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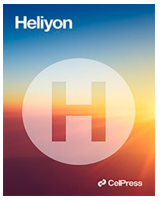

Research article

Assessing the visibility and public engagement of bone marrow and stem cell transplantation research: An altmetric analysis

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ABSTRACT

Background: Bone marrow and stem cell transplantation have led to significant advancements in modern medicine, offering potential cures for various hematological disorders and specific cancers. This study aims to investigate and analyze research in this field using altmetrics in a world outside the academic scholarly and publishing environment.

Methods: This study examines articles in the field of bone marrow and stem cell transplantation in a ten-year period (2013–2022) extracted from the Web of Science database. The Altmetric Explorer database and tool were used to extract data. After an initial review of the data for their completeness and accuracy, the study considered descriptive reports, statistical analyses, bibliometric network analysis, and overlaps between articles, journals, and research centers in terms of the Altmetric Attention Score (AAS) and citations using Excel, SPSS, Python, R, and VOSviewer.

Result: This study evaluated 12924 articles published in 293 journals. Findings show that 85.67% of the articles were mentioned at least once on various social media and their tools. The AAS varied between 0 and 1125, and the median of this score was 2. The highest score was assigned to an article that provides critical insights into the outcomes of patients with refractory diffuse large B-cell lymphoma (DLBCL). Mendeley, X (formerly Twitter), and News were the most important and active social tools, respectively, where these articles were mentioned. The highest number of tweets, news stories, Facebook posts, and policy documents were from the USA, USA, USA, and UK, respectively. The @PaperbirdsM and @MayoClinic accounts on X had the highest tweet and follower statistics, respectively. The University of Texas MD Anderson Cancer Center also had the highest number of mentions on social networks. Network analysis maps of the top AAS articles showed "Stem Cell Transplantation" as the most popular author keyword, with *Blood* having the most influence at the journal level, the USA at the country level, Memorial Sloan Kettering Cancer Center at the research center level, and Kenneth C. Anderson at the author level. Finally, the results of the tests showed a significant correlation between citation and Altmetric indicators/AAS. However, nor were there differences in AAS based on the open access status of articles or the journal quartile.

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Conclusion: A high percentage of articles in this field are present on social networks and platforms. Furthermore, highly cited articles on social media have attracted more attention. Both traditional and web-based metrics offer different perspectives on scholarly impact. While each provides valuable insights, further research is needed to explore how these metrics can be effectively combined for a more comprehensive evaluation of scientific outputs.

Abbreviations

HSCT	Hematopoietic Stem Cell Transplantation
BM/SCT	Bone Marrow and Stem Cell Transplantation
AAS	Altmetric Attention Score
WoS	Web of Science
AE	Altmetric Explorer
H	H-Index
OA	Open Access
HC	Highly Cited
IF	Impact Factor
Q	Quartile
IQR	Interquartile range

1. Introduction

Hematopoietic stem cell transplantation (HSCT) involves the intravenous administration of hematopoietic stem cells to re-establish the production of blood cells in patients whose bone marrow or immune system has been damaged or is defective [1]. After approximately 60 years of research, this method evolved from an ineffective treatment in the 1960s to a standard treatment for malignant and non-malignant blood diseases. Nearly 1.5 million transplants have been performed in over 1500 transplant centers worldwide [2–4]. Despite the significant progress in HSCT, challenges remain in patient selection, conditioning regimen, and management of complications [5,6]. Future research aims to enhance the efficacy and safety of HSCT, making it a more accessible and successful treatment option for a broader range of patients.

The growing number of publications, increased use of social media, and the shift of journals to web-based platforms underscore the need for new metrics like altmetrics to evaluate research impact across social networks [7,8]. The digital transformation of publishing and the internet's development as a social platform have enabled faster dissemination and monitoring of research, providing new methods for assessing scientific outputs [9,10]. Unlike traditional scientific journals, social media allows for rapid public engagement, attracting attention from both medical professionals and the general public shortly after publication [11,12]; therefore, Altmetrics tools were created to measure the online attention an article receives across social networks [13].

Traditional metrics, such as citation counts, measure an article's impact based on how often it is cited, but citations alone do not always reflect an article's quality or broader influence [14–16]. Additionally, citation accumulation can take years and may be biased by self-citation or strategic journal citations [17,18]. In contrast, the Altmetric Attention Score (AAS) quantifies an article's online engagement through metrics like views, shares, and posts across blogs, news media, and social platforms [19,20]. As both the scientific community and the public increasingly seek relevant, engaging content, altmetrics provides a broader view of how research reaches and impacts audiences [21–23]. Altmetrics, based on Web 2.0 technologies, has been studied extensively for its strengths, limitations, and correlation with traditional citations, highlighting their complexity and the need for further research [7,20,24,25].

This study contributes to the growing body of research on the visibility and engagement of bone marrow and stem cell transplantation (BM/SCT) research, a field marked by significant advancements in medical and scientific arenas. BM/SCT, recognized as a curative therapy for various malignant and non-malignant diseases, has yet to be examined for its online presence using altmetrics. This study aimed to fill that gap by assessing the social visibility of BM/SCT research across both academic and public platforms, utilizing altmetrics to measure engagement. We specifically sought to identify the most prominent articles, evaluate their dissemination on social media and the web, and investigate potential correlations between the AAS and traditional citation counts, to provide new insights into the impact of this pioneering research.

2. Materials & methods

2.1. Study design

This study is a cross-sectional study conducted using the Altmetric method. The research population includes scientific original BM/SCT articles indexed in the Web of Science (WoS) Core Collection database over 10 years (2013–2022). We chose the WoS for its

extensive coverage and established reputation within the scientific community. This database includes articles from reputable journals across various disciplines, providing a diverse and reliable dataset for analysis. Conducting Altmetric analyses on the scientific outputs indexed in WoS allows for examining public attention and engagement with research published in widely recognized journals.

2.2. Search strategy

The relevant keywords were first identified with the help of the Medical Subject Headings (MeSH) thesaurus, similar articles, and experts in this field to retrieve the desired records. Then, the search strategy was developed using the advanced search section of the WoS database and was executed with the following formula on March 11, 2023:

*TS = ("*Stem Cell* *Transplant*" OR "*Bone Marrow *Transplant*" OR "*Stem Cell* *Graft*" OR "*Bone Marrow *Graft*" OR "*Bone Marrow Cell* *Transplant*" OR "*Bone Marrow Cell* *Graft*")*

2.3. Data extraction and variables

The necessary bibliographic information (title, authors, affiliations, year, journal, citation (also excluding self-citations), country, research center, h-index (H), open access (OA) status, highly cited (HC) status, impact factor (IF), and quartile (Q)) was extracted in a tab-delimited format. OA is a global initiative to provide unrestricted and open online access to research outputs. It entails the free and immediate availability of scholarly articles or books online, allowing users to utilize and fully share these resources in the digital environment. OA content is accessible to everyone without any access fees [26]. HC articles rank within the top 1% regarding the number of citations they receive compared to other articles published within the same field during the same year [27,28]. The IF is a scientometric index calculated by Clarivate that represents the average number of citations received by articles published in a specific journal during the past two years. It measures the journal's influence and popularity within the scientific community [29]. The Journal Citation Reports (JCR) determines quartile rankings based on the Journal IF. Quartiles are defined as follows: Q_1 represents the highest-ranked journals in a category, corresponding to a Z-score of $0.0 < Z \leq 0.25$; Q_2 includes journals ranked from $0.25 < Z \leq 0.5$, while Q_3 encompasses those with $0.5 < Z \leq 0.75$. Finally, Q_4 consists of the lowest-ranked journals in a category, defined by a Z-score of $0.75 < Z$. The Z-score is calculated using formula $Z = (X/Y)$, where X is the journal rank in the category, and Y is the total number of journals in that category. This classification helps evaluate the relative standing of journals within their respective fields [30].

Due to the incomplete number of scientific publications in 2023 and to prevent bias, 10 years from 2022 and earlier were considered. Two researchers reviewed the output file for missing/wrong data, and the necessary items were resolved by referring to the full text of the article. Subsequently, to extract AAS and its indicators, Altmetric Explorer (AE) (Altmetric LLP, London, UK) was used as a search engine and source data. Sourced data included the number of News, Blog, Policy, Patent, X, Weibo, Facebook, Wikipedia, Google+, LinkedIn, Reddit, Pinterest, F1000, Q&A, Video, and Syllabi mentions; the Number of Mendeley readers; and X, News,

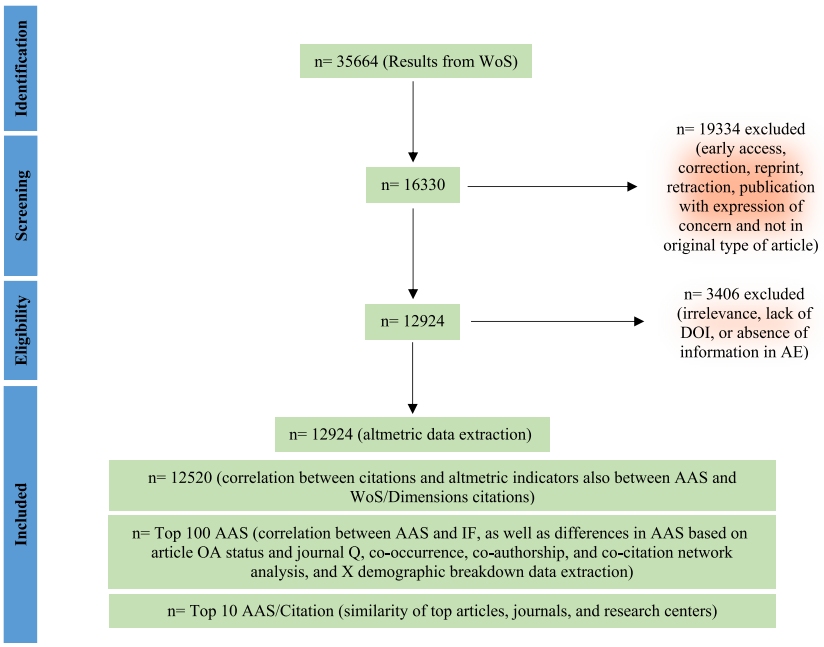

Fig. 1. PRISMA flowchart of articles screened, excluded, and included.

Facebook and Policy Demographics. The Altmetric database includes 60 million mentions from over 9 million scientific outputs. This system tracks the online attention that an article receives by aggregating data from social media such as X and Facebook, mainstream media from over 2000 outlets, reference management software such as Mendeley and CiteULike, and blogs (both from large organizations and individual researchers) [31]. Mendeley is primarily recognized as reference management software designed to assist researchers in organizing research papers, references, and documents. It also offers social networking features, such as user profiles, group interactions, and the ability to share research. These social aspects enable researchers to connect with one another, discover new studies, and engage in scholarly discussions. In Altmetric studies, Mendeley can be considered a social network due to its role in facilitating academic interactions and tracking engagement through the addition of papers to Mendeley libraries. The Altmetric algorithm generates a weighted score (AAS) displayed in a colored ring (donut) and shows the type and amount of attention received. The colors of the Altmetric donut each represent a different source of attention [32]. The DOI or PubMed ID of all retrieved documents was used for the AE search. Then, the number of citations from Dimensions was also extracted to create a more comprehensive view, as the citation counts for a specific article may vary across different databases. Finally, the correlation between the number of citations received by articles in the WoS database with Altmetric indicators/AAS was measured, and the correlation between AAS and IF, as well as the differences in AAS based on the OA status of articles and journal Q were also measured separately. In this study, bibliometric analysis and similarity of top articles, journals, and research centers in terms of AAS and citation were also examined. At last, to gather Altmetric data about X demographic breakdown of the top 100 AAS articles, the Altmetric Bookmarklet tool was employed. This free tool, stored as a browser bookmark, allows for extracting social media engagement data [33]. Researchers manually searched for each article via Google, accessed the journal websites, and used the Bookmarklet to collect Altmetric data. This method provided detailed insights into the online attention these high-scoring articles received (Fig. 1).

2.4. Data analysis

Considering the objectives of the research, Microsoft Excel 2021 (Microsoft Corporation, Redmond, WA, USA) [https://www.microsoft.com/excel], IBM SPSS Statistics 27 (IBM Corporation, Armonk, NY, USA) [https://www.ibm.com/products/spss-statistics], Python 3.11.4 (Python Software Foundation, Wilmington, DE, USA) [https://www.python.org], R 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria) [https://www.r-project.org], and VOSviewer 1.6.19 (Centre for Science and Technology Studies, Leiden University, Leiden, Netherlands) [http://www.vosviewer.com] were used for descriptive analysis, correlation and difference measurements, as well as author keyword co-occurrence, co-authorship, and co-citation network analysis. After examining the type of variables and the normality of the data, Spearman correlation, Kruskal-Wallis, and Mann-Whitney statistical tests were utilized. The first test assessed the statistical correlation between citation counts and Altmetric indicators/AAS. The second test examined the differences in AAS among the classification states of journals in the JCR. Additionally, the third test investigated the difference in AAS between open access and subscription access articles. In order to examine the extent of associations, the rule (r values < 0.250 = weak, 0.250–0.499 = moderate, 0.500–0.749 = strong, and ≥ 0.750 = very strong correlations) was applied [20,34,35].

3. Results

With the formulated search strategy, a total of 16330 articles were retrieved. Among these, only the information of 12924 (79.14%) relevant records were available at the Altmetric Institute, and 11072 (85.67%) of them were mentioned at least once in various social media and their tools, meaning they had an AAS. From these, the demographic breakdown of X engagement for the top 100 AAS articles (median: 224; IQR: 259) was as follows: members of the public (n = 5463), scientists (1289), healthcare practitioners, including doctors and other professionals (1147), science communicators, such as journalists, bloggers, and editors (259), and a small

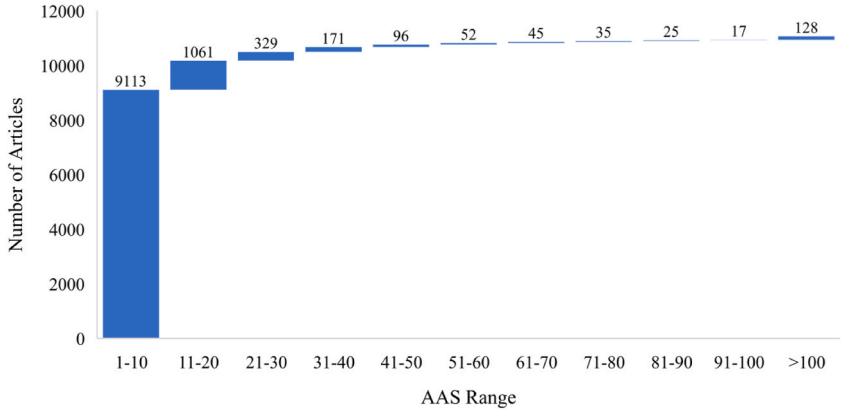

Fig. 2. AAS distribution of articles in BM/SCT (2013–2022). As AAS increases, the number of articles decreases, and only a small percentage of articles have achieved a high AAS.

Table 1
Top 10 highly AAS articles in BM/SCT (2013–2022).

	Article	Author; Year	Journal, Publisher		
1125	Outcomes in refractory diffuse large B-cell lymphoma: results from the international SCHOLAR-1 study	Crump,M; 2017	*Blood*, Elsevier BV	Y	Y
961	Multiple myeloma: 2020 update on diagnosis, risk-stratification and management	Rajkumar, SV; 2020	*American Journal of Hematology*, Wiley-Liss Inc.	Y	Y
739	Global characteristics and outcomes of SARS-CoV-2 infection in children and adolescents with cancer (GRCCC): a cohort study	Mukkada, S; 2021	*Lancet Oncology*, Elsevier Ltd.	Y	Y
608	Ibrutinib combined with bendamustine and rituximab compared with placebo, bendamustine, and rituximab for previously treated chronic lymphocytic leukaemia or small lymphocytic lymphoma (HELIOS): a randomised, double-blind, phase 3 study	Chanan-Khan, A; 2016	*Lancet Oncology*, Elsevier Ltd.	Y	Y
600	Seroconversion rates following COVID-19 vaccination among patients with cancer	Thakkar, A; 2021	*Cancer Cell*, Cell Press	Y	Y
597	Outcomes and Predictors of 28-Day Mortality in Patients with Hematologic Malignancies and Septic Shock Defined by Sepsis-3 Criteria	Manjappachar, NK; 2022	*Journal of the National Comprehensive Cancer Network* (JNCCN), Cold Spring Publishing LLC	Y	N
578	Off-the-Shelf Virus-Specific T Cells to Treat BK Virus, Human Herpesvirus 6, Cytomegalovirus, Epstein-Barr Virus, and Adenovirus Infections After Allogeneic Hematopoietic Stem-Cell Transplantation	Tzannou, I; 2017	*Journal of Clinical Oncology*, Lippincott Williams and Wilkins Ltd.	Y	Y
558	The Influence of the Gut Microbiome on Cancer, Immunity, and Cancer Immunotherapy	Gopalakrishnan, V; 2018	*Cancer Cell*, Cell Press	Y	Y
536	Lenalidomide Maintenance After Autologous Stem-Cell Transplantation in Newly Diagnosed Multiple Myeloma: A Meta-Analysis	McCarthy, PL; 2017	*Journal of Clinical Oncology*, Lippincott Williams and Wilkins Ltd.	Y	Y
516	Global Burden of Multiple Myeloma: A Systematic Analysis for the Global Burden of Disease Study 2016	Cowan, AJ; 2018	*JAMA Oncology*, American Medical Association	Y	Y

: AAS; : OA; : HC; Y: Yes; N: No; In this table, refers to the articles being OA, not the journals. The listed journals primarily operate as hybrid journals, allowing authors to publish their articles as OA by paying a fee. If not published as OA, articles generally become freely accessible after a 12-month embargo. OA articles in these journals typically use Creative Commons licenses such as CC BY, CC BY-NC, or CC BY-NC-ND. While most journals follow this hybrid model, the *Journal of the National Comprehensive Cancer Network* (JNCCN) is primarily subscription-based, with only some content available as OA. These licensing and access policies ensure a balance between subscription-based and open access publishing, providing authors with flexible options for disseminating their research.

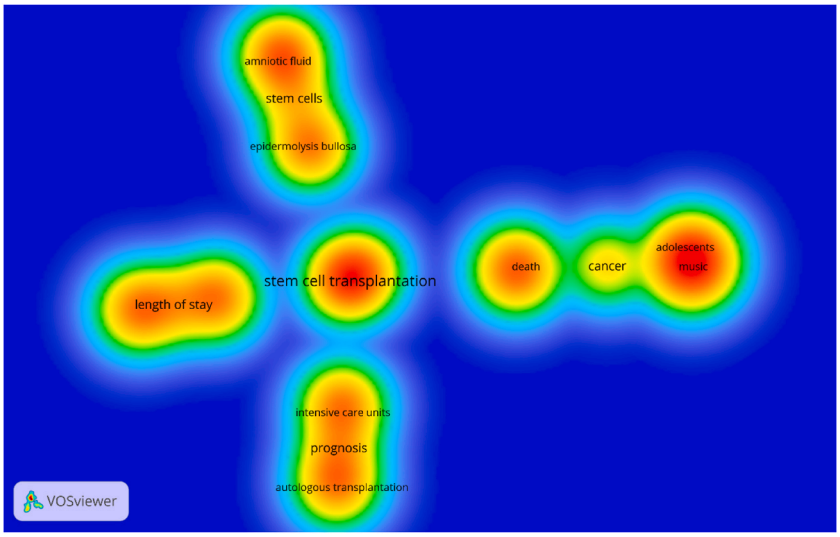

Fig. 3. Hot topics among author keywords of top AAS articles in BM/SCT (2013–2022).

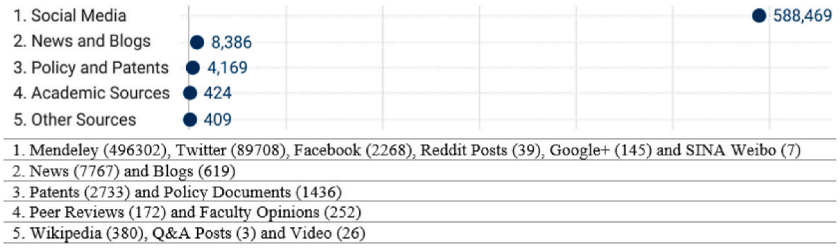

Fig. 4. Attention breakdown of articles in BM/SCT (2013–2022). The most attention statistics were from social media, followed by news and blogs, policy and patents, and academic sources. Also, 409 mentions are related to other sources.

Table 2
Distribution of top 10 countries' X, news, Facebook, and policy users of articles in BM/SCT (2013–2022).

Tweets and Tweeters			News Stories and Outlets			Facebook Posts and Pages			Policy Documents and Sources		
C	*TT n (%)*	*UT*	*C*	*TNS*	*UNO*	*C*	*TFP*	*UFP*	*C*	*TPD*	*UPS*
USA	26,394 (29.4)	4050 (23.8)	USA	5681 (73.1)	451 (60.3)	USA	323 (14.2)	114 (19.7)	UK	449 (31.1)	5 (20.8)
Spain	5243 (5.8)	965 (5.7)	UK	800 (10.3)	60 (8)	Italy	60 (2.6)	10 (1.7)	Canada	422 (29.2)	1 (4.2)
UK	3813 (4.3)	987 (5.8)	Germany	196 (2.5)	30 (4)	Costa Rica	29 (1.3)	1 (0.2)	Germany	396 (27.4)	1 (4.2)
Saudi Arabia	1889 (2.1)	247 (1.4)	Turkey	179 (2.3)	3 (0.4)	Spain	28 (1.2)	7 (1.2)	Switzerland	77 (5.3)	2 (8.3)
Canada	1583 (1.8)	417 (2.4)	Australia	161 (2.1)	17 (2.3)	UK	23 (1)	13 (2.2)	USA	59 (4.1)	5 (20.8)
France	1542 (1.7)	287 (1.7)	India	143 (1.8)	43 (5.7)	Brazil	22 (1)	7 (1.2)	Netherlands	20 (1.4)	3 (12.5)
India	1459 (1.6)	409 (2.4)	Canada	50 (0.6)	10 (1.3)	Germany	20 (0.9)	6 (1)	Sweden	8 (0.6)	2 (8.3)
Mexico	1043 (1.2)	242 (1.4)	China	47 (0.6)	9 (1.2)	Saudi Arabia	18 (0.8)	3 (0.5)	Australia	6 (0.4)	1 (4.2)
Brazil	983 (1.1)	189 (1.1)	Italy	43 (0.6)	7 (0.9)	Canada	17 (0.7)	14 (2.4)	Luxembourg	4 (0.3)	1 (4.2)
Australia	952 (1.1)	325 (1.9)	Japan	43 (0.6)	8 (1.1)	Australia	11 (0.5)	7 (1.2)	Denmark	2 (0.1)	1 (4.2)
others	44,807 (49.9)	8934 (52.3)	others	424 (5.4)	110 (14.7)	others	1717 (75.7)	397 (68.5)	others	3 (0.2)	2 (8.3)

C: Country; TT: Total Tweets; UT: Unique Tweeters; TNS: Total News Stories; UNO: Unique News Outlets; TFP: Total Facebook Posts; UFP: Unique Facebook Pages; TPD: Total Policy Documents; UPS: Unique Policy Sources.

group categorized as unknown (14).

AASs varied from 0 to 1125 (Median: 2, IQR: 5), and most articles (82.30%) fell within the 1–10 range, followed by 9.58% and 2.97% respectively in the 11–20 and 21–30 ranges. With the increase in the range of AAS, the number of articles decreases. Notably, the share of articles with an AAS of 100 and above is only 1.15% of all articles (Fig. 2).

Table 1 shows the top 10 articles in terms of AAS. According to it, the highest AAS belonged to an article titled "Outcomes in refractory diffuse large B-cell lymphoma: results from the international SCHOLAR-1 study" (AAS: 1125, Citations: 773, Journal: *Blood*, and publication year: 2017). This article has been read a total of 774 times on Mendeley and has been tweeted 68 times. Most readers of this article on Mendeley were researchers in medicine and dentistry, and most of the tweeters were from the USA. This article results from the collaboration of 17 authors from Canada, the USA, and France. Following this, "Multiple myeloma: 2020 update on diagnosis, risk-stratification and management" and "Global characteristics and outcomes of SARS-CoV-2 infection in children and adolescents with cancer (GRCCC): a cohort study" are ranked second and third, respectively. Also, all 10 articles have been published in OA status, and nine are among the HC articles.

Keyword co-occurrence analysis identifies frequently paired keywords in publications, helping researchers uncover major themes and emerging trends within a field. This technique offers insights into topic relationships and the overall structure of research domains. 46 of the 108 author keywords analyzed formed a network of seven clusters. Density visualization highlighted "stem cell transplantation", "stem cells", "cancer", "prognosis", and "length of stay" as the most frequently used keywords, reflecting central themes in the field (Fig. 3).

The frequency distribution of various social media showed that the total number of mentions of articles in this field is 601857 (Fig. 4). In total, Mendeley, with 496302 readers and an average of 38.64 per document, ranked first as the most significant social tool. X followed by 89708 mentions and an average of 8.69 per document. News ranked third, with 7767 mentions and an average of 4.91 per document. The highest value for each is related to "Investigation of the freely available easy-to-use software 'EZR' for medical statistics" (1959), "Analysis of control arm quality in randomized clinical trials leading to anticancer drug approval by the US Food and Drug Administration" (640), and "Multiple myeloma: 2020 update on diagnosis, risk-stratification and management" (597). Also, Mendeley, with sharing 12841 documents (median: 25; IQR: 31; range: 0–1959), ranked first in terms of the most active social network, followed by X (document share: 10322; 2; 5; 0–640) and News (1581; 0; 0; 0–597).

Out of 89708 tweets sent by 17052 unique tweeters from 141 countries, most tweets were related to the USA, Spain, and the UK (the origin of 35799 tweets was unknown). The total number of news stories from 51 countries was 7767, of which 748 unique news outlets were published, and the highest statistics were related to the USA, the UK, and Germany (information about 140 stories was not available). 2268 Facebook posts were assigned by 579 unique Facebook pages from 39 countries, with the first to third ranks belonging to the USA, Italy, and Costa Rica (information about 1656 posts was unavailable). Also, 1446 policy documents were prepared by 24 unique policy sources from 12 countries. The top ones were the UK, Canada, and Germany (Table 2).

Of 293 journals publishing articles in this field and present on social media, *Blood*, *Journal of Clinical Oncology*, and *Biology of Blood & Marrow Transplantation* ranked first to third, respectively. Except for *Haematologica*, which is from Italy, the rest of the journals are from the USA (that is, *Blood*, *Journal of Clinical Oncology*, *Biology of Blood & Marrow Transplantation*, *American Journal of Hematology*, *Blood Advances*, and *Cancer*) and the UK (*Bone Marrow Transplantation*, *The Lancet Hematology*, and *Lancet Oncology*) (Fig. 5).

According to the list of the top 10 accounts regarding the number of tweets and followers (Fig. 6), @PaperbirdsM had the first rank with 1872 tweets and 925 followers. Following that, @Lymphoma_Papers (1346 mentions, 2454 followers) and @mtmdphd (1338, 23025) were ranked. In terms of the number of followers, @MayoClinic (USA, 2 million), @NIH (USA, 1.6 million), and @H_swilhy (Saudi Arabia, 1.1 million) were ranked first to third, respectively.

Based on the number of mentioned outputs and the total number of their mentions at the research center level, The University of Texas MD Anderson Cancer Center ranks first with 639 outputs and 14298 mentions. Following that are the Mayo Clinic and the Memorial Sloan Kettering Cancer Center (Fig. 7).

Network analysis provides a comprehensive view of key contributors and their collaborative relationships across all levels, offering insights into the overall structure and strength of the collaborative network (Fig. 8). In the countries' network, 14 out of 46 countries met the criterion of at least five documents, forming a network with a TLS of 810 and 174 links, organized into three clusters. The

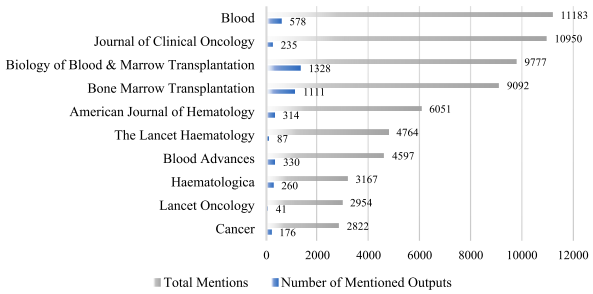

Fig. 5. Top 10 journals based on total mentions in BM/SCT (2013–2022). Mentions are online posts such as news articles, policy documents, or blog posts referencing a research output. To be considered as a mention, a post needs to appear on an attention source tracked by Altmetric and include the appropriate data required for tracking by Altmetric, such as a URL to a research output.

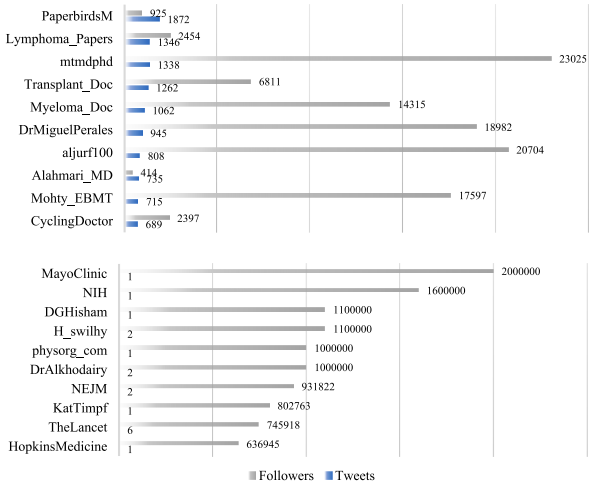

Fig. 6. Top 10 X accounts, based on the tweets and followers in BM/SCT (2013–2022). Altmetric uses an API to monitor X's attention instantly. It automatically gathers tweets, reposts, and quotes with direct links to scholarly outputs and relies on these links to accurately match posts/tweets with the relevant ones.

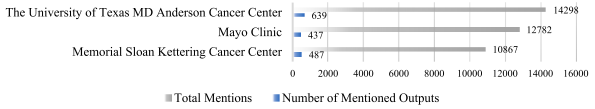

Fig. 7. Top three research centers based on total mentions in BM/SCT (2013–2022). It is determined by identifying the research centers whose outputs hold the most significant share of attention. Data regarding author affiliations are provided to Altmetric by Dimensions, a comprehensive research information platform that aggregates scholarly outputs across various fields. This data matches specific research outputs to enhance their visibility and impact assessment.

leading countries, according to total collaborations, are the USA (TLS: 120; 13 links), UK (88; 13), and Germany (80; 13) (Fig. 8A). In the research centers' network, 25 out of 569 centers met the minimum requirement of five documents, resulting in a network with a TLS of 834 and 452 links, also divided into three clusters. The top collaborating centers include Memorial Sloan Kettering Cancer Center (TLS: 57; 22 links), Dana-Farber Cancer Institute (53; 23), and Duke University (46; 21) (Fig. 8B). Lastly, the authors' network comprises 82 out of 1572 authors who met the threshold of two documents, with a TLS of 964 and 748 links, divided into seven clusters. The most prominent authors in terms of collaborations are Kenneth C. Anderson (TLS: 33; 20 links), Philippe Moreau (30; 19), and Robert Z. Orlowski (27; 20) (Fig. 8C).

Journal co-citation networks reveal relationships between academic publications by identifying frequently co-cited journals. This aids researchers in uncovering critical thematic connections and influential sources within a specific field. In this study, among the 917 journals in the field, 44 met the minimum requirement of 20 documents, forming a network with TLS of 269100 and 1710 links, organized into four clusters (Fig. 9). As shown in the map, the leading journals in terms of total collaborations are *Blood* (TLS: 59452; 43 links), *New England Journal of Medicine* (26287; 43), and *Journal of Clinical Oncology* (24656; 43).

The results of statistical analyses showed a significant correlation between the number of citations and most Altmetric indicators ($n = 19520$; $p < 0.001$), which was reported to have a weak association. However, for Mendeley Readers (rho = 0.812) and Patent Mentions (rho = 0.260), the associations were very strong and moderate, respectively. Ultimately, the results of the Spearman test regarding the correlation between the number of article citations in WoS (rho = 0.296) and Dimensions (rho = 0.333) with the AAS were also significant, with a moderate degree of association. No significant correlation was observed between AAS and IF ($n = 100$; median: 25.7; IQR: 43.1; $p = 0.71$). Also, no significant AAS differences among articles in terms of OA status ($n = 100$ (OA: 82); $p = 0.71$) and journal Q ($n = 100$ (Q_1: 86; Q_2: 3; Q_3: 6; Q_4: 2); $p = 0.53$). The details related to the rho are separately observable in Fig. 10.

4. Discussion

Although the growth rate of research in the field of BM/SCT has not been high over the past decade, it has been on an upward trend, and with the increase in scientific publications, measuring their value and impact is very important. The increasing use of online social media by patients, doctors, funding agencies, universities, and journals has made the online attention of scientific publications undeniable. The findings of this study showed that 85.67% of the articles in this field had an AAS. Most studies have reported a high percentage as at least one mention in various social media and their tools. This is supported by the study conducted by Ahmadian et al., who examined a thousand cancer-related publications in the Scopus database with a reported percentage of 96.3% [20]. However, two

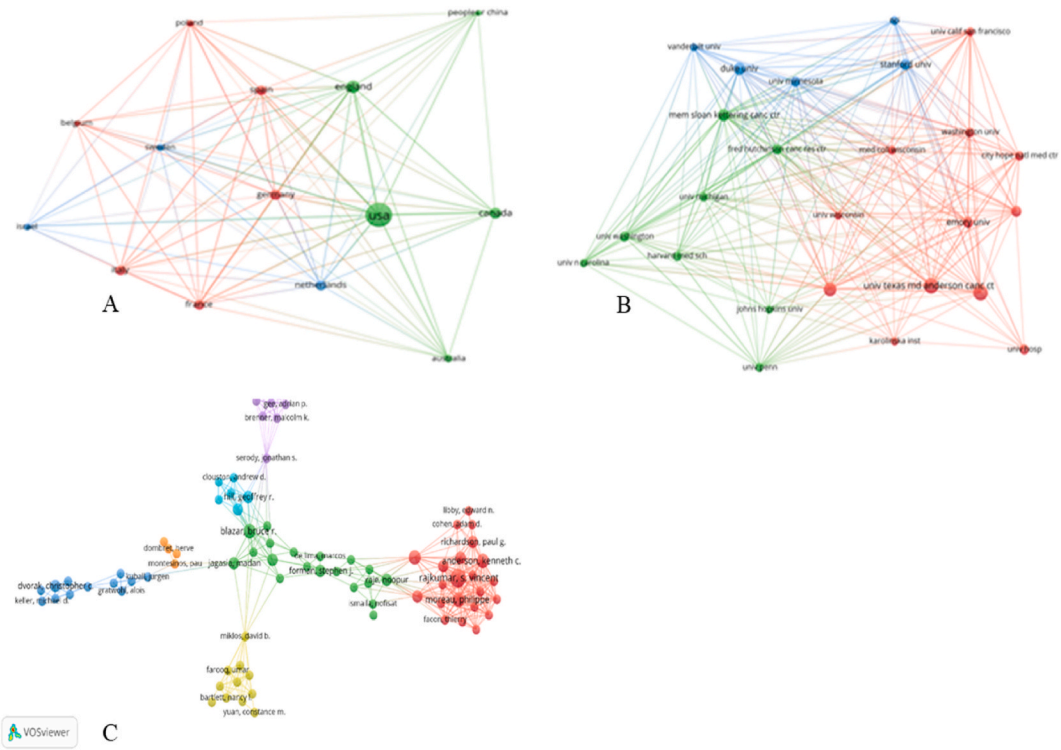

Fig. 8. Collaborative networks of top AAS articles by countries, research centers, and authors in BM/SCT (2013–2022). Each node represents a country, research center, or author, with node size corresponding to the number of articles. Colors indicate clusters of closely collaborating entities, and the thickness of the connecting lines reflects the collaboration frequency. The distance between nodes represents the strength of relationships, with shorter distances indicating stronger connections. Also, the links attribute refers to the number of direct collaborative connections between an item and others, while Total Link Strength (TLS) represents the cumulative strength of these connections.

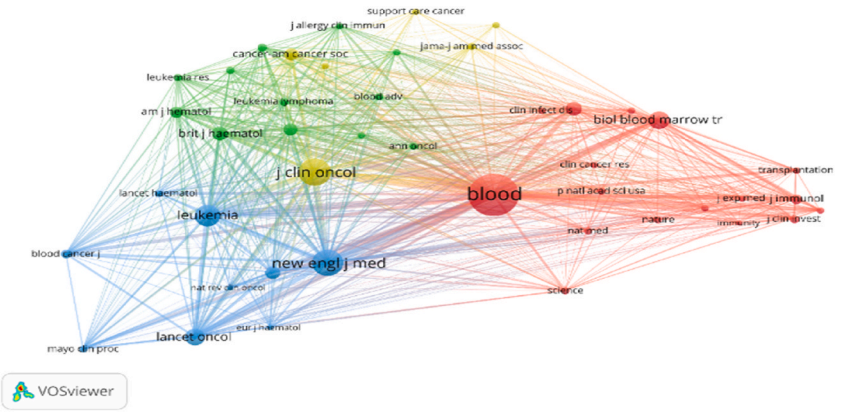

Fig. 9. Co-citation network among journals of top AAS articles in BM/SCT (2013–2022). Different colors represent the clusters of journals. Each cluster indicates a group of journals frequently cited together, and the size of each node reflects the number of citations received by that journal. The thickness of the lines corresponds to the frequency of co-citation, while the links denote co-citation between nodes, with the distance between them illustrating the strength of their co-citation relationship.

studies have stated this percentage below 30. The study by Haustein et al. considered only 1.3 million articles published in WoS without any subject area limitation in 2012 alone [36], and the research by Robinson-García et al. examined all publications between 2011 and 2013 that were indexed in the WoS database using Centre for Science and Technology Studies (University of Leiden) [37].

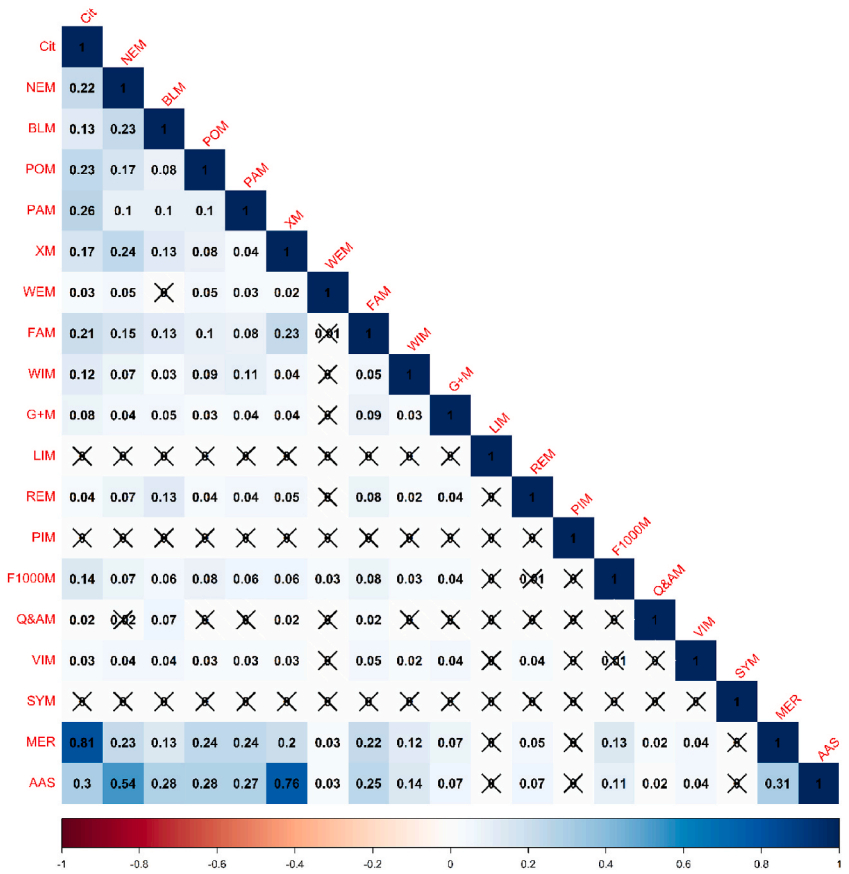

Fig. 10. Correlation between citation and Altmetric indicators/AAS of articles in BM/SCT (2013–2022). The cells marked with a cross (×) indicate they are not statistically significant. Citation: Cit; News Mentions: NEM; Blog Mentions: BLM; Policy Mentions: POM; Patent Mentions: PAM; X Mentions: XM; Weibo Mentions: WEM; Facebook Mentions: FAM; Wikipedia Mentions: WIM; Google + Mentions: G + M; LinkedIn Mentions: LIM; Reddit Mentions: REM; Pinterest Mentions: PIM; F1000 Mentions: F1000M; Q&A Mentions: Q&AM; Video Mentions: VIM; Syllabi Mentions: SYM; And Mendeley Readers: MER.

4.1. AAS

AASs for articles in this field varied between 0 and 1125 (Median: 2, IQR: 5), and only 1.15% had a score higher than 100. Given the lack of similar studies to measure the AAS of articles in this field, understanding these figures might be challenging. Also, we cannot compare the median index and score distribution with other studies because we face a significant difference in the statistical community; other studies have mainly analyzed the top 100 articles. However, regarding the maximum score compared to other studies conducted in the fields of skin oncology (2861) [10], oral cancer (1307) [38], and cancer (2864) [20], articles in this field have a lower AAS, and higher compared to some others like cancer treatments (428) [25] and cleft lip and palate (458) [9].

4.2. Top articles

Among the top 10 articles in terms of AAS and citation, seven were conducted with international collaborations; it seems that writing internationally can positively impact receiving citations and higher AAS. Perhaps presence in international communities and the use of the unlimited potential of social networks, including specialized discussion groups, researcher-centric social media, and specialized pages of public social media, can help find topics and offer research proposals and international collaborations. The common point of the top 10 articles in terms of AAS and citation is only an article titled "Outcomes in refractory diffuse large B-cell lymphoma: results from the international SCHOLAR-1 study," which had received the highest AAS and was ranked third in terms of citations. This study represents a landmark analysis of outcomes in patients with refractory DLBCL, pooling data from multiple cohorts to provide comprehensive insights into this challenging condition. With an objective response rate of only 26% and a median overall survival of just 6.3 months, the findings underscore the urgent need for more effective treatment options for these patients. This extensive research not only highlights the poor prognosis associated with refractory DLBCL but also sets a crucial benchmark for future therapeutic developments in this area. *Blood*, *Lancet Oncology*, *Journal of Clinical Oncology*, and *Biology of Blood & Marrow Transplantation* were common journals regarding AAS and citation. Also, the OA status of each of the 10 articles labeled HC (9 articles) was

probably not ineffective. This statistic was the opposite for the 10 most cited articles; 9 cases were OA, and all 10 articles were HC. Additionally, studies related to cleft lip and palate [9] and oral cancer [38], each of which had considered the top 100 articles, were more focused on treatment, etiology, and risk factors; this study found that the top 100 articles focused on stem cell transplantation, stem cells, cancer, prognosis, and length of stay.

4.3. Social media

Mendeley, X, and News Outlets were the most used in sharing articles in this field. This study's findings indicated that these platforms had the highest engagement levels, which can indicate their influence. The high presence of articles on Mendeley highlights its importance in disseminating scientific outputs; other studies also have similar patterns of use of these tools [38–41]. Mendeley, as noted in the study by Ahmadian et al. [20], X in the study by Haustein et al. [36], and both Mendeley and X in the study by Robinson et al. [37], showed significant coverage. Mendeley's ability to provide some of the demographic statuses of readers, widespread use by researchers from different fields, and its open access status can be effective in this matter [42]. Also, X provides relatively high coverage of scientific outputs [43] and is commonly used by researchers to share findings [44,45]. As a potential tool, it fills the gap between biomedical research and health policymaking [46]. Healthcare professionals use this platform to create virtual communities and share information with other healthcare professionals and other people from the public [47–49]; therefore, it is essential that researchers be able to write tweets that are understandable for non-professional readers and the general public to witness its potential positive impacts on public health. As reported, most tweets related to the top 100 articles in this field have been from members of the public. The study by Mohammadi et al. also emphasized this issue, and their findings support X as a tool in discovering scientific information and expanding interdisciplinary knowledge [50]. Encouraging authors to share their works on Mendeley and X can make published articles more visible.

4.4. Geographical breakdown

Geographic data analysis showed that the majority of tweets in this field originated from the USA, Spain, and the UK. Additionally, the USA was the most influential on the network. In the study related to cancer publications by Ahmadian et al., most of the tweets were also from these three countries [20]. In some dental studies as well, most tweets were from the USA and the UK [40,41,44,51]. The USA and Italy also had the highest statistics in terms of Facebook posts and pages. The highest statistics of news stories and outlets and policy document and sources were from the USA and the UK, respectively. In the study by Hassona et al., it was the same [38]. It seems that News can act as a suitable social platform for distributing research findings in the field of BM/SCT. Apparently, the uneven access to the internet in different parts of the world [52] has influenced the superiority of the USA and Europe.

4.5. Journals

Blood, the flagship journal of the American Society of Hematology, was recognized as having the highest number of total mentions and most influence on the network. This journal ranks third in terms of article production and has the highest H and IF among the active journals in this field. It also ranks first in terms of the number of citations received, even with excluded self-citation, and the average citation per document. *Biology of Blood and Marrow Transplantation*, published by Elsevier, also ranks third in terms of total mentions and first in terms of the number of documents. Overall, there was an overlap between the top 10 articles with high AAS and the 10 most cited articles in the four journals: *Blood*, *Biology of Blood and Marrow Transplantation*, *Bone Marrow Transplantation*, and *Blood Advances*. In other words, there was a relative overlap between the top journals from both bibliometric and Altmetric perspectives, which could indicate the importance and impact of these journals in the field under study. According to the results of a paper conducted in 2015 to investigate the relationship between scientific merit and mainstream popularity of medical journals, only 28% of journals had an X profile and the number of followers for these journals was found to correlate with their IF and citation counts [53]. It has also been reported in studies that journals with a profile on social networks will achieve a higher AAS for their articles [54,55]. Indeed, a model proposed by Lee and Hoon Kwak may offer a systematic structure to enhance social media engagement, particularly focusing on the most impactful components. In summary, they propose advancing through five maturity levels, including (i) initial conditions, (ii) data transparency, (iii) open participation, (iv) open collaboration, and (v) ubiquitous engagement [56]. Therefore, as much as possible, authors, journals, and funding agencies in this field should pay maximum attention to social networks like X by creating an account and sharing information about their scientific findings.

4.6. X accounts

The @PaperbirdsM account on X, with 1872 tweets, had the highest number of tweets in the field of BM/SCT. Paperbirds is an initiative committed to delivering unbiased daily updates on literature and information about new clinical trials to healthcare professionals. However, in terms of the number of followers and the social impact, the @MayoClinic account, with two million followers, ranked first. This account belongs to a research center that also ranked tenth in terms of the number of published articles and had the lowest self-citation rate among the institutions in this field. This institute also ranks second in the findings obtained from the top research centers in terms of total mentions and has received 12782 mentions for its 437 outputs. It seems that the presence of this institute on X, with the highest number of followers compared to competitors, has led to its scientific outcomes being more visible.

4.7. Correlation and differences between variables

Statistical tests showed a significant correlation between Altmetric indicators and the number of citations received. The results of the study by Thelwall et al. [57] also refer to this issue in relation to X, Facebook, blogs, mainstream media and forums; however, for Google+ Mentions, unlike the present study, no significant correlation was reported in their findings. There was also insufficient evidence to compare and measure the correlation for LinkedIn, Pinterest, and Syllabi Mentions, which was similarly noted in their study regarding LinkedIn and Pinterest. It seems that these media have not been well received by the scientific community and no related activity is taking place in them. Other studies have reported similar results in terms of the correlation between the number of citations and tweets [51,58,59]. Also, the moderate association between AAS and the number of citations of articles in the present study has been reported as weak in other studies related to pediatric surgery [60], urology [61], emergency medicine [62], and anesthesiology [63]. Similarly, a meta-analysis of 27 articles in health science also reported a pooled correlation coefficient of 0.19 [64]. It is evident that the relevance of the subject area of this study—stemming from advancements in the treatment of previously untreatable diseases and publication in reputable international journals—has significantly influenced its visibility and resulted in higher AAS and citation rates. In some other studies, like this study, the result of statistical tests was moderate [10,20,65]. Although in some studies, no significant statistical correlation was found [38,66]. The lack of a significant correlation does not mean that Altmetric indicators are ineffective or that they have low impact. This lack of correlation indicates that Altmetric analysis evaluates different aspects of articles compared to traditional citation analysis [20,67]; in other words, it evaluates aspects of research that bibliometrics cannot evaluate [68]. Reasons for the lack of a significant correlation in some studies may include the small sample size used, or the failure to identify articles with a high AAS. This is acknowledged by the authors themselves in the limitations section, where they state that a larger sample size could have increased the study's power. Another possible influencing factor may be that authors and researchers in a specific field do not have sufficient familiarity with and awareness of altmetrics.

Also, there was no significant correlation or difference between the top AAS articles and the IF/Q of the publishing journals. This finding is consistent with similar studies on online attention to research in various fields including nursing [69], radiology [70], dentistry [39], and cleft lip and palate [9]. On the other hand, reports on common metrics indicate that HC articles are usually published in Q_1 journals with a high IF [71–73]. According to the study by Delli et al., social media users may be directed towards articles with lower scientific evidence for unknown reasons [39]. It seems that in some fields, the perceived generalizability of research and its potential applications in the real world, compared to the scientific importance or level of scientific evidence presented by the study itself, carries more weight. There were also no significant statistical differences among AAS and the access status of articles. Although the results of a study in 2018 showed that publicly accessible articles in the field of health education received higher online attention on social media platforms [74]. In general, it can be stated that the presence of scientific outputs on social media probably increases visibility and hence the chance of receiving citations and access. So, it may be a good indicator for predicting citations in the future.

4.8. Strengths & weaknesses

The findings of this study examined a significant statistical population in detail and is not specifically focused on any particular journal or journals. To our knowledge, no study has examined the correlation between more than one thousand articles. In this study, with the help of the Python programming language, relatively large number of articles were statistically analyzed. Also, the tool of choice was AE, selected for its capability to effectively clean and normalize collected data before analysis, as well as to control the manipulation of AAS by counting one mention from each individual in each source.

The comparison between citations and Altmetric indicators, and ultimately AAS, can vary so much at different times and in different scientific fields that it can change the statistical correlation between the three states of weak, moderate, and strong, or even eliminate and reverse it. Therefore, considering the impact of time and subject area when using altmetrics in ranking is undeniable. In addition, issues such as uneven access to the internet and social networks worldwide can create bias, as certain regions may have limited engagement with online content. Negative perceptions towards certain authors due to high-profile retractions can also influence public perception and engagement with their works. The type of study—whether it is a clinical trial, case study, or another format—affects the level of public interest and visibility. Furthermore, the number of authors and institutions involved can impact how widely the research is disseminated, as collaborations often lead to greater exposure. Finally, the practices of publishers in promoting their publications can significantly affect the visibility of research outputs.

5. Conclusion

Based on the findings of the study, it can be concluded that a high percentage of published articles in the field of BM/SCT is present on online platforms and social networks. Three social media platforms, namely, Mendeley, X, and News, have played a prominent role in providing a platform for the dissemination of outputs in this field, and developed countries such as the USA and UK have played a prominent role in reflecting research findings on social media. Also, the results indicated that HC articles have also attracted more attention on social media. As Altmetric coverage increases in the future, more valid results may be obtained from such studies, and to improve the efficiency of Altmetric, it needs to expand its scope to include platforms such as Instagram and TikTok. This action means creating a more comprehensive view and aligning with a broader perspective of online communications. It is hoped that, in the future, a composite index using two Altmetric and bibliometric criteria will help predict the impact of scientific publications on a large scale. It is suggested that in future studies, as far as possible, the nature of mentions, posts, and tweets to articles in different subject areas on

social media should be examined.

CRediT authorship contribution statement

Mohammad Ahmadian: Conceptualization, Methodology, Investigation, Software, Formal analysis, Validation, Data curation, Resources, Visualization, Writing – original draft, Writing – review & editing. **Shaban Alizadeh:** Conceptualization, Funding acquisition, Resources, Validation, Writing – review & editing. **Azadeh Omidkhoda:** Conceptualization, Validation, Writing – review & editing. **Fatemeh Sheikhshoaei:** Conceptualization, Methodology, Investigation, Supervision, Project administration, Writing – review & editing. **Brenda Van Wyk:** Conceptualization, Validation, Writing – review & editing.

Ethical consideration

This study has been ethically approved by the Ethics Committee of Tehran University of Medical Sciences with code number: IR.TUMS.SPH.REC.1401.189.

Data availability statement

All data generated or analyzed during this study are available from the WoS and AE databases. Any additional data or information can be obtained from the first author upon reasonable request.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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