: From basics to clinical applications. *World Journal of Radiology*, *9*(3), 112. https://doi.org/10.4329/wjr.v9.i3.112

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, *16*(1), 39. https://doi.org/10.1186/s41239-019-0171-0