

Integrating Bibliometrics and Bioinformatics to Map Knowledge Structure and Trend Synthesis in Rheumatoid Arthritis and Bone Erosion (2015–2024)

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Objective: To comprehensively analyze the international trends and dynamics in rheumatoid arthritis and bone erosion research over the past 10 years, identifying research hotspots and challenges to provide references for future research directions and therapeutic strategies.

Methods: A bibliometric analysis was conducted by retrieving relevant literature published between 2015 and 2024 from the Web of Science (WoS) database. A further bibliometric analysis and visualization of the relevant literature was conducted using CiteSpace, VOSviewer, Scimago Graphica, and Excel. Further, disease-related targets were retrieved from Genecards using “rheumatoid arthritis” and “bone erosion” as keywords, followed by PPI network analysis to identify core targets and KEGG pathway enrichment analysis to elucidate key signaling pathways.

Results: A total of 1,502 publications were included through a search of the WoS database. The number of publications initially showed a gradual increase but declined sharply after 2021. China and the United States ranked as the top two contributors, with China's proportion of publications increasing while the US proportion decreased. Cluster analysis of institutional collaboration networks revealed significant regional clustering. *Arthritis Research & Therapy* published the most articles in this field, while Schett, Georg ranked first in both the number of publications (34) and citations (1,436). Keyword cluster analysis indicated that research primarily focused on imaging and mechanistic exploration. PPI and KEGG analyses revealed that rheumatoid arthritis (RA) and bone erosion are closely associated with inflammatory factors and inflammation-related signaling pathways.

Conclusion: This study highlights the evolving trends in rheumatoid arthritis and bone erosion research from 2015 to 2024, demonstrating China's growing research contributions while international collaboration remains regionally concentrated. Future efforts should emphasize interdisciplinary integration and global cooperation to advance the understanding of bone erosion mechanisms and precision medicine approaches.

Keywords: rheumatoid arthritis, bone erosion, bibliometric analysis, CiteSpace, VOSviewer

Introduction

Rheumatoid arthritis (RA) is a chronic systemic autoimmune disease characterized by synovial inflammation and progressive bone erosion, and it affects approximately 0.5–1% of the global population.¹ The core pathological mechanisms of RA involve immune-mediated synovitis, subsequent pannus formation, and abnormal activation of osteoclasts that drive progressive bone erosion.^{2–4} As the primary cause of joint deformities, bone erosion in RA imposes substantial healthcare burdens and socioeconomic costs annually.^{5,6} Over the past decade, rapid advancements in molecular biology, imaging technologies, and targeted therapeutics have redefined RA bone erosion research, evolving from isolated pathological studies to dynamic cross-disciplinary research frameworks.^{7–10} Current research encompasses diverse domains including immune regulation, osteoclast differentiation, signaling pathway interventions, and biomaterial-based tissue repair, creating a complex and multifaceted research landscape.^{11–15} However, despite the rapid



expansion of scientific outputs, the academic community still lacks systematic integration of shifting research priorities, knowledge network dynamics, and predictive trend modeling in RA bone erosion studies.

Bibliometrics, a quantitative research methodology grounded in big data analytics, reveals the intrinsic logic and frontier directions of disciplinary development by mining temporal-spatial distributions of academic literature, collaborative networks among authors, keyword co-occurrence patterns, and citation relationships.¹⁶ When integrated with knowledge graph visualization techniques, this approach transforms complex research themes, interdisciplinary intersections, and evolutionary trajectories into intuitive network structures, thereby offering panoramic insights into field advancement.^{17,18} This study employs bibliometric methods and analytical tools such as CiteSpace and VOSviewer to systematically analyze decade-long trends in scholarly output (2015–2024), characteristics of leading authors and institutional collaborations, evolution of research hotspots, and shifts in knowledge foundations within the RA bone erosion domain, using literature from the Web of Science (WoS) Collection as the dataset. A dynamic knowledge graph is constructed to visualize these findings. The results aim to provide empirical evidence for optimizing resource allocation and facilitating basic-to-clinical translation in this field, while establishing a visual reference framework to help researchers rapidly grasp the discipline’s intellectual landscape.

Materials and Methods

Data Acquisition and Search Strategies

This study conducted a comprehensive search in the WoS database on April 30, 2025, with the specific search strategy detailed in Table 1, covering a publication date range from January 1, 2015 to December 31, 2024. After preliminary screening, non-research document types such as conference abstracts, conference papers, editorial materials, book chapters, and retracted articles were excluded, and only English-language publications were retained. The final dataset was exported in plain text format for compatibility with CiteSpace and tab-delimited format tailored to the input requirements of VOSviewer, ensuring seamless integration with bibliometric analysis tools.

Bibliometric Analysis Tools

The software tools employed in this study included CiteSpace 6.4.R1, VOSviewer 1.6.19, Scimago Graphica 1.0.25, and WPS Excel 2023, complemented by the web platform Bioinformatics.com.cn (an online bioinformatics analysis and visualization cloud platform, <http://www.bioinformatics.com.cn>). CiteSpace was utilized for deduplication and organization of articles retrieved from WoS, with subsequent analyses encompassing co-occurrence networks, clustering networks, timeline mapping, and burst detection of references and keywords, followed by visualization. Parameter configurations were set as follows: time slicing (2015–2024, annual slices), threshold selection via the g-index (K=10), and network optimization using the Pathfinder algorithm to prune slice networks followed by secondary pruning after network merging. In visualized graphs, node diameters were proportional to frequency of occurrence, while link widths reflected co-occurrence strength. VOSviewer was applied to analyze and visualize collaborative networks of journals, cited journals, institutions, countries, authors, and cited authors within the paper corpus, with node diameters scaled to publication or citation counts and link widths indicating collaboration intensity. Scimago Graphica primarily facilitated country collaboration network visualization by importing GML-format country collaboration tables derived from VOSviewer, with parameters configured as: label=Country, cluster=String; node diameters mapped to national publication volumes, and link thickness determined by inter-country collaboration frequency. WPS Excel was employed for descriptive statistical analysis, generating bar charts and column graphs to represent diverse datasets.

Table 1 The Search Strategies

Set	Search Query
#1	TS= (“Rheumatoid Arthritis” OR “Juvenile Rheumatoid Arthritis” OR “Seropositive Rheumatoid Arthritis”)
#2	TS= (“Bone Erosion”)
#3	#1 and #2

Target Acquisition and Enrichment Analysis

The GeneCards database (<https://www.genecards.org/>) was searched using the keywords “rheumatoid arthritis” and “bone erosion” and targets with a Score ≥ 10 were screened and exported as disease-related targets.^{19,20} The intersection of targets obtained from “rheumatoid arthritis” and “bone erosion” was used for subsequent PPI and KEGG enrichment analyses. For the PPI analysis, the acquired targets were imported into the STRING database (<https://cn.string-db.org/>), with the species set to “Homo sapiens.” The following parameters were applied: minimum required interaction score = high confidence (0.700), and “hide disconnected nodes in the network” was selected.^{21,22} The resulting PPI network data were exported in TSV format and visualized using Cytoscape_v3.7.2 software (<https://cytoscape.org/>).²³ Based on the R 4.4.2 platform (www.r-project.org/), the clusterProfiler 4.6.2 package was employed to perform KEGG pathway enrichment analysis on the intersecting genes.^{24,25} The Benjamini-Hochberg method was used to correct for multiple hypothesis testing, and significant pathways (FDR < 0.05) were screened. After excluding human disease-related pathways, a “gene-pathway” regulatory network was constructed and visualized using Cytoscape.

Results

Annual Trends in Publication Output and Citation Frequency

Over the past decade, a total of 1,502 articles have been published on RA and bone erosion, with their annual publication volume and citation counts from 2015 to 2024 illustrated in Figure 1. The number of publications demonstrated an upward trend from 2015 to 2021, followed by a sharp decline in 2022 (42 articles), with subsequent recovery observed in 2023 and 2024. Regarding citation frequency, a linear growth trend was evident between 2015 and 2021, while the growth rate exhibited a significant reduction during the 2022–2024 period.

Country/Region-Specific Publication Output and Collaborative Networks

Scimago Graphica software was used to analyze countries/regions collaboration networks, identifying 5 distinct clusters (Figure 2A). The associations between countries were further illustrated by a chord diagram (Figure 2B). The proportion of publications contributed by the top 10 countries/regions ranked by total output was further visualized (Figure 2C). The number of articles, total citations, average citations, and Total Link Strength for the top 10 countries/regions ranked by total publication output are presented in Table 2.

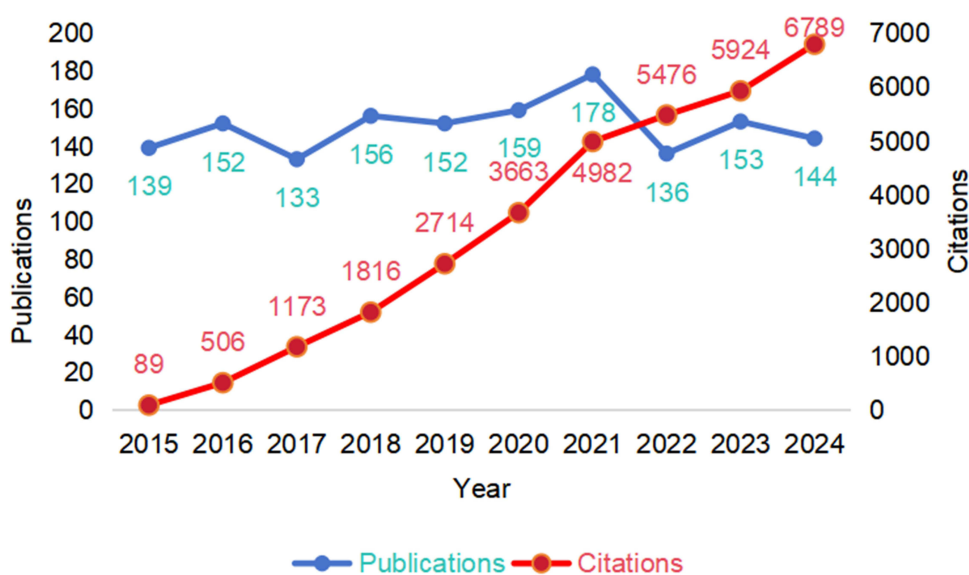


Figure 1 Publication Output and Citation Frequency in Rheumatoid Arthritis and Bone Erosion Research (2015–2024).

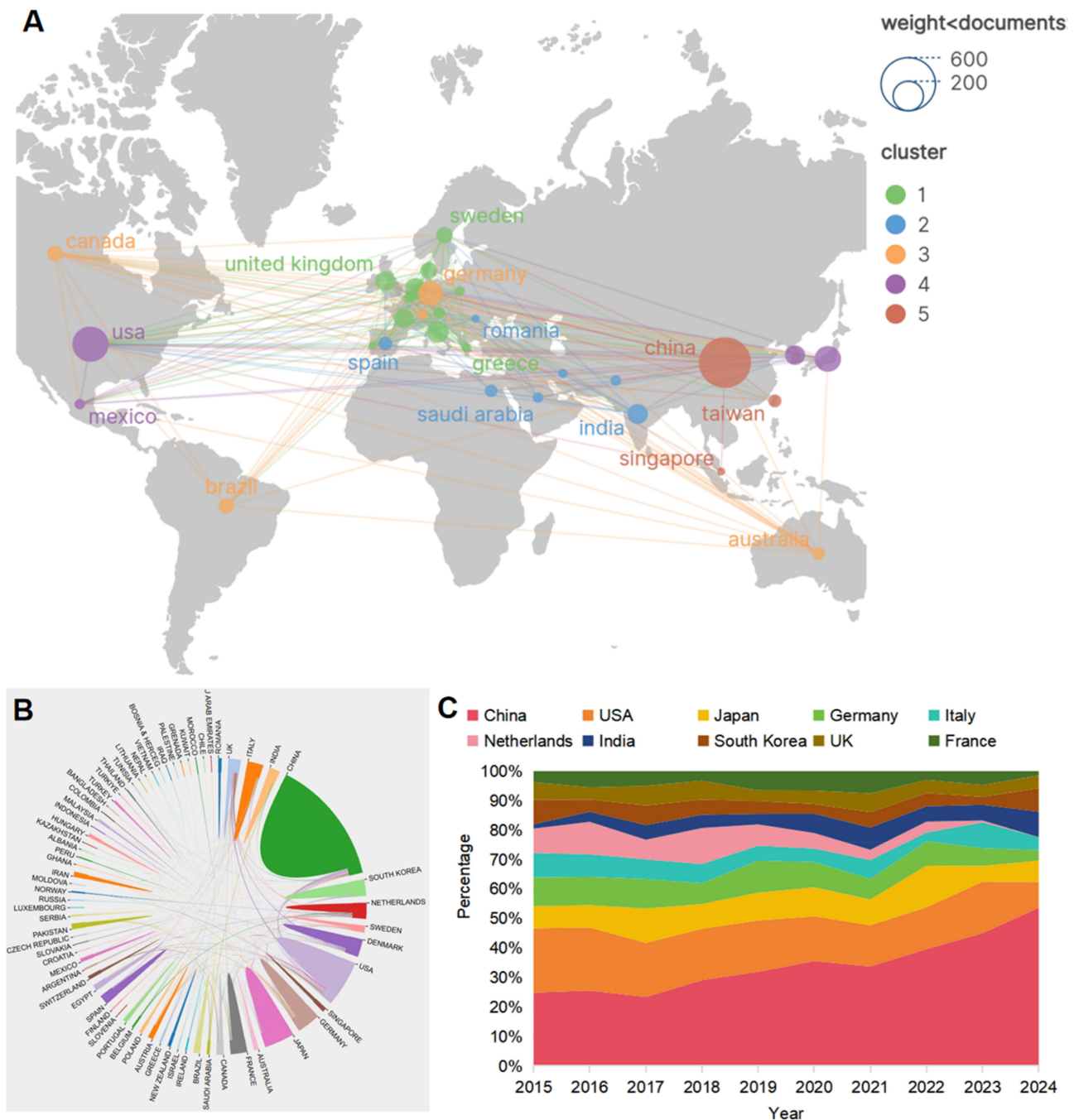


Figure 2 (A) Cluster analysis diagram of international collaboration networks among countries/regions. (B) Chord diagram visualizing inter-country/region collaborative linkages. (C) Proportional distribution of publications from the top 10 productive countries/regions by total article output.

Research Institutions and Association Analysis

The collaborative networks among research institutions were clustered and visualized via VOSviewer (Figure 3A). The top 10 institutions ranked by research output volume include Leiden University (31), University of Leeds (31), University of Copenhagen (27), China Medical University (26), Peking University (25), Sun Yat-sen University (24), University Hospital Erlangen (24), Sichuan University (22), Shanghai University of Traditional Chinese Medicine (22), Shanghai Jiao Tong University (22) (Figure 3B). Further analysis of institutional citation metrics revealed that while Leiden University (Netherlands) and the University of Leeds (UK) both ranked first with 31 research outputs, Leiden University demonstrated significantly higher citation impact (1,764 citations) and collaboration network strength (link strength 33), underscoring its

Table 2 The Top 10 Countries/Regions by Total Publication Volume

Rank	Country	Counts	Total Citations	Average Citation per Paper	Total Link Strength
1	China	493	11,186	22.7	98
2	USA	237	7833	33.1	257
3	Japan	128	3259	25.5	53
4	Germany	115	3971	34.5	145
5	Italy	88	1968	22.4	61
6	Netherlands	84	3130	37.3	154
7	India	75	1628	21.7	36
8	South korea	73	1238	17	24
9	United kingdom	73	2568	35.2	140
10	France	69	1834	26.6	102

pivotal influence and robust international partnerships in this field. In addition, research institutions such as the University of Copenhagen (Denmark), China Medical University (China), and Peking University (China) have demonstrated significant research capabilities and potential for international collaboration (Figure 3C and Table 3).

Distribution of Publications Across Journals

The top 10 journals by publication volume in RA and bone erosion research over the past decade, are comprehensively summarized in Table 4. The journal with the highest number of publications is *Arthritis Research & Therapy* (64), followed by *Frontiers in immunology* (47), *Clinical rheumatology* (43), *Annals of the rheumatic diseases* (40). It is noteworthy that although *Annals of the Rheumatic Diseases* has published only 40 articles in this research field, the journal holds a JCR Quartile Q1 ranking with an impressive impact factor of 20.3. The relevant articles exhibit an average citation count of 22.61 and a link strength of 258, underscoring its academic authority in RA and bone erosion research. This study employed VOSviewer software to conduct a visualization analysis of the association network among relevant journals (Figure 4).

Author Collaboration Network and Scholarly Impact

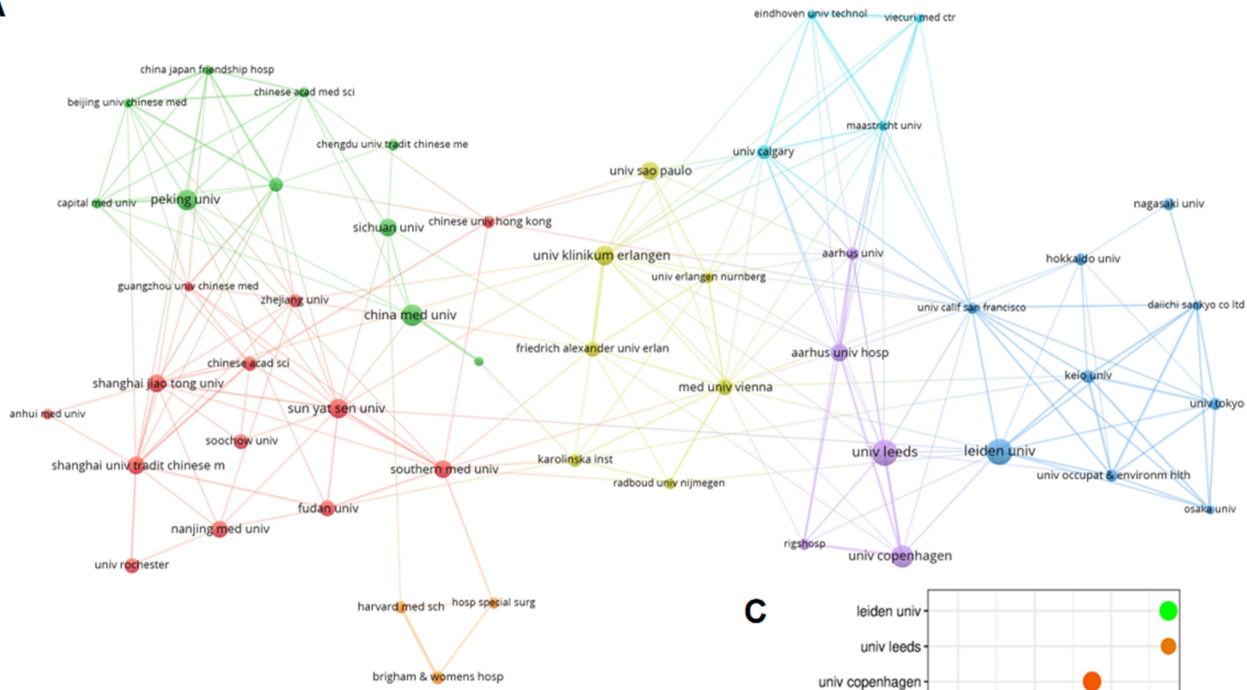
This study utilized VOSviewer software to analyze the authors engaged in RA and bone erosion research over the past decade, as well as their collaboration networks and academic influence (Figure 5). A total of 834 authors participated in studies related to RA and bone erosion. Information on the top 10 authors by number of publications is presented in Table 5. The most prolific author is Schett, Georg, with 34 published studies, the highest citation counts of 1,436, and a collaboration strength of 114. The second-ranking author is Kleyer, Arnd, with 19 publications, 706 citations, and a collaboration strength of 92. In addition, authors such as Rech, Juergen; Simon, David; and Conaghan, Philip G. also demonstrated considerable academic influence.

Keyword Co-Occurrence and Thematic Evolution Analysis

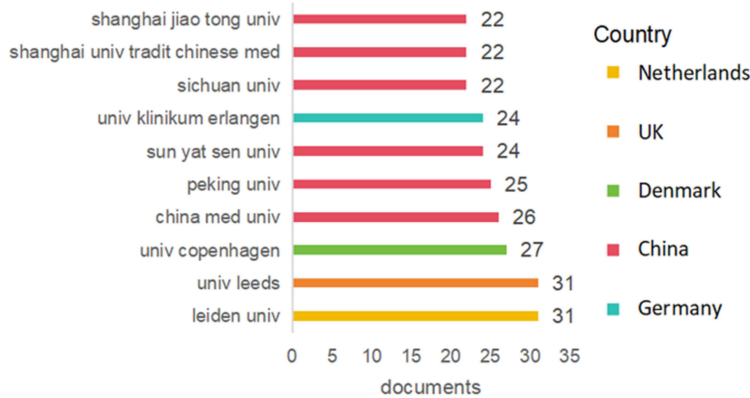
The keyword co-occurrence network and clustering analysis generated by VOSviewer identified 11 distinct keyword clusters (Figure 6A). A temporal mapping of keywords was performed using CiteSpace to reveal the composition and time distribution of each cluster (Figure 6B). In the analysis of burst keywords, the keywords that emerged in 2015 included wrist (9.26), joint inflammation (5.2). In 2016, new bursts appeared for joint damage (8.26), ankylosing spondylitis (6.38). Between 2017 and 2018, radiographic progression (7.56), joint destruction (5.86), bone marrow edema (6.5), quantitative computed tomography (6.48), cytokines (5.1), and early rheumatoid arthritis (4.64) showed significant activity. From 2019, ultrasonography (4.85) emerged. After 2020, keywords such as receptor (6.23), protein (5.8), reliability (5.23), and apoptosis (4.58) became prominent. Since 2021, burst keywords have included diagnosis (7.27), nanoparticles (9.57), delivery (7.38), mineral density (6.73), and proliferation (6.21) (Figure 6C).

According to keyword frequency and betweenness centrality statistics, rheumatoid arthritis was the most frequently mentioned keyword (1131 occurrences), representing the central theme in the literature on RA and bone erosion. In terms of

A



B



C

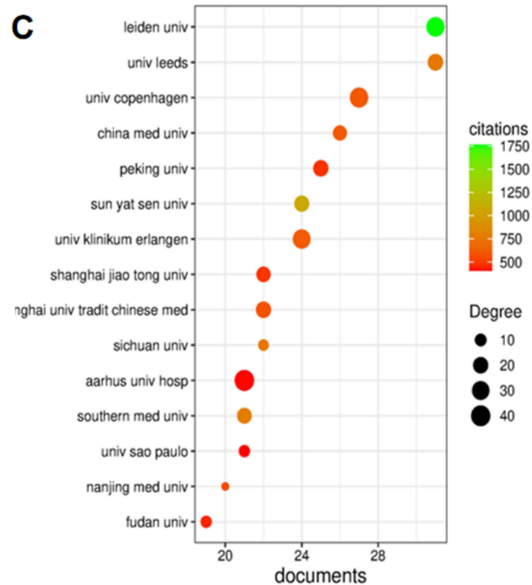


Figure 3 (A) Institutional collaboration network in rheumatoid arthritis and bone erosion research. **(B)** Top 10 institutions by number of publications. **(C)** Publications, citations, and degree centrality of leading institutions.

centrality, synovitis and double blind were tied for the highest centrality value (1.13). Other keywords such as bone mineral density (0.92), structural damage (0.88), and necrosis factor alpha (0.74) also exhibited strong network influence (Table 6).

Analysis of Cited References and Knowledge Structure

High-frequency co-cited references located at the core of the co-citation network include Smolen JS (2016, 2018), Takeuchi T (2016, 2019), McInnes IB (2011), Colebatch AN (2013), Harre U (2012), and Schett G (2012), with dense interconnections (Figure 7A). The co-citation clustering analysis identified 13 clusters (Figure 7B). Citation burst analysis revealed that 20 references exhibited significant citation bursts during 2015-2024. The reference with the strongest burst was Schett G (2012) (23.85), occurring from 2015 to 2017. This was followed by Smolen JS (2018) (17.91, 2020-2024), McInnes IB (2011) (17.31, 2015-2016) and Aletaha D (2018) (13.55, 2021-2024). The citation bursts were primarily concentrated in two periods: 2015-2016 and 2019-2021. Several references, such as Guo QY (2018) and Smolen JS (2020), showed sustained citation bursts over the past three years (Figure 7C).

Table 3 Ranking of the Top 10 Institutions by Publication Volume

Rank	Organization	Documents	Citations	Total Link Strength	Country
1	Leiden University	31	1764	33	Netherlands
2	University of Leeds	31	758	21	UK
3	University of Copenhagen	27	601	35	Denmark
4	China Medical University	26	602	16	China
5	Peking University	25	470	20	China
6	Sun Yat-sen University	24	1072	19	China
7	University Hospital Erlangen	24	608	32	Germany
8	Sichuan University	22	752	8	China
9	Shanghai University of Traditional Chinese Medicine	22	572	20	China
10	Shanghai Jiao Tong University	22	481	17	China

Table 4 Top 10 Journals by Total Number of Publications

Rank	Journal Title	Countries	Counts	Average Citations	IF (2024)	JCR (2024)	Total Link Strength
1	Arthritis Research & Therapy	Britain	64	13.6	4.4	Q2	152
2	Frontiers in Immunology	Switzerland	47	11.83	5.7	Q1	87
3	Clinical Rheumatology	Germany	43	3.96	2.9	Q3	92
4	Annals of the Rheumatic Diseases	Britain	40	22.61	20.3	Q1	258
5	Rheumatology	Britain	37	5.05	4.7	Q1	119
6	Scientific reports	Britain	35	6.99	3.8	Q2	75
7	International Immunopharmacology	Netherlands	34	8.10	4.8	Q2	53
8	Arthritis & Rheumatology	The United States	30	12.50	11.4	Q1	134
9	International Journal of Rheumatic Diseases	Australia	30	3.24	2.4	Q3	95
10	Journal of Rheumatology	Canada	28	4.08	3.6	Q2	125

Co-Expressed Genes and Functional Enrichment Analysis

Through retrieval of the Genecard database, we identified 467 and 721 differentially expressed genes associated with RA and bone erosion, respectively, with 211 overlapping genes obtained via cross-analysis. Key targets were identified through PPI analysis of the overlapping genes (Figure 8A), and the top 20 of these targets were subsequently visualized using a bar chart (Figure 8B). KEGG pathway enrichment analysis of the overlapping genes identified 68 relevant signaling pathways. The top 15 enriched pathways were presented in a bubble plot (Figure 8C), and their associations with the targets were further visualized using Cytoscape software (Figure 8D).

Discussion

Bone erosion represents a core pathological mechanism in RA, wherein synovitis-derived inflammatory mediators drive osteoclast activation and pannus development, resulting in progressive and irreversible articular structural destruction with subsequent functional disability.^{45–47} Bone erosion can occur early in RA, with radiographic evidence appearing in 10% of patients within 8 weeks of disease onset and in up to 60% of patients within one year.⁴⁸ Bone erosion is typically correlated with disease activity and joint functional deterioration, playing a critical role in predicting RA prognosis and monitoring treatment efficacy.^{49,50} Since the occurrence of bone erosion is closely linked to joint damage, halting its progression has become a critical objective in the treatment of RA.

At different stages of bone erosion development in RA, various medical disciplines exhibit distinct therapeutic characteristics, and multidisciplinary care plays a crucial role.^{51–54} Rheumatology serves as the leading discipline in the diagnosis and management of the disease, with rheumatology healthcare professionals involved in diagnosis, treatment, and prognostic care. Radiology is essential for assessing the severity of RA-related bone erosion damage. Rehabilitation medicine employs multiple therapies, such as functional exercise, thermotherapy, and electrotherapy, to restore function,

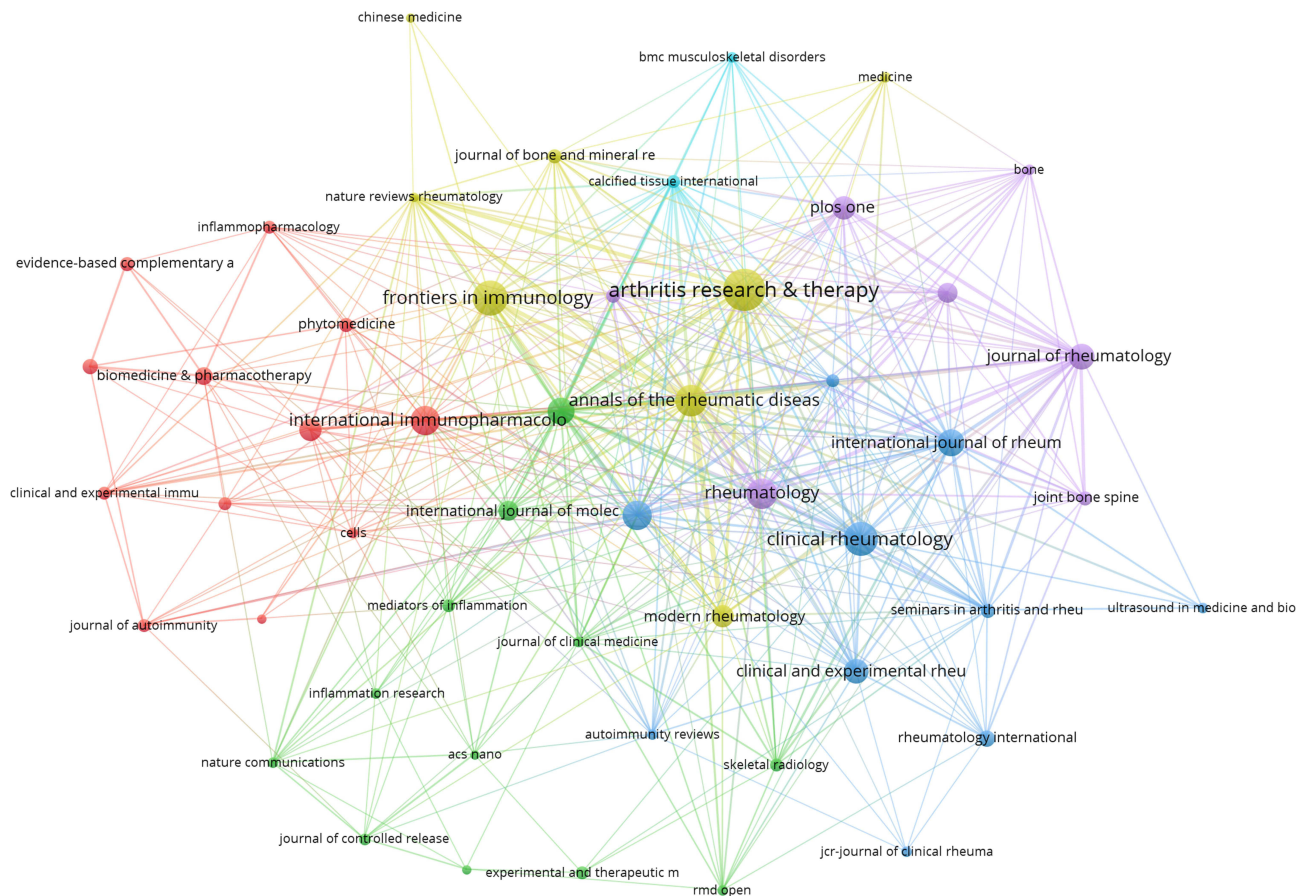


Figure 4 Co-citation network of journals related to rheumatoid arthritis and bone erosion research.

prevent disability, and enable patients to return to normal life to the greatest extent possible. Comprehensive multidisciplinary treatment contributes to improving the prognosis of RA patients with bone erosion.^{55–57} Therefore, conducting a bibliometric analysis of RA and bone erosion can help reveal patterns of disease progression, treatment principles, and research trends from a multidisciplinary medical perspective.

Bibliometric analyses indicate that publications in the field of RA and bone erosion over the past decade have exhibited a trend of initial growth, followed by a decline and subsequent resurgence. The early increase in publication volume and citation frequency suggests rapid development in this research area, likely driven by advances in immunology and imaging technologies. The decline in publication output and citation growth in 2022 may be attributed to disruptions in clinical trials and the diversion of research resources to COVID-19 studies, consistent with findings from prior research.⁵⁸ By 2023, publication numbers gradually recovered to near-previous levels, indicating a revival of interest in this field. At the national level, China ranked first in total publications, with a proportion that has steadily increased, underscoring its dominant position in this research domain. The United States ranked second, though its proportion has gradually declined, suggesting a relative weakening of its leadership in this area. Analysis of international collaboration networks revealed close cooperation among countries, with clustering analysis further demonstrating that these collaborations exhibit distinct regional characteristics.

At the institutional level, the top 10 contributing institutions were concentrated in Europe and China, with Leiden University (Netherlands) and the University of Leeds (UK) producing the highest number of research outputs. However, Leiden University's higher citation counts and stronger total link strength indicate greater influence and international collaboration capabilities compared to the University of Leeds. Co-occurrence clustering analysis of institutions revealed that collaborations are predominantly regionally constrained, highlighting the need for stronger cross-regional and inter-institutional partnerships to overcome geographical barriers. The journal *Arthritis Research & Therapy* published the

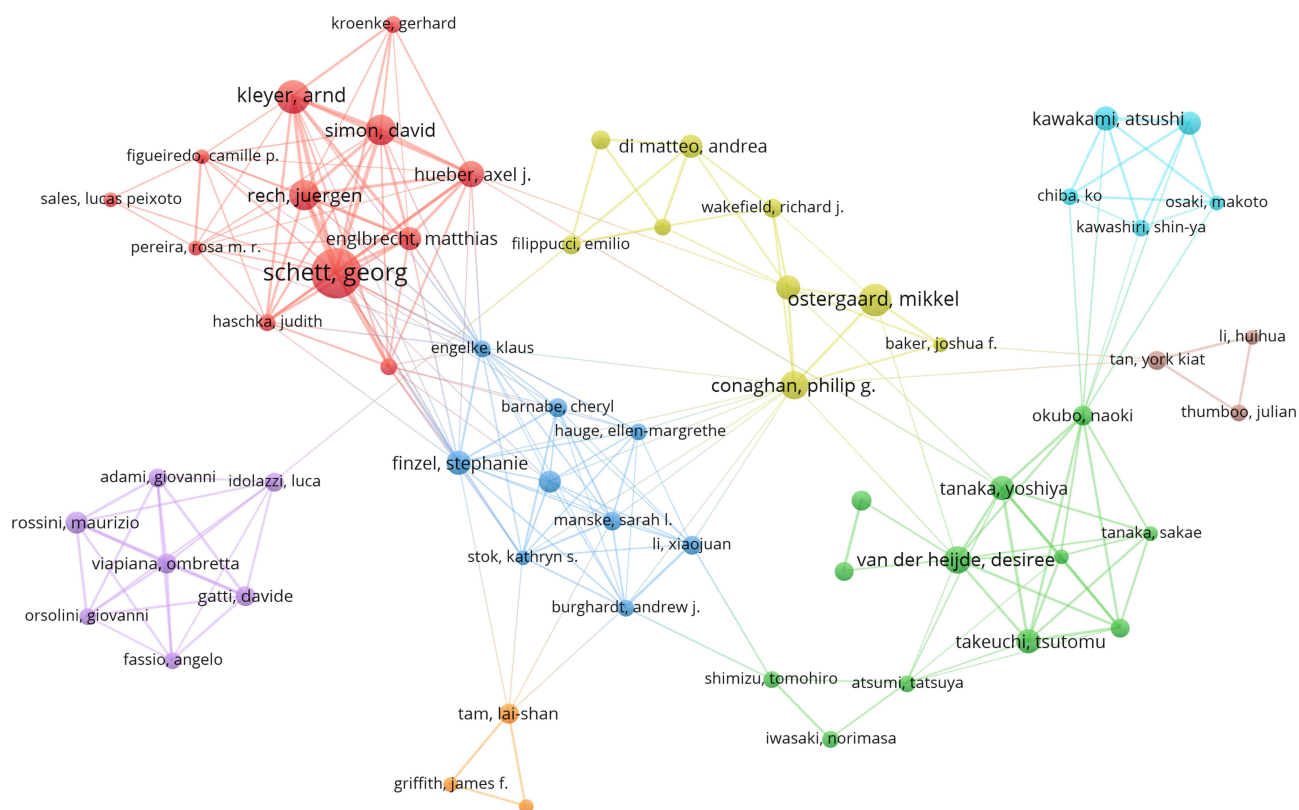


Figure 5 Author collaboration network in rheumatoid arthritis and bone erosion research.

highest number of studies in this field, while *Annals of the Rheumatic Diseases* held greater academic authority in RA and bone erosion research. Among authors, Professor Georg Schett ranked first in publication volume, citation frequency, and collaboration strength, demonstrating exceptional academic influence and pioneering contributions to the study of bone erosion mechanisms.

Keyword clustering analysis identified research hotspots in three main areas: RA diagnostic techniques, bone erosion mechanisms, and therapeutic research. Keywords such as ultrasound, magnetic resonance imaging, and ultrasonography reflected the application of imaging technologies in assessing RA-related bone erosion. High-frequency ultrasound has become a cornerstone tool for early RA diagnosis, enabling simplified disease evaluation by detecting synovial thickening, blood flow signals, and bone erosion markers.⁵⁹ Standardization of ultrasound protocols has facilitated its use

Table 5 Top 10 Most Productive Authors in Rheumatoid Arthritis and Bone Erosion Research

Rank	Author	Documents	Citations	Total Link Strength	Country
1	Schett, Georg	34	1436	114	Germany
2	Kleyer, Arnd	19	706	92	Germany
3	Ostergaard, Mikkell	18	464	18	Denmark
4	Rech, Juergen	16	868	81	Germany
5	Simon, David	16	567	77	Germany
6	Conaghan, Philip G.	15	440	31	UK
7	Van der Heijde, Desiree	14	1251	39	Netherlands
8	Hueber, Axel J.	13	608	68	Germany
9	Rasool, Mahaboobkhan	13	427	0	India
10	Takeuchi, Tsutomu	12	599	42	Japan

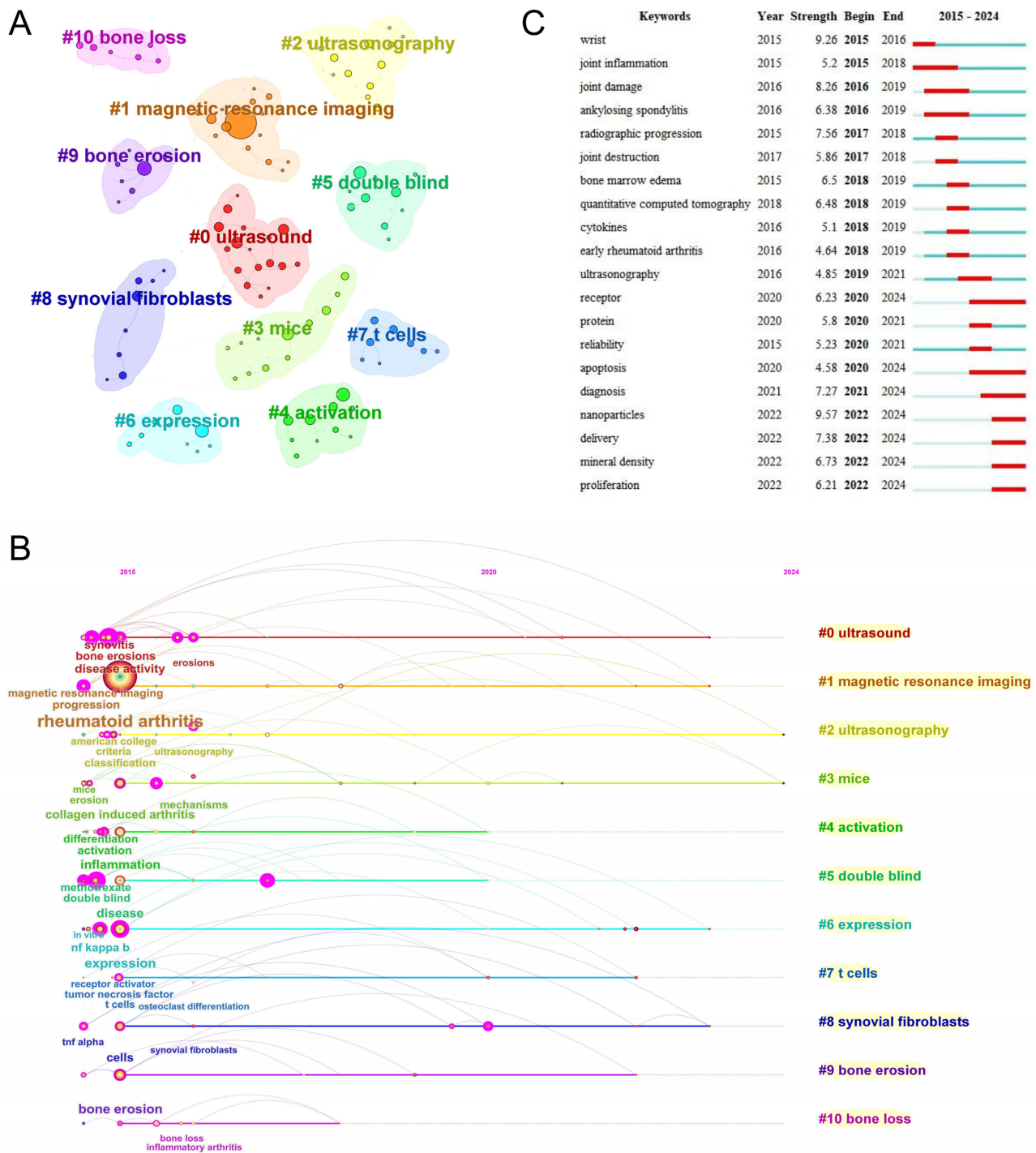


Figure 6 (A) Keyword clustering map based on co-occurrence network analysis. (B) Timeline view of keyword evolution across major clusters. (C) Top 20 keywords with the strongest citation bursts from 2015 to 2024.

in RA subtyping and treatment efficacy assessment.^{60–62} MRI, with its high soft-tissue resolution, can identify early bone marrow edema and joint structural damage, offering unique advantages in predicting bone erosion progression and informing prognosis.^{63,64} Keywords such as T cells, synovial fibroblasts, and mice reflected mechanistic and methodological research on bone erosion, including inflammation and immune regulation mechanisms, as well as animal model applications. T cell-mediated inflammatory responses drive bone erosion in RA by secreting cytokines such as IL-17 and

Table 6 Top 10 Keywords by Frequency and Top 10 Keywords by Centrality

Rank	Keyword	Count	Keyword	Centrality	Rank
1	Rheumatoid arthritis	1131	Synovitis	1.13	1
2	Bone erosion	201	Double blind	1.13	2
3	Expression	195	Bone mineral density	0.92	3
4	Inflammation	172	Structural damage	0.88	4
5	Disease	156	Necrosis factor alpha	0.74	5
6	Collagen induced arthritis	143	Rankl	0.68	6
7	disease activity	127	bone marrow edema	0.61	7
8	cells	118	magnetic resonance imaging	0.56	8
9	bone erosions	113	nfkB	0.55	9
10	activation	104	erosions	0.49	10

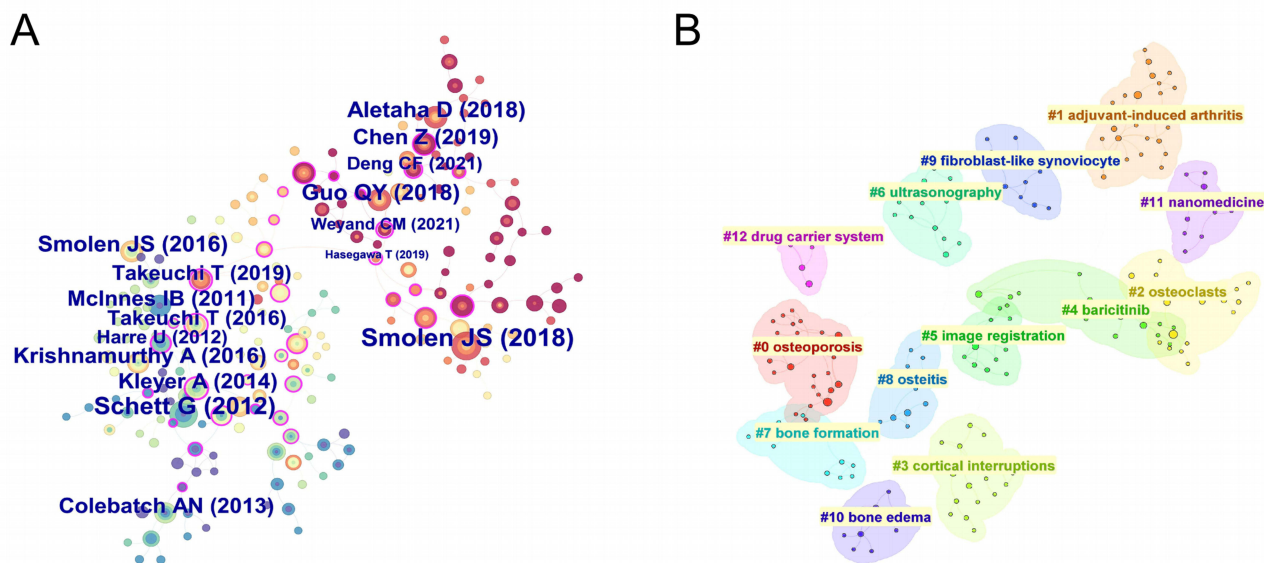
RANKL, which activate osteoclasts and suppress osteoblast function. Aberrant proliferation and proinflammatory cytokine secretion by synovial fibroblasts promote pannus formation, leading to cartilage and bone destruction.^{65,66} The CIA mouse model is widely used to simulate RA-induced bone erosion, providing a platform for mechanistic studies and targeted therapy development.⁶⁷ Keywords such as double blind and activation reflected research on therapeutic strategies and clinical trials for RA-related bone erosion. The emerging keyword timeline revealed a clear research trajectory: early studies (2015–2018) focused on disease symptoms and pathological manifestations, including joint inflammation and structural damage; mid-term studies (2018–2021) emphasized technological innovations, particularly diagnostic techniques and standardization; and recent studies (2020–2024) prioritized molecular mechanisms and precision medicine, exploring targeted biologic therapies.

Citation-based analysis demonstrated that highly cited literature in this field forms a tightly interconnected knowledge network, confirming its foundational role in RA bone erosion research. Clustering analysis further identified three major research themes: pathological mechanisms, diagnostic technologies, and treatment strategies, aligning with keyword clustering results. Temporally, citation burst themes evolved from mechanistic exploration to therapeutic translation, with novel treatments such as JAK inhibitors gaining prominence.

Genetic analysis of RA and bone erosion revealed substantial overlap in core genes and signaling pathways, synergistically driving disease progression. Overlapping genes frequently included inflammation-related molecules (TNF, IL6, IL1B, IL10, IFNG) and immune regulators (STAT3, TLR4, CCL2), further corroborating the central role of chronic inflammation and immune dysregulation in RA-related joint and bone damage. KEGG enrichment analysis showed that overlapping genes were significantly enriched in immune response and osteoclast differentiation. Cytokine-cytokine receptor interaction signaling pathway plays a pivotal role in the pathogenesis of RA. In RA, dysregulated cytokine networks involving TNF- α , IL-6, IL-1 β , and IL-17 mediate chronic synovial inflammation, osteoclast activation, and joint destruction by binding to their respective receptors and activating downstream signaling pathways.⁶⁸ The activation of key signaling pathways, including the TNF, Toll-like receptor, IL-17, NF κ B, JAK-STAT, NOD-like receptor, and PI3K-Akt pathways, is closely associated with pro-inflammatory cytokines.⁶⁹ These inflammatory responses further modulate T cell differentiation, thereby influencing Th17 cell differentiation, Th1/Th2 cell polarization, and T cell receptor signaling, which collectively exacerbate immune dysregulation. Additionally, the inflammatory microenvironment upregulates the Receptor Activator of Nuclear Factor- κ B Ligand (RANKL), promoting osteoclast differentiation and ultimately exacerbating bone erosion in RA.⁷⁰

Limitations

This study has several limitations in data sources and methodology: First, the literature search was confined to the WOS Collection, ensuring quality but potentially omitting emerging or regional studies from other platforms. Second, the analysis included only research articles and reviews, excluding conference papers, case reports, and technical documents, which may contain innovative findings or technical details. Additionally, the bibliometric framework emphasized



(C) Top 20 references with the strongest citation bursts and their active periods (2015–2024).

References	Year	Strength	Begin	End	2015 - 2024
Schett G, 2012, NAT REV RHEUMATOL, V8, P656, DOI 10.1038/nrrheum.2012.153, DOI	2012	23.85	2015	2017	
McInnes IB, 2011, NEW ENGL J MED, V365, P2205, DOI 10.1056/NEJMr1004965, DOI	2011	17.31	2015	2016	
Colebatch AN, 2013, ANN RHEUM DIS, V72, P804, DOI 10.1136/annrheumdis-2012-203158, DOI	2013	10.36	2015	2018	
Harre U, 2012, J CLIN INVEST, V122, P1791, DOI 10.1172/JCI60975, DOI	2012	10.25	2016	2017	
Kleyer A, 2014, ANN RHEUM DIS, V73, P854, DOI 10.1136/annrheumdis-2012-202958, DOI	2014	10.24	2016	2019	
Smolen JS, 2014, ANN RHEUM DIS, V73, P492, DOI 10.1136/annrheumdis-2013-204573, DOI	2014	9.21	2016	2017	
Hecht C, 2015, ANN RHEUM DIS, V74, P2151, DOI 10.1136/annrheumdis-2014-205428, DOI	2015	8.06	2016	2018	
Smolen JS, 2016, LANCET, V388, P2023, DOI 10.1016/S0140-6736(16)30173-8, DOI	2016	7.88	2017	2019	
Barnabe C, 2016, J RHEUMATOL, V43, P1935, DOI 10.3899/jrheum.160648, DOI	2016	8.24	2018	2021	
Smolen JS, 2017, ANN RHEUM DIS, V76, P960, DOI 10.1136/annrheumdis-2016-210715, DOI	2017	12.49	2019	2021	
Smolen JS, 2016, LANCET, V388, P1984	2016	11.22	2019	2021	
Zayat AS, 2015, ANN RHEUM DIS, V74, P897, DOI 10.1136/annrheumdis-2013-204864, DOI	2015	10.28	2019	2020	
McInnes IB, 2017, LANCET, V389, P2328, DOI 10.1016/S0140-6736(17)31472-1, DOI	2017	8.61	2019	2022	
Smolen JS, 2018, NAT REV DIS PRIMERS, V4, P0, DOI 10.1038/nrdp.2018.1, DOI	2018	17.91	2020	2024	
Guo QY, 2018, BAMBOO SILK, V1, P1, DOI 10.1038/s41413-018-0016-9, DOI	2018	10.67	2020	2024	
Aletaha D, 2018, JAMA-J AM MED ASSOC, V320, P1360, DOI 10.1001/jama.2018.13103, DOI	2018	13.55	2021	2024	
Takeuchi T, 2019, ANN RHEUM DIS, V78, P899, DOI 10.1136/annrheumdis-2018-214827, DOI	2019	9.82	2021	2024	
Smolen JS, 2020, ANN RHEUM DIS, V79, P685, DOI 10.1136/annrheumdis-2019-216655, DOI	2020	9.08	2021	2024	
Burmester GR, 2017, LANCET, V389, P2338, DOI 10.1016/S0140-6736(17)31491-5, DOI	2017	8.62	2021	2022	
Nygaard G, 2020, NAT REV RHEUMATOL, V16, P316, DOI 10.1038/s41584-020-0413-5, DOI	2020	10.9	2022	2024	

Figure 7 (A) Co-citation network of highly cited references from 2015 to 2024. (B) Cluster analysis of co-cited references revealing thematic research areas. (C) Top 20 references with the strongest citation bursts and their active periods (2015–2024).^{26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44}

quantitative metrics, with limited depth in qualitative dimensions such as theoretical model construction or clinical translation. Future studies should address these limitations by incorporating diverse data sources and methodologies to more comprehensively reveal the research dynamics and knowledge evolution in RA bone erosion.

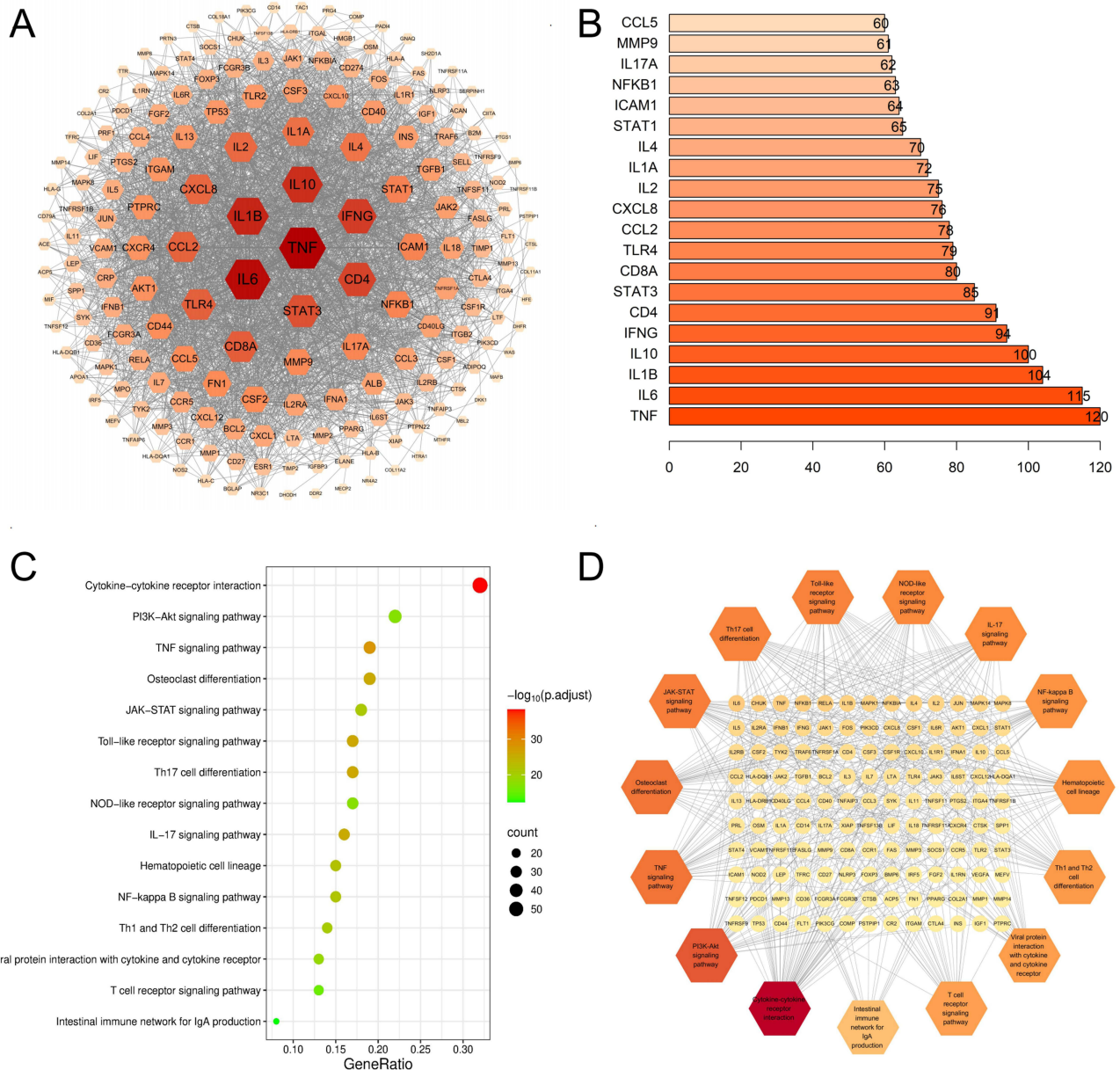


Figure 8 (A) Protein-protein interaction (PPI) network visualization generated using Cytoscape. (B) Top 20 hub targets identified from the PPI network. (C) Top 15 significantly enriched KEGG pathways based on pathway enrichment analysis. (D) Interaction network depicting associations between signaling pathways and their corresponding targets.

Conclusion

Based on the WOS Collection, this study employed bibliometric methods to analyze RA and bone erosion research from 2015 to 2024 and systematically reviewed the research landscape, hotspots, and frontier trends. Bioinformatics analysis further elucidated shared targets and pathways between RA and bone erosion, offering insights to improve disease management and therapeutic strategies. The findings demonstrate growing global interest in this field over the past decade, with research focuses centered on RA diagnostic technologies, bone erosion mechanisms, and therapeutic research. Early studies emphasized disease symptoms and pathological manifestations, mid-term studies prioritized diagnostic technologies and standardization, and recent studies explored molecular mechanisms and precision medicine, including targeted biologic therapies. Bioinformatics analysis highlighted significant enrichment of immune response, infection-related, and bone metabolism pathways, suggesting their critical roles in RA-bone erosion comorbidity. This

study provides a quantitative perspective on the evolution of RA bone erosion research, informing clinical decision-making and guiding future investigations through bioinformatics-driven insights.

Ethical Statement

According to article 32 of the “Measures for Ethical Review of Life Sciences and Medical Research Involving Humans” issued by Chinese government departments on February 18, 2023, ethical review may be exempted for life sciences and medical research involving humans that uses personal information data or biological samples under the following circumstances, provided that it causes no harm to human subjects, involves no sensitive personal information or commercial interests, thereby reducing unnecessary burdens on researchers and facilitating the conduct of such research. These circumstances include: (1) research utilizing legally obtained public data or data generated through observation without interference in public behaviors; (2) research conducted using anonymized information data. In this study, the retrieval and bibliometric analysis of relevant literature via the WOS database fulfill the above conditions, thus qualifying for an ethics exemption.

Funding

This study was supported by the National Natural Science Foundation of China (No. 82274435, 82074223).

Disclosure

The authors report no conflicts of interest in this work.

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