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Bibliometric Analysis of Magnesium and Bone

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Abstract

Background: In recent years, research on the association between magnesium and bone has gained widespread attention. Magnesium plays an important role in bone health, and magnesium alloys and magnesium nanoparticles have potential applications as biomaterials in the field of orthopedics. ***Methods:*** This study employed a comprehensive literature review and analysis to summarize the interactions and application areas of magnesium and bone. Through bibliometric analysis, the research trends and international landscape of zinc and bone studies were evaluated. ***Results:*** The results indicate a continuous growth in research related to zinc and bone, with China playing a key role in this field. The Chinese Academy of Sciences was identified as the core institution for zinc and bone research, and Qin Ling emerged as a central author in this domain. The study also found that magnesium alloys hold potential for applications in orthopedic implant materials, while magnesium nanoparticles can promote bone formation and exhibit anti-inflammatory and antibacterial activities. ***Conclusions:*** This study emphasizes the importance of international collaboration and interdisciplinary research in advancing global research on zinc and bone. However, bibliometric analysis has certain limitations and should be complemented with qualitative methods and expert knowledge for comprehensive evaluation. Future research directions include optimizing the degradation performance of magnesium alloys, gaining a deeper understanding of the mechanisms underlying magnesium's role in bone formation, and exploring innovative approaches such as functional coatings and material surface modification techniques. These findings provide valuable guidance and prospects for further exploration of the relationship between magnesium and bone and the development of innovative solutions for bone health.

Keywords: magnesium, bone, bibliometric, VOSviewer

1. Background

Magnesium is one of the essential minerals required by the human body, playing a crucial role in numerous biological processes. In addition to its functions in protein synthesis, nerve conduction, and energy metabolism, magnesium is vital for maintaining skeletal health (Erem S, Atfi A & Razzaque MS., 2019). The skeleton serves as the supportive system of the human body, providing not only stability and mobility but also serving as a reservoir for calcium and other minerals, supplying essential nutrients to the body. However, the increasing occurrence of skeletal disorders such as osteoporosis has sparked concern regarding the maintenance of skeletal health. Calcium has traditionally been regarded as the most crucial nutrient for skeletal health, with magnesium emerging as its important partner. There is a causal relationship between dietary magnesium intake and the maintenance of normal bone structure (Rondanelli M, Faliva MA, Tartara A, et al, 2021). Magnesium not only participates in the regulation and absorption of calcium in the bones but also directly influences the functionality

of bone cells and the synthesis of the bone matrix. Inadequate magnesium levels may lead to osteoporosis and an increased risk of fractures, while sufficient magnesium intake helps maintain bone density and the overall health of the skeletal system (Nakamura K, Ueno K, Nishiwaki T, Saito T, Tsuchiya Y & Yamamoto M., 2007; Hayhoe RPG, Lentjes MAH, Luben RN, Khaw KT & Welch AA., 2015). Furthermore, in the field of orthopedics, magnesium has garnered significant attention due to its excellent biodegradability and mechanical properties (Weng L & Webster TJ., 2012).

Bibliometrics is a discipline that studies the quantity, quality, distribution, and utilization of scientific literature. It applies mathematical and statistical methods to analyze and evaluate the characteristics and trends of scientific publications, aiming to understand the dynamics and impact of academic research. The main objectives of bibliometrics include literature production analysis, citation analysis, academic evaluation and ranking, and scientific collaboration network analysis. Common indicators include literature output indicators (such as the number of papers, citation frequency), impact indicators (such as impact factor, h-index), and collaboration indicators (such as co-authorship count, co-authorship network). Researchers can utilize these indicators for quantitative analysis and comparison, providing reference for scientific decision-making, academic evaluation, and research planning. Currently, bibliometrics has been widely applied in the field of orthopedics. However, there is currently a lack of bibliometric analysis on research related to magnesium in the field of bone. Therefore, the purpose of this study is to conduct statistical and analytical research on publications, countries, institutions, authors, and keywords related to zinc and bone research, in order to explore the development trends and frontier hotspots in zinc and bone research.

2. Methods

The literature was sourced from the Web of Science (WOS) Core database. The search method used was as follows: TI= magnesium and bone. The search period was from January 1, 2001, to June 14, 2023. The selected document types were articles and reviews. Irrelevant content, conference papers, and duplicate literature were excluded. The literature language was limited to Chinese. To ensure consistency, the search was completed on June 14, 2023, to avoid any database updates. The literature search process is illustrated in Figure 1. The search results were exported in plain text format, and information such as country, institution, author, and keywords were extracted. Visualization tools used included Excel 2019 and VOSviewer. Excel 2019 was used to create charts for annual publication output and citation analysis. VOSviewer was used for visual analysis of countries, institutions, authors, and keywords.

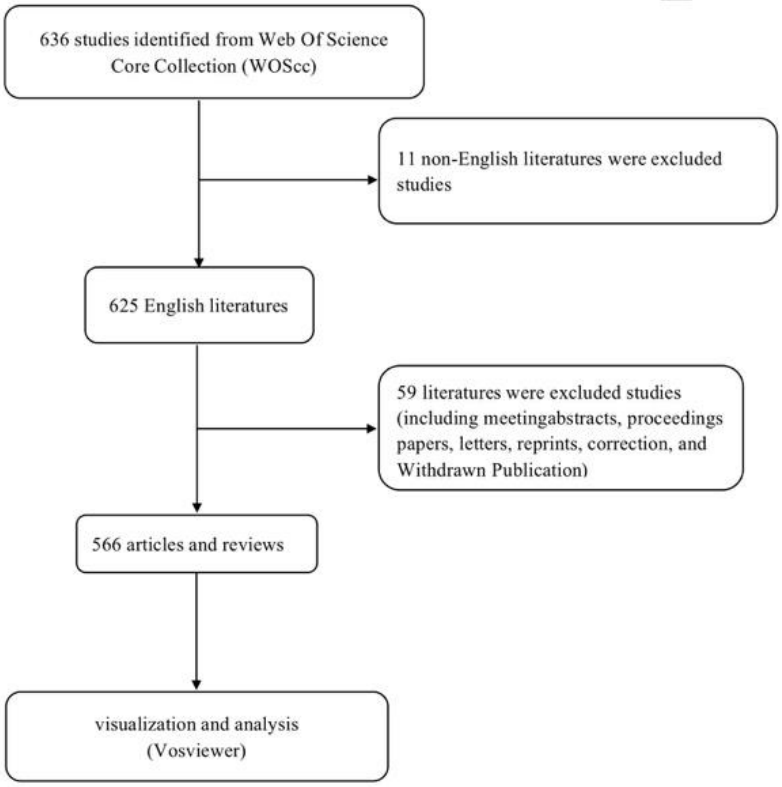


Figure 1. Documents retrieval flow chart

3. Results

3.1 General Information

A total of 566 literature items related to magnesium and bone were found. The total citation count was 10,637, with an average citation count of 31.94 and an h-index of 62. Figure 2 shows the annual trends in publication output and citation count. It can be observed that research related to magnesium and bone has shown an upward trend from 2001 to 2023. The publication output slowly increased from 2001 to 2013, followed by a rapid increase in publication output after 2014, reaching a peak of 87 publications in 2018. The citation count has also increased over the years. These results indicate a vibrant development trend in research related to magnesium and bone.

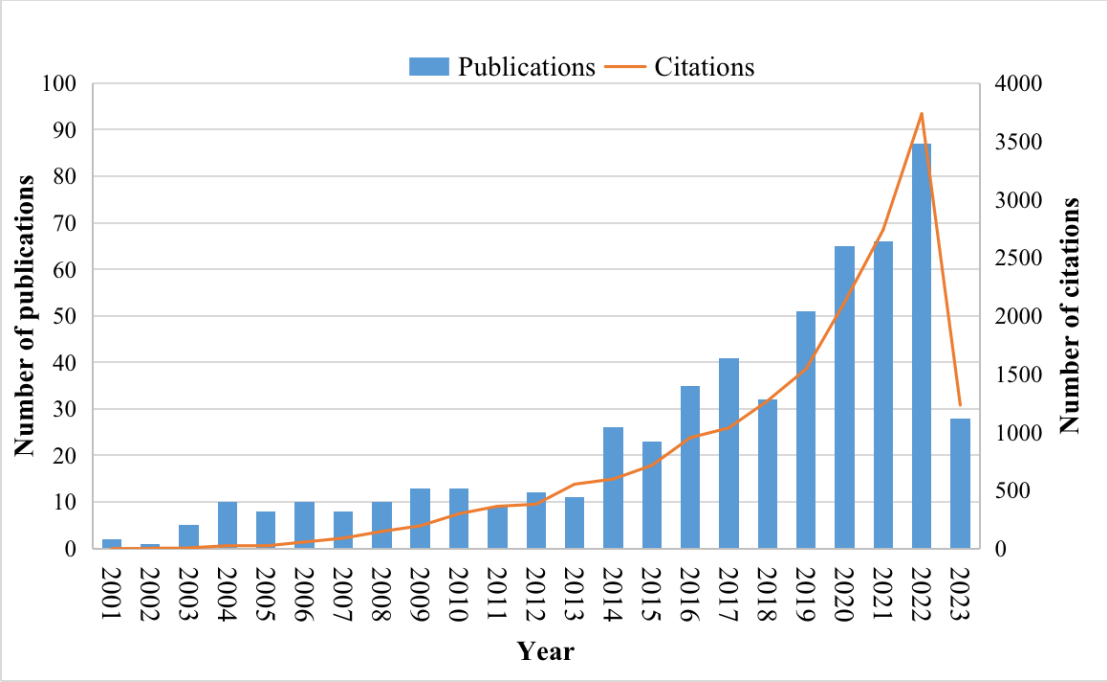


Figure 2. The annual number of publications and citations related to magnesium and bone

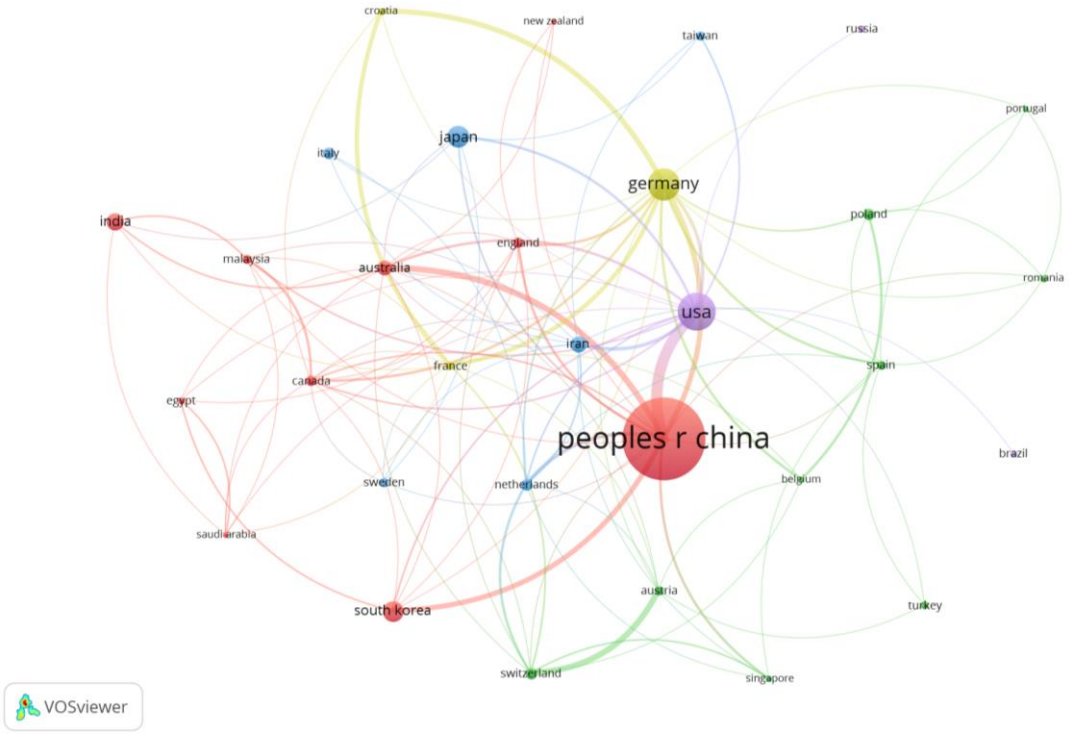
3.2 Countries/Regions Analysis

A total of 60 countries/regions have contributed articles related to magnesium and bone. The top ten countries/regions in terms of publication output are listed in Table 1. Among them, China ranks first with 227 articles, followed by the United States with 75 articles, and Germany with 61 articles. In terms of citations, China ranks first with 6,844 citations, followed by Germany (3,678 citations) and the United States (3,678 citations). Figures 3A and 3B display the network map of country collaborations and overlay visualization, respectively. It can be observed that China collaborates with countries such as the United States, Australia, Germany, and Japan. Additionally, the United States and Japan have an earlier average publication time, China has a middle-range average publication time, while countries like India, France, and the Netherlands have a relatively later average publication time. Therefore, based on the above information, it can be concluded that China not only has the closest collaborations with other countries in magnesium and bone research but also holds the most significant influence.

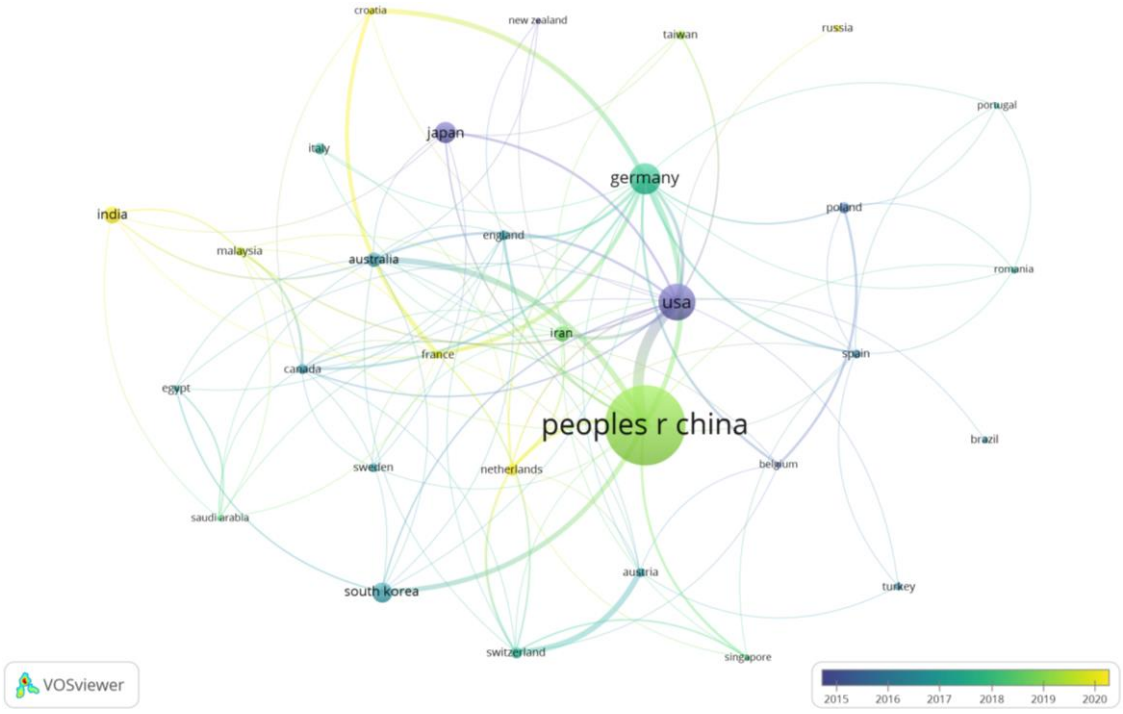
Table 1. The top ten productive countries

Rank	Country	Documents	Citations
1	China	227	6844
2	USA	75	3678
3	Germany	61	4398
4	Japan	35	513

5	South Korea	32	1016
6	India	346	26
7	Iran	23	406
8	Australia	20	586
9	Switzerland	15	1278
10	Poland	15	243



(**A**) Cooperation networks across countries



(**B**) Overlay Visualization of countries

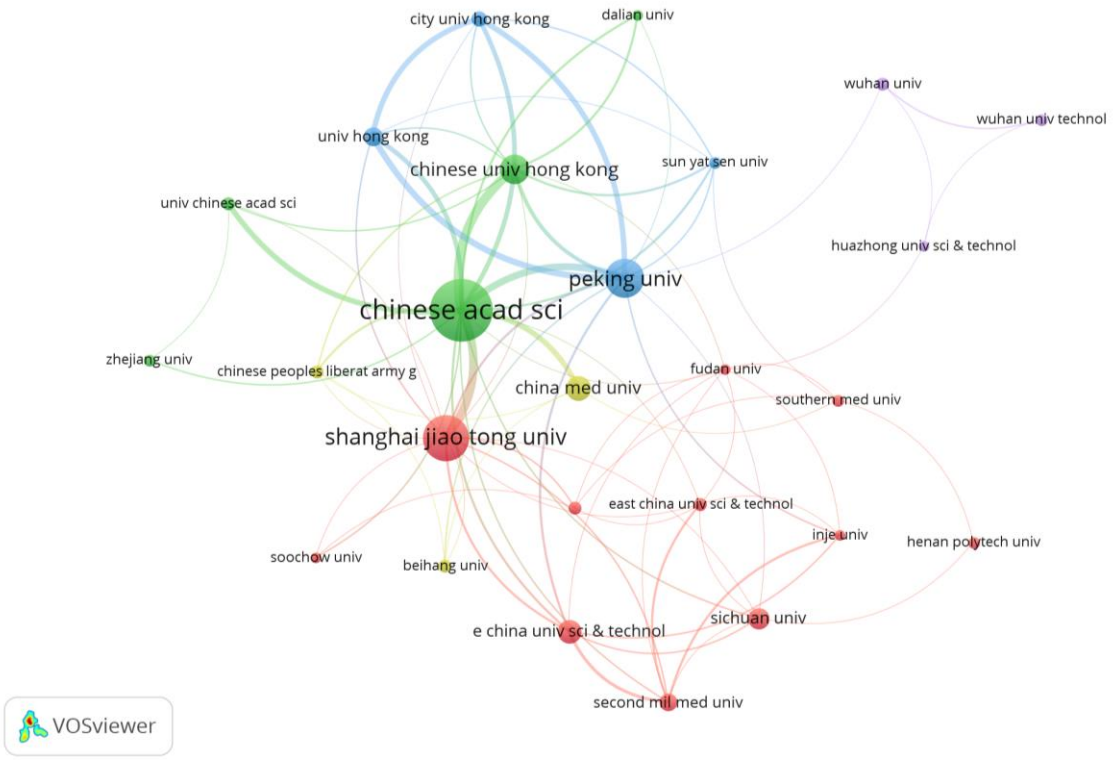
Figure 3. Co-authorship analysis of countries

3.3 Institutional Analysis

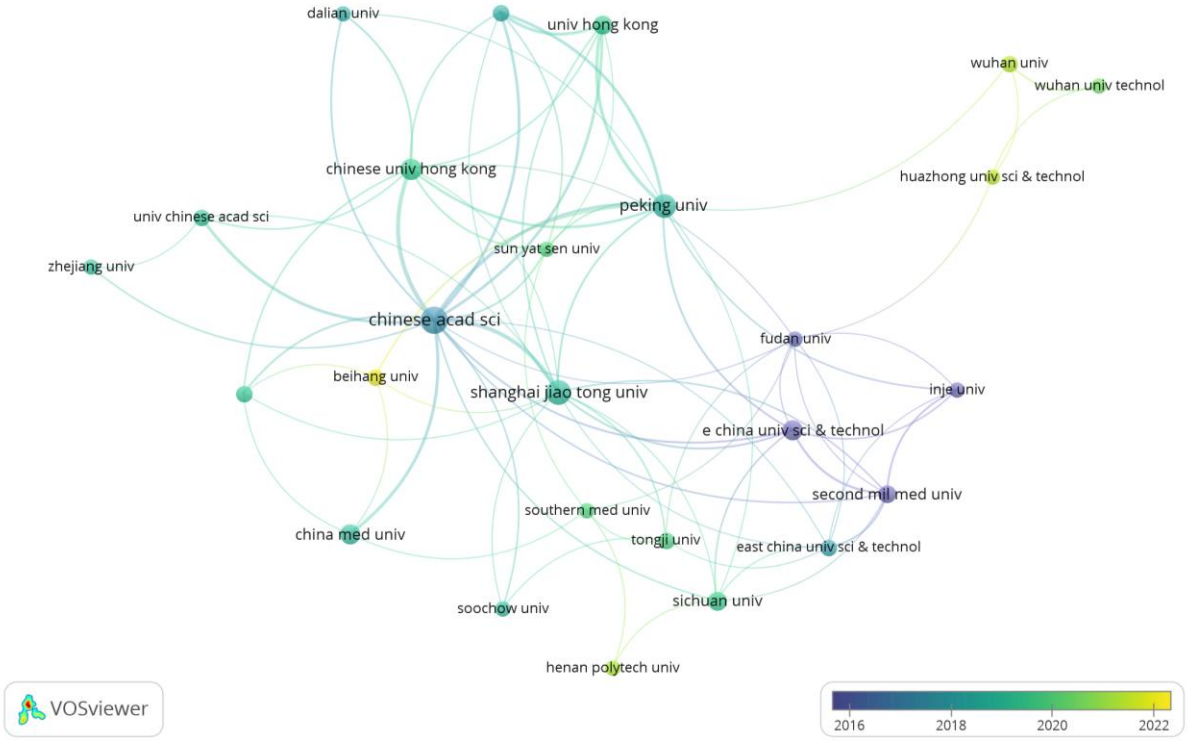
A total of 867 institutions have contributed articles on magnesium and bone. The top ten institutions in terms of publication output are listed in Table 2. Among them, Chinese Academy of Sciences ranks first with 52 publications, followed by Shanghai Jiao Tong University with 35 publications, and Peking University with 28 publications. In terms of citations, Chinese Academy of Sciences ranks first with 2,576 citations, followed by Chinese University of Hong Kong (1,648 citations) and Peking University (1,457 citations). Interestingly, among the top ten institutions, 8 are from China and 2 are from Germany. The collaboration network and overlay visualization of institutions can be seen in Figures 4A and 4B. Figure 4A shows that the Chinese Academy of Sciences has relatively close collaborations with other institutions. Figure 4B indicates that East China University of Science and Technology has an earlier average publication time, while Beihang University has a relatively later average publication time. Therefore, it can be concluded that the Chinese Academy of Sciences is a core institution in research related to magnesium and bone.

Table 2. The top ten productive institutions

Rank		Country	Documents	Citations
1	Chinese Acad Sci	China	52	2576
2	shanghai Jiaotong University	China	35	1252
3	Peking University	China	28	1457
4	Chinese University Hong Kong	China	20	1648
5	China Med University	China	16	566
6	E China Univ Sci & Technol	China	15	1004
7	Sichuan University	China	13	195
8	Leibniz Univ Hannover	Germany	12	555
9	Hannover Med Sch	Germany	12	2844
10	University Hong Kong	China	11	463



(**A**) Cooperation networks across institutions



(**B**) Overlay Visualization of institutions

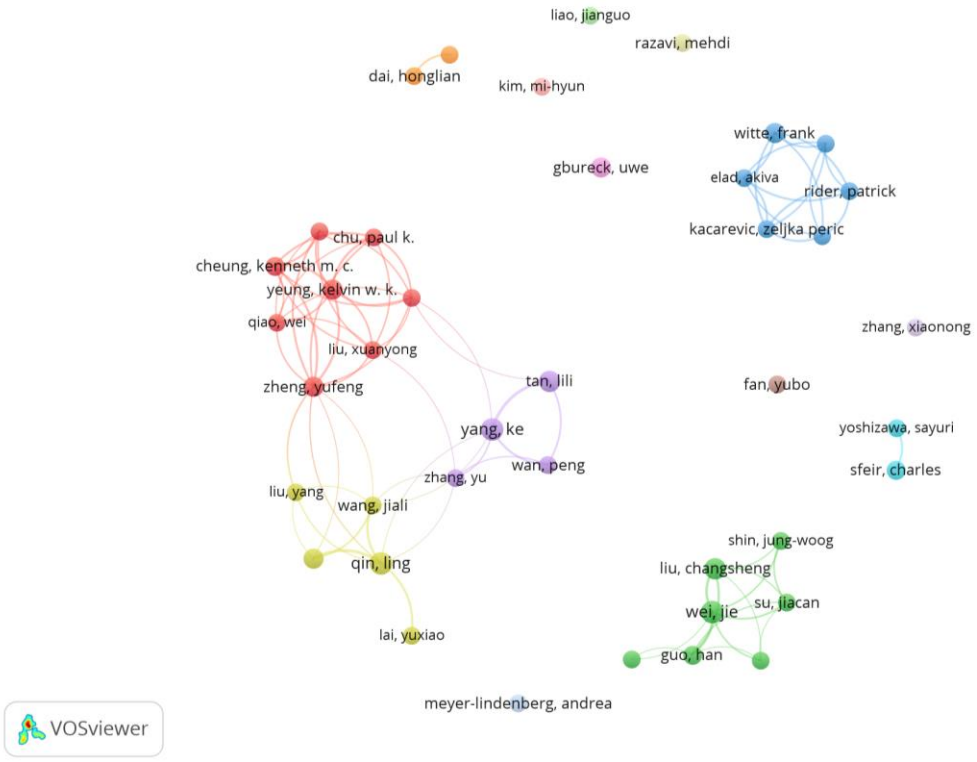
Figure 4. Co-authorship analysis of institutions

3.4 Author Analysis

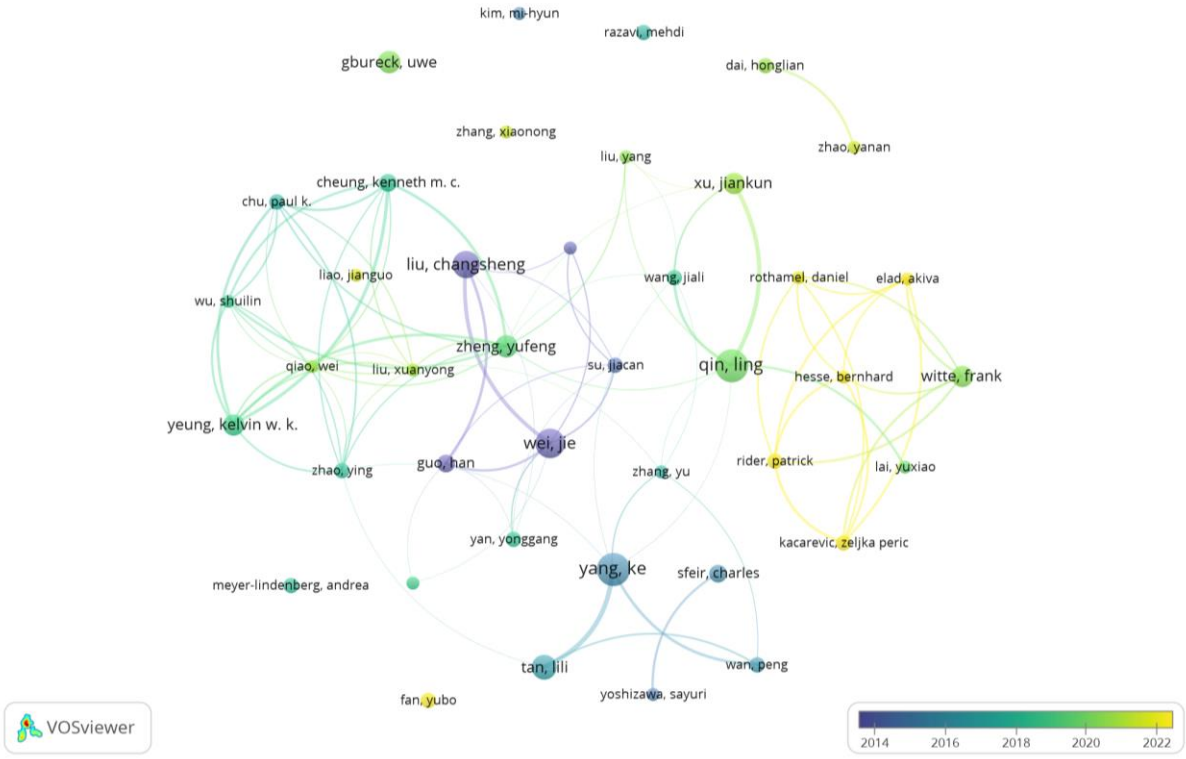
A total of 3,045 authors have contributed to publications on magnesium and bone. The top ten authors in terms of publication output are listed in Table 3. In terms of publication output, Qin Ling (16 publications) and Ke Yang (16 publications) are tied for first place, followed by Jie Wei (14 publications) in second place, and Changsheng Liu (13 publications) in third place. In terms of citations, Changsheng Liu ranks first with 1,000 citations, followed by Qin Ling (909 citations) in second place, and Ke Yang (866 citations) in third place. The collaboration network and overlay visualization of authors can be seen in Figures 5A and 5B. From the figures, it can be observed that authors from China have relatively close collaborations. Changsheng, Han Guo, and Jie Wei have an earlier average publication time, while Rider, Patrick, and Elad, Akiva have a relatively later average publication time. Therefore, Qin Ling can be identified as a core author in research related to magnesium and bone.

Table 3. The top ten productive authors

Rank		Documents	Citations
1	Qin Ling	16	909
2	Ke Yang	16	866
3	Jie Wei	14	783
4	Changsheng Liu	13	1000
5	Lili Tang	11	362
6	Yufeng Zheng	10	461
7	Gbureck Uwe	10	224
8	Yeung kelvin w.k.	9	426
9	Witte Frank	9	167
10	Jiankun Xu	9	257



(**A**) Cooperation networks across institutions



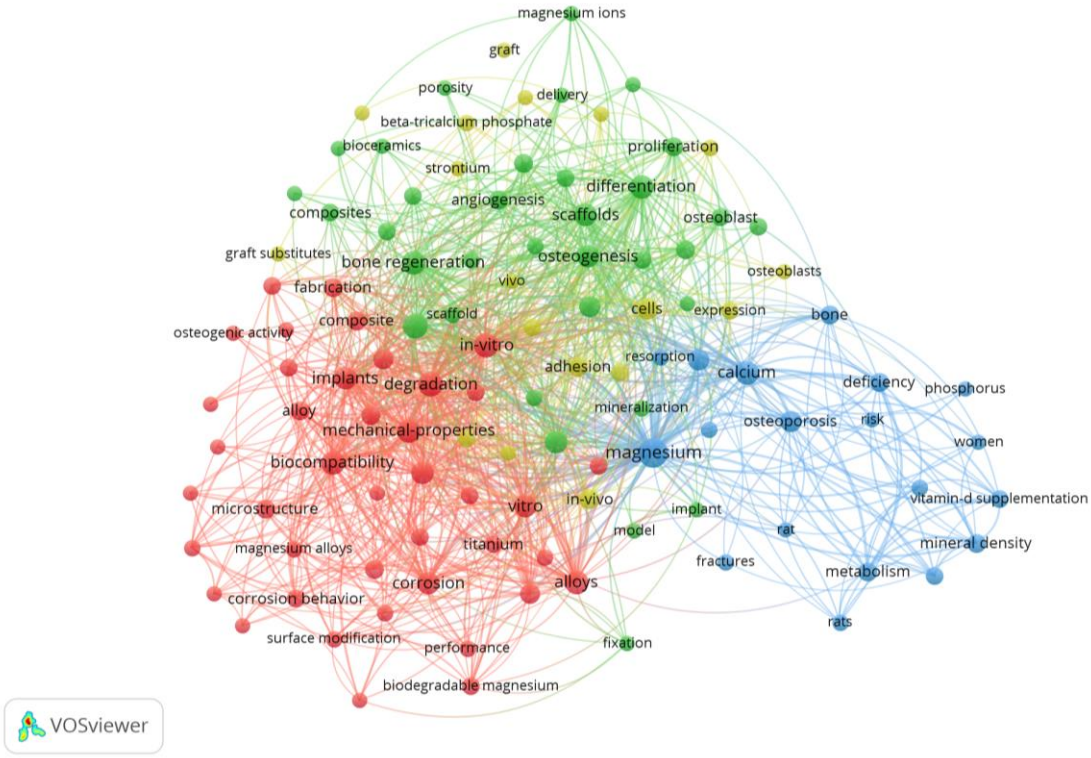
(**B**) Overlay Visualization of institutions

Figure 5. Co-authorship analysis of institutions

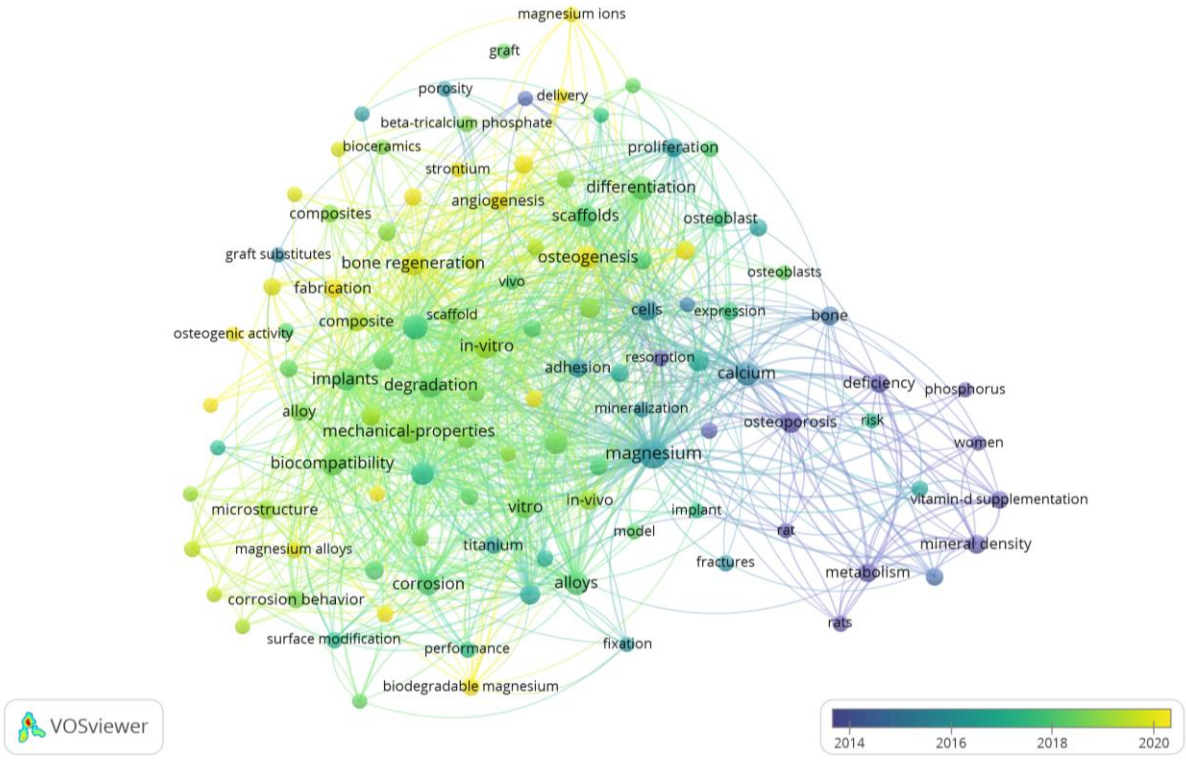
3.5 Keyword Analysis

A total of 2,496 keywords related to magnesium and bone research have been generated. The top ten keywords, ranked by frequency, are as follows: magnesium (163 occurrences), in-vitro (81), degradation (77),

hydroxyapatite (73), calcium (72), biocompatibility (67), differentiation (65), bone regeneration (63), mechanical properties (62), and alloys (60). The clustering and overlay visualization of keywords can be seen in Figures 6A and 6B. Figure 6A shows that the keywords can be divided into four clusters: green, yellow, blue, and red. Figure 6B indicates that the keywords “osteogenesis” and “nanoparticles” are the latest research hotspots.



(**A**) Cooperation networks across keywords



(**B**) Overlay Visualization of keywords

Figure 6. Co-authorship analysis of keywords

4. Discussion

Through the bibliometric analysis of research literature on zinc and bone, we have observed a continuous growth trend in this field over the past few decades. This indicates that the importance of zinc in bone health research is increasingly gaining widespread attention. Zinc plays a crucial role as a trace element in the human body, particularly in bone formation, maintenance of bone density, and regulation of bone metabolism. Therefore, in-depth research on the relationship between zinc and bone is of significant importance in promoting bone health and preventing diseases such as osteoporosis.

In the international landscape of zinc and bone research, China plays a key role. China not only maintains close connections with research institutions in other countries but also possesses significant influence in this field. The Chinese Academy of Sciences has been recognized as a core institution in zinc and bone research, indicating that China has strong research capabilities and resources in this area. The contributions of Chinese researchers in zinc and bone research, particularly represented by core author Qin Ling, are invaluable. Their work not only enriches our understanding of the relationship between zinc and bone but also provides important insights and directions for further development in this field.

In terms of international collaboration, research institutions from different countries can enhance communication and cooperation, sharing data and research findings to drive global progress in zinc and bone research. Collaborative models and experiences among different countries and institutions can be mutually beneficial, accelerating the development of global research in this field. Transnational collaborative projects can facilitate interdisciplinary research, such as biochemistry, genetics, nutrition, and clinical medicine, to gain a more comprehensive understanding of the relationship between zinc and bone.

Overall, the findings from this bibliometric analysis highlight the growing importance of zinc and its relationship with bone health. They underscore the significant contributions of Chinese researchers and institutions in this field, while emphasizing the need for international collaboration and interdisciplinary approaches to advance global research in the realm of zinc and bone.

5. Hot Topics and Frontiers

5.1 Magnesium and Osteogenesis

Magnesium alloys, as biodegradable biomaterials with excellent osteoinductive and biocompatible properties, have shown promising potential in tension-induced bone formation and may achieve bone fixation by activating the hedgehog pathway as an alternative to the Wnt signaling pathway (Hamushan M, Cai WJ, Zhang YB, et al, 2021). Magnesium and its alloys, when present at appropriate concentrations, promote bone and blood vessel formation. However, further research is needed to understand the effects of their degradability and magnesium ion concentrations on cellular behavior (Liu WW, Guo S, Tang Z, et al, 2020). Injectable bone cement containing magnesium microspheres exhibits controllable biodegradability and anti-inflammatory immunomodulatory capabilities. It demonstrates potential clinical applications in minimally invasive surgical repair of small irregular bone defects by mediating tissue growth and promoting osteogenesis (Tan SL, Wang YF, Du YY, Xiao Y & Zhang SM, 2021). A novel mesoporous magnesium silicate-calcium sulfate composite bone cement (m-MSC) was developed by combining mesoporous magnesium silicate (m-MS) with calcium sulfate bone cement (CS). The research results showed that the addition of m-MS could prolong the setting time of m-MSC, improve its degradability, and neutralize acidic substances. In vitro cell culture and bone injury model experiments demonstrated that mesenchymal stem cells promoted bone cell proliferation and differentiation, showing promising results in the process of osteogenesis (Chen J, Dong XP, Liu ZH, Hu Xing L & Wei J., 2016). Additionally, a magnesium/zinc-metal organic framework coating prepared by alkali heat treatment on titanium surfaces exhibited superior stability and multifunctional characteristics. It possessed antibacterial, anti-inflammatory, and osteogenic properties, offering potential solutions for implant failures caused by infections in revision surgeries (Shen XK, Zhang YY, Ma PP, et al, 2019). However, future research directions include optimizing the degradation performance of magnesium alloys, gaining a deeper understanding of the mechanisms of magnesium in bone formation, developing functional coatings and surface modification techniques, studying magnesium-based composite materials, and conducting translational research for clinical applications. Exploring these research directions will propel the development of magnesium-based biomaterials in the field of orthopedics and provide innovative solutions for clinical practice.

5.2 Magnesium, Nanoparticles, and Bone

Translation into medical academic English: In recent years, magnesium nanoparticles as a new hot topic in the field of biomaterials have received widespread attention. Graphene nanoparticle-modified magnesium alloys have shown significantly improved stability and anti-inflammatory properties, reduced degradation rate, excellent antibacterial activity, and the ability to promote bone formation. This lays the foundation for the development of stable absorbable magnesium-based bone implants and effectively reduces the risk of

implant-related infections (Safari N, Golafshan N, Kharaziha M, et al, 2020). Moreover, magnesium oxide nanoparticles at appropriate concentrations possess dual advantages of promoting proliferation of bone marrow mesenchymal stem cells and reducing bacterial adhesion (Wetteland CL, Nguyen NYT & Liu HN, 2016). However, high concentrations of magnesium oxide nanoparticles have detrimental effects on bone marrow mesenchymal stem cells. Therefore, when applying magnesium oxide nanoparticles to medical implants, it is necessary to control their concentration to avoid adverse effects and further investigate their application methods, such as coating materials or as part of composite materials, to achieve their potential clinical applications. These findings provide valuable guidance and prospects for the application of magnesium nanoparticles in the field of orthopedics.

6. Conclusion

The bibliometric analysis reveals a continuous growth trend in zinc and bone-related research, with China playing a crucial role as the most closely connected and influential country in this field. The Chinese Academy of Sciences is recognized as the core institution for zinc and bone research, and Qin Ling is a key author in this field. The hot topics and frontiers in zinc and bone research include the application of magnesium alloys in orthopedic implants and the study of injectable bone cement with magnesium microspheres. International collaboration and interdisciplinary research can drive the progress of global zinc and bone research.

7. Limitations

It is important to note that while bibliometric analysis provides quantitative indicators and data, it also has certain limitations. For example, relying solely on quantitative metrics cannot fully reflect the quality and innovativeness of academic research. Additionally, bibliometric analysis cannot completely replace in-depth understanding and evaluation of the content of academic research. Therefore, when conducting bibliometric analysis, it is necessary to combine other qualitative methods and professional knowledge to comprehensively and accurately assess the value and impact of academic research.

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