Bibliometric evaluation of ultrasound in orthopaedics global publications: 10-year trends and hotspots

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Research article

Keywords: ultrasound, orthopaedics, publications, citation frequency, bibliometrics

DOI: https://doi.org/10.21203/rs.3.rs-206743/v1

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Abstract

**Background.** The past decade has witnessed the development of ultrasound in orthopaedics, the growth rate of publications has been accelerating. In this study, analysis of the publications on ultrasound in orthopaedics over the past decade has been completed. We aim to provide inspiration for future research on ultrasound in orthopaedics through our work.

**Methods.** All relevant publications between 2009 and 2020 from Web of Science were collected. Statistical Package for Social Science and GraphPad Prism 8 software were used to generate and analyse diagrams. Meanwhile, from the aspects of co-occurring keywords, VOSviewer software and CiteSpace were employed to visualize the research trends.

**Results.** 1,677 publications with a citation frequency of 20,311 were identified. The United States published most publications in this field and the number of citations was also the highest, as well as the highest H-index. Although China ranked sixth in terms of the number of publications, the growth trend in the future will be fastest. Furthermore, Skeletal Radiology published the most papers related to ultrasound in orthopaedics, Ozcakar, L had published the most papers, and a study by Kwon, YM received the highest citation frequency. The keywords about "MRI", "complication", "female" and "male" were noted as new topics.

**Conclusions.** Through the research, while the contributions of the publications from the United States were significant, the growth rate of Chinese publications in the future cannot be ignored. Moreover, it is hypothesized that diagnosis and epidemiology studies may become hotspots.

**Background**

As a diagnostic tool, ultrasound has convenient, fast, non-invasive and other advantages and has been widely used in the fields of medical imaging diagnosis(1). For example, during the diagnosis of thyroid tumour, ultrasound has always played an important role. In the aspects of the diagnosis of breast cancer(2), atherosclerosis(3) and hepatic fibrosis(4), the accuracy of ultrasonic diagnosis is also high. Especially in the assessment of COVID-19, the application of CT in the ICU is limited, so bedside ultrasound has become the main method of diagnosis(5). The use of ultrasound in treatment also reduces some unnecessary surgeries and reduces the pain of patients. For example, the rate of urinary calculi surgery has dropped because of the use of ultrasonic lithotripsy technique(6). The use of ultrasound-guided lateral thoracolumbar interfascial plane block also reduces the pain of lumbar spine fusion surgery patients(7). Orthopaedics is a comprehensive discipline, including multiple subdisciplines such as trauma, joints, spine and so on. Just in terms of osteoporosis, 22 million women and 5.5 million men were affected by this disease in the EU in 2010(8). Therefore, orthopaedics has always been at the centre of medical research. Moreover, the application of ultrasound in the field of orthopaedics has received increasing attention. For example, in the identification of low and high probability of osteoporotic fracture, quantitative ultrasound has shown a unique advantage(9). Similarly, in the treatment of femoral head necrosis(10), ultrasound also performs well. Therefore, it may be necessary to master the trends and hotspots of ultrasound in osteology.
Using literature databases and literature metrology characteristics, bibliometrics is a viable way to quantitatively and qualitatively evaluate trends in research activity over time. It provides a convenient way to understand development trends in a certain field and evaluates academic groups and individual researchers(11). Similarly, in terms of policy and decision making, bibliometrics can also provide supporting evidence(12). In many scientific fields, including diabetes(13), cardiovascular disease(14), gastrointestinal diseases(15) and respiratory medicine(16), bibliometric research methods have been widely used. The present study was aimed at comprehensively analysing the research progress with respect to ultrasound in orthopaedics based on the Web of Science (WOS). We applied a bibliometric analysis for the purpose of grasping the research trends related to ultrasound in orthopaedics and predicting its possible future hotspots.

Although Julien Dartus et al. assessed the past two decades of orthopaedic publications in France using bibliometric science(17), Xiao Zhai et al. also used bibliometric methods to report the publication trends of ultrasound in spines from 1994 to 2015(18). To date, no study has reported ultrasound research in orthopaedics. We will explore the comprehensive review of the publication trends and analyse future hotspots covering ultrasound in orthopaedics.

**Methods**

**Data sources and search strategies**

Studies published from 2009 to 2020 were used in this study. It has been widely accepted that the online database Science Citation Index-Expanded (SCI-E) of Thomson Reuters’WOS is one of the most suitable tools for collecting data, so all publications we studied were obtained from this database. To avoid omissions introduced by the rapid update of the database, we finished all of the search progresses in a single day, September 19, 2020. The search strategies were set as follows: TS = ((ultrasound) OR ultrasonography) OR (ultrasonic) OR (sonography)) AND Web of Science Categories = Orthopaedics AND Language = English. Only original articles and reviews with standard peer reviews were selected for our research, while other types of studies were excluded. Specific processes of enrolment and selection are shown in Fig. 1.

**Data collection**

All types of data were extracted from the correlative publications by three authors (WS XDM and ZZT), including titles, keywords, authors, publication dates, origin countries and regions, institutions, published journals, sum of citations, H-index, and so on. Microsoft Excel 2016 (Redmond, Washington, USA), Statistical Package for Social Sciences (SPSS, version 24, IBM Corporation, USA), GraphPad Prism 8 (GraphPad Prism Software Inc., San Diego, CA), VOSviewer version 1.6.12 (Leiden University, Leiden, the Netherlands), CiteSpace version 5.6. R5 64bit (Drexel University, Philadelphia, PA, USA), and the Online Analysis Platform of Literature Metrology (http://bibliometric.com/) were used for presenting, analysing the data and describing the figures. Meanwhile, the data regarding the gross domestic product (GDP) were retrieved according to the World Bank website. Completed and fruitful clinical randomized controlled trials about the ultrasound in orthopaedics have been collected by us from website (http://Clinicaltrials.gov/).
Bibliometric analysis

Thomson Reuters’ WOS had a large collection of studies, especially those focused on biomedicine, so we chose the WOS to obtain the characteristics of all incorporated publications. The term relative research interest (RRI) was defined as the number of publications in a particular research field divided by the total publications across all fields per year. The impact factor (IF) was obtained from the information provided by the journal citation reports (JCRs) published in 2020. It is widely accepted that the H-index plays an important role in evaluating the scientific research impacts of a scholar or a country. Especially in medicine, the H-index of articles serves as a potential tool to measure academic productivity. The index of H means that a scholar or a country has published at least H papers, and each paper has been cited in other publications at least H times, which takes up a larger part than other indicators we collected (total citation count, citations per paper, and total paper count) in assessing scientific achievement.

Citespace is a practical statistical software. We used the links between nodes in the map to show the bibliometric characteristics, such as reference, institution, author and terms, and we also analysed the potential research trends of future research. Meanwhile, the keywords were extracted according to this software. Using the Java programming language, VOSviewer is a convenient science mapping software tool which is widely used for co-citation network analysis and visualization. The technique used for map construction is based on a co-occurrence matrix.

Results

In all, 1,677 articles dated from 2009 to 2020 met our inclusion criteria, with the United States ranking first in the number of publications at 469 (27.9%), followed by England at 164 (9.8%) and Japan at 160 (9.5%). By comparing the number of papers published per year, we found that the largest number of publications occurred in 2019, with 194 publications (11.6%) (Fig. 2A). When the numbers of all-field publications were considered, the global interest of ultrasound in orthopaedics measured by the value of RRI started to increase since 2016 and increased to 0.045% in 2019; meanwhile, the peak of the curve also emerged in 2019 during this progress (Fig. 2B). We believe that the trend of growth will also accelerate in the future. The cooperative relations between countries can also be visualized (Fig. 3). As the country with the highest number of publications, the United States also had the closest ties to other countries.

Growth trends of publications

The global cumulative publication numbers and the top 6 countries, as well as the corresponding model fitting curves, are shown in Fig. 4. Based on these growth curves, we found that the growth of publications of the entire world was on a fast curve, which was also applicable for several major countries, such as South Korea and China (Fig. 4F and 4G). The number of papers published by those countries per year has grown rapidly in recent years, especially China, which will show an obviously faster growth curve in publications in this field compared to other countries over the next twenty years (Fig. 4G). Although some countries still lead in the number of papers published now, their growth rate will decline over the next twenty years, such as the United States and Japan (Fig. 4B and 4D).
Citations and H-index analysis

By retrieving the Journal Citation Report from the WOS database, all articles related to ultrasound in orthopaedics had been cited 20,311 times since 2009 (18,730 times without self-citations), with an average citation frequency of 12.11 times per paper. The United States accounted for 32.7% of the total citations, i.e., 6650 times (6387 times without self-citations), and exhibited an H-index of 40. The number of citations from England was 2,397 (2,343 times without self-citations) with an H-index of 25 and thus ranked second among all involved countries and districts. Although the number of publications from Canada ranked ninth, the citation frequency was 1,213 times with an H-index of 20 and thus ranked fourth among all considered countries and districts (Fig. 2A).

Journals with research publications on ultrasound in orthopaedics

More than one-third of the papers within this scope were published in 10 journals (660, 39.36%). The number of papers published on skeletal radiology (IF=1.618) was the highest, with 202 records. BMC Musculoskeletal Disorders (IF=1.879) ranked second with publications. The IF of journals ranked first and second was American Journal of Sports Medicine (IF=5.810), and Knee Surgery Sports Traumatology Arthroscopy (IF=3.116) had 52 and 57 publications on ultrasound in orthopaedics, respectively, ranking fifth and fourth on the number of publications. Meanwhile, the H-index of the American Journal of Sports Medicine also ranked first in the top 10 journals, and the top 10 journals with most publications on ultrasound in orthopaedics are listed in Table 1.

Table 1. The top 10 researches on ultrasound in orthopaedic publications

| SCR * | Journal                                         | Contribution (%) | H-index | IF ** |
|-------|------------------------------------------------|-----------------|---------|-------|
| 1st   | Skeletal Radiology                             | 202 (12.0)      | 25      | 1.618 |
| 2nd   | BMC Musculoskeletal Disorders                  | 83 (4.9)        | 17      | 1.879 |
| 3rd   | Journal of Shoulder and Elbow Surgery          | 69 (4.1)        | 19      | 2.817 |
| 4th   | Knee Surgery Sports Traumatology Arthroscopy   | 57 (4.0)        | 15      | 3.116 |
| 5th   | American Journal of Sports Medicine            | 52 (3.1)        | 26      | 5.810 |
| 6th   | Journal of Back and Musculoskeletal Rehabilitation | 43 (2.6)      | 8       | 0.821 |
| 7th   | Clinical Biomechanics                          | 42 (2.5)        | 15      | 1.624 |
| 8th   | Journal of Hand Surgery-American volume        | 39 (2.3)        | 10      | 2.124 |
| 8th   | Orthopaedics & Traumatology: Surgery & Research| 39 (2.3)        | 8       | 1.809 |
| 10th  | Journal of Foot and Ankle Surgery              | 34 (2.0)        | 6       | 1.598 |

SCR standard competition ranking, IF impact factor

*Equal journals have the same ranking number, and then a gap is left in the ranking numbers
The impact factor was reported according to the journal citation reports (JCR) 2020

Institutions with research publications on ultrasound in orthopaedics

The Mayo Clin in the United States had the highest number of publications among institutions worldwide, with 33 papers documented by this affiliation, which accounted for 2.0% of all publications. Within the list of the top 20 institutions in this field, American institutions account for over half, three institutions were in China, two were Canada institutions, one was a Turkey institution, one was a Brazil institution, one was a Japan institution, and one was Korea (Table 2).

Table 2. Top 20 institutes with most researches on ultrasound in orthopaedics.

| Rank | Institution                  | Contribution (%) | Country |
|------|------------------------------|------------------|---------|
| 1st  | MAYO CLIN                    | 1.968            | USA     |
| 2nd  | HOSP SPECIAL SURG            | 1.431            | USA     |
| 3rd  | HACETTEPE UNIV               | 1.371            | Turkey  |
| 4th  | HONG KONG POLYTECH UNIV      | 1.132            | China   |
| 5th  | WASHINGTNO UNIV             | 1.013            | USA     |
| 6th  | NYU                          | 0.954            | USA     |
| 6th  | UNIV SAO PAULO               | 0.954            | Brazil  |
| 8th  | MCMASTER UNIV                | 0.894            | Canada  |
| 9th  | UNIV PITTSBURGH              | 0.834            | USA     |
| 10th | CHINESE UNIV HONG KONG      | 0.775            | China   |
| 10th | KYOTO UNIV                  | 0.775            | Japan   |
| 12th | MASSACHUSETTE GEN HOSP      | 0.715            | USA     |
| 12th | THOMAS JEFFERSON UNIV       | 0.715            | USA     |
| 12th | KOREA UNIV                  | 0.715            | Korea   |
| 12th | UNIV CALIF SAN FRANCISCO    | 0.715            | USA     |
| 12th | UNIV MICHIGAN               | 0.715            | USA     |
| 17th | HARVARD NUIV                | 0.655            | USA     |
| 17th | NATL TAIWAN UNIV            | 0.655            | China   |
| 17th | NORTHW UNIV                 | 0.655            | USA     |
| 17th | UNIV ALBERTA                | 0.655            | Canada  |
We can also obtain information about the publication time of all articles in various institutions (Fig. 5A). The blue colour indicates that the articles belonging to the institution were published relatively early in the research stage, while the red colour indicates a more recent appearance. Through this figure, the Mayo Clin, with the highest number of publications among institutions worldwide, had not decreased in the number of publications in recent years. In Fig. 5B, the size of the ball represents the number of publications of the institutions, so the top three publications of the institutions are Mayo Clin, Hosp Special Surg and Hacettepe Univ.

Authors with research publications on ultrasound in orthopaedics

A total of 95 papers published by the top 10 authors accounted for 5.7% of all literature in this research area. Ozcakar, L. from the University of Hacettepe published 13 papers related to ultrasound in orthopaedics, ranking first in the number of publications. Adler, RS and Maffulli, N published 11 papers and ranked second among all authors. As shown in Table 3, among the top 10 authors with most publications on ultrasound in orthopaedics, there were 3 authors from the United States, 2 from Turkey, 2 from Brazil, 1 from China, 1 from England and 1 from South Korea. Notably, the citation frequency of Adler, RS from the University of Cornell in the United States ranked first (363 times) (Table 3).

Table 3. Top 10 authors with most researches in the research scope of ultrasound in orthopaedics

| Author       | Country    | Affiliation                  | No. of Publications | No. of Citations |
|--------------|------------|------------------------------|---------------------|------------------|
| Ozcakar, L   | Turkey     | Hacettepe Univ              | 13                  | 76               |
| Adler, RS    | USA        | Cornell Univ                | 11                  | 363              |
| Maffulli, N  | England    | Mile End Hosp               | 11                  | 190              |
| Jacobson, JA | USA        | Univ Michigan               | 9                   | 262              |
| Lee, SH      | South Korea| Inje Univ                   | 9                   | 31               |
| Mazzer, N    | Brazil     | Univ Sao Paulo              | 9                   | 44               |
| Zheng, YP    | China      | Hong Kong Polytech Univ     | 9                   | 218              |
| Akkaya, N    | Turkey     | Pamukkale Univ              | 8                   | 77               |
| Amadio, PC   | USA        | Mayo Clin                   | 8                   | 197              |
| Barbieri, CH | Brazil     | Univ Sao Paulo              | 8                   | 40               |

Analysis of keywords in publications of ultrasound in orthopaedics

We analysed the keywords extracted from 1,677 publications using VOSviewer. As presented in Fig. 6A, 66 keywords, defined as terms that occurred more than 60 times within titles and abstracts in all papers during the analysis process, were identified and classified into three clusters, namely, diagnosis, treatment and epidemiology. Within the cluster of diagnosis, the following keywords were frequently mentioned: diagnosis (338 times), case (337 times), examination (330 times), value (270 times), sensitivity (163 times), and MRI
In the cluster of treatment, relevant keywords were also listed, including treatment (459 times), group (440 times), pain (391 times), month (318 times), and score (316 times). In the cluster of epidemiology, the primary keywords were measurement (302 times), change (285 times), thickness (215 times), correlation (197 times), and image (189 times). Detailed consequences with respect to the co-occurrence analysis of all incorporated keywords are presented in Fig. 6A.

We can also obtain information about the keywords from Fig. 7. The most salient keyword is exercise; its strength is 7.4015. It strengthened from 2013 to 2016. More recently, the newest salient keyword in our research is instability, which was highlighted from 2017 and 2020, and its strength is 4.1026. The heat of keywords, such as bone, articular cartilage, thickness and radiography, lasted the longest (6 years), with an increase in strength from 2009 to 2014.

**Discussion**

**Research trends of ultrasound in orthopaedics**

In terms of the publication volume of all countries, the United States leads the first (Fig. 2), while China had the fastest growth rate (Fig. 4G). We speculate that the reason for this phenomenon is related to the index of the country's GDP (Fig. 2A). We can also find that the developed countries published more research, such as the United States, England and Japan (Fig. 2A). This shows that countries leading in science and technology are exploring more of the uses of ultrasound. Improvements have emerged in ultrasonic technologies in developed countries, such as the invention of ultrasound and microbubble therapy(19), which can efficiently increase cell membrane permeability, resulting in enhanced tissue distribution and intracellular drug delivery of molecules, the popularity of small probes(20) and the combination of ultrasound, X-ray and MRI(21). these new technologies often appear in developed countries.

Published articles with the highest citation frequency are associated with correlative academic impacts in a certain field. Detailed information regarding the top ten most frequently cited publications on ultrasound in orthopaedics is provided in Table 4. The study published in The Journal of Arthroplasty in 2011 with Kwon, YM as the corresponding author provides the most common combination of ultrasound in orthopaedics, and the research indicates that in metal-on-metal hip resurfacing arthroplasty, ultrasound is essential as a diagnostic tool(22). The ranked second to fourth articles are all from the same journal, the American Journal of Sports Medicine, which describes the application of ultrasound diagnosis for the repair of chronic Achilles tendinopathy, large and massive rotator cuff tears and double-row rotator cuffs, respectively(23-25). For the top 10 cited articles about ultrasound in orthopaedics, their focus was an evaluation of the effectiveness of ultrasound diagnosis in the treatment of a disease. The results were similar to clusters such as diagnosis, treatment and statistics (Fig. 6A).

Table 4. Top 10 most-cited researches related to ultrasound in orthopaedics
| Title                                                                 | Corresponding Authors | Journal                                        | Publication Year | Total Citations | Corresponding Author's Country |
|----------------------------------------------------------------------|-----------------------|------------------------------------------------|------------------|-----------------|-------------------------------|
| "Asymptomatic" Pseudotumours After Metal-on-Metal Hip Resurfacing Arthroplasty | Kwon, YM              | JOURNAL OF ARTHROPLASTY                         | 2011             | 216             | USA                           |
| One-Year Follow-up of Platelet-Rich Plasma Treatment in Chronic Achilles Tendinopathy A Double-Blind Randomized Placebo-Controlled Trial | de Jonge, S           | AMERICAN JOURNAL OF SPORTS MEDICINE             | 2011             | 176             | Netherlands                   |
| Factors Affecting Healing Rates After Arthroscopic Double-Row Rotator Cuff Repair | Tashjian, RZ          | AMERICAN JOURNAL OF SPORTS MEDICINE             | 2010             | 171             | USA                           |
| When Do Rotator Cuff Repairs Fail? Serial Ultrasound Examination After Arthroscopic Repair of Large and Massive Rotator Cuff Tears | Miller, BS            | AMERICAN JOURNAL OF SPORTS MEDICINE             | 2011             | 138             | USA                           |
| Hyaline cartilage involvement in patients with gout and calcium pyrophosphate deposition disease. An ultrasound study | Filippucci, E         | OSTEOARTHRITIS AND CARTILAGE                    | 2009             | 138             | Italy                         |
| Title                                                                 | Author | Journal                                      | Year | IF  | Country     |
|----------------------------------------------------------------------|--------|----------------------------------------------|------|-----|-------------|
| The diagnostic value of ultrasonography-derived edema of the temporal artery wall in giant cell arteritis: a second meta-analysis | Sfikakis, PP | BMC MUSCULOSKELETAL DISORDERS | 2010 | 134 | Greece      |
| The Sensitivity and Specificity of Ultrasound for the Diagnosis of Carpal Tunnel Syndrome: A Meta-analysis | Fowler, JR | CLINICAL ORTHOPAEDICS AND RELATED RESEARCH | 2011 | 116 | USA         |
| Long-term Survivorship of Rotator Cuff Repairs Using Ultrasound and Magnetic Resonance Imaging Analysis | Kluger, R | AMERICAN JOURNAL OF SPORTS MEDICINE | 2011 | 104 | Austria     |
| Prevalence and characteristics of asymptomatic tears of the rotator cuff: an Ultrasonographic and Clinical study | Moosmayer, S | JOURNAL OF BONE AND JOINT SURGERY-BRITISH VOLUME | 2009 | 104 | Norway      |
| Prospective analysis of arthroscopic rotator cuff repair: Prognostic factors affecting clinical and ultrasound outcome | Nho, SJ | JOURNAL OF SHOULDER AND ELBOW SURGERY | 2009 | 103 | USA         |

Although there have been few outstanding articles (Table 4) and few high IF journals (Table 3) in this field, RRI displayed a quickly rising trend (Fig. 3). We analysed the reason for the increase in research interest from the special advantages of ultrasound. On the one hand, hospitals are increasingly using ultrasonic devices
to reduce exposure to X-ray radiation during examinations with the improvement of people's health awareness(13), and in the diagnosis of some orthopaedic diseases, the diagnostic rate of ultrasound is not inferior to CT. For example, ultrasound is more accurate in assessing the early healing process of fractures(26); the last but not the least, ultrasound as a diagnostic and therapeutic method does have overwhelmingly taken its place in the scientific arena(27), and the use of bedside ultrasound also provides ideas for rapid diagnosis in critical and emergency situations in the future. For example, the advent of portable ultrasound makes rapid diagnosis of soft tissue injury possible in the wild(28). Thus, the acceptance of ultrasound is improving, and the study of ultrasound in orthopaedics is also undergoing a development process.

Regarding the top 10 institutions and top 10 authors, half of the top 10 institutions are from the United States (Table. 2), and three of the top 10 authors are also from the United States (Table. 3). We predicted that these phenomena were related to the cooperation between countries. For example, the map based on WOS data reveals that the United States has connections with many countries in the field (Fig. 3); however, other countries have few connections. Therefore, the quality of articles in other countries is lower than in the United States. This phenomenon has called on scientists from all over the world to break through boundaries and bring about deeper cooperation. Only in this way can we promote the development and application of ultrasound in the orthopaedics field.

Research focused on ultrasound in orthopaedics

According to the map based on the bibliographic data from the analysis of all keywords (Figs. 6A, B), we found that the key words were divided into three clusters, namely, diagnosis research, treatment research and epidemiology research. The density of the keywords outlined the overall structure of the figure and draw attention to the most important areas of ultrasound in orthopaedics, revealing an even distribution among the three groups that was consistent among the three clusters. However, the clusters of diagnosis and epidemiology studies were relatively new with respect to the publication dates, and the potential reasons for this are as follows.

First, the research over the past decade indicates that the research direction has transitioned towards various aspects of diagnosis rather than just assessing the fracture. For example, doctors can use ultrasound to diagnose arthritis(29), dysplasia of the hip(30), subacromial pain syndrome(31), neuromuscular diseases(32) and so on. Furthermore, scientists from different countries have also tried to analyse ultrasound studies in orthopaedics using statistical methods in recent years. Thus, keywords such as correlation and reliability have emerged within the epidemiology research cluster. According to the results of the pictures (Fig. 6B), the research direction has shifted towards epidemiology research. For example, in the aspects of the prediction of tendon injury risk, assessment of tendon healing and provision of further insight into tendon physiology, the usefulness of ultrasound was confirmed by epidemiology methods(33). However, the application of ultrasound in osteology is in its infancy, and scientists must further strengthen their research efforts (Fig. 6A).

With respect to the latest research hotspots, MRI from the diagnosis research cluster is the most recent (cluster 1), which indicates that ultrasonic diagnosis has been used in combination with other diagnostic
tools to improve diagnostic efficiency. For example, the assessment of fracture healing remains challenging due to a lack of consensus on imaging and clinical criteria as well as the lack of a true gold standard(26). However, ultrasound signs of healing can be identified as early as 1-2 weeks post fracture. By attaching a position sensing device to the ultrasound probe, 3D reconstructed images can be generated, which can help in the interpretation of complex fracture pattern healing(34). In clinical practice, Aspelin P et al. also conducted ultrasonic diagnosis on 32 patients with lower limb soft tissue injury and found that the diagnosis of haematoma was good(35). In the diagnosis of deep tissue damage, MRI has been shown to play a significant role, especially in spinal cord injury(36) and disc herniation(37), compared with ultrasound and CT. Thus, investigating the combination of kinds of imaging rather than just ultrasound is likely to be a new hotspot in future research. For example, MRI performed better in the diagnosis of inflammation, but ultrasound was more valuable in the diagnosis of small bone lesions (38). Therefore, in the treatment of rheumatoid joints, the researchers assessed the disease in three ways: synovitis, osteitis, and erosions. They found that the combination of ultrasound and MRI improves the accuracy of diagnosis(38), which is a trend for future diagnosis.

The complication from the treatment research cluster (cluster 2) was among the most recently identified words in the latest research. As an important indicator to evaluate the therapeutic effect, complications have received much attention by clinicians. In the field of orthopaedics, accurate positioning and navigation during surgery are particularly important; otherwise, nerve and blood vessel damage and other postoperative complications will be caused, leading to poor prognosis of patients. For example, in lateral ankle stabilization techniques, ultrasound-guided arthroscopy can make the direct visualization of ankle anatomical landmarks and structures possible and can also effectively reduce surgical time and decrease the incidence of iatrogenic damage to neurovascular and other soft tissue structures(39). Similarly, Yang et al. conducted a randomized controlled study in which ultrasound-mediated anaesthesia was used in 38 patients who needed surgery on the ankle joint and not in another 38; they found that the use of ultrasound results in fewer complications, which points out the direction of the development of ultrasound in treatment.

According to the epidemiology research cluster (cluster 3), key words such as female and male in the latest research appeared more frequently. Therefore, epidemiological factors such as gender and age have gradually drawn attention in a large number of clinical studies, and gender is one of the important influencing factors in the diagnostic models and prognostic analysis models of some diseases. For example, in a study of combined ultrasound and nerve stimulator-guided deep nerve block, the research objects were also grouped by sex(40). Similarly, in a study of risk factors for osteoporosis and associated fractures, females have long been listed as a risk factor, and due to the secretion of female oestrogen, it has also become a point of consideration in the treatment of osteoporosis patients(41).

In Fig. 7, the words that catch people’s attention and last the longest included bone, articular cartilage, and the new salient keywords included instability and fracture. Therefore, we speculated that the study of bone joints would be a trend. Over the last two decades, a number of technical advances have improved ultrasound imaging of joints and soft tissues, increasing accuracy in joint disease assessment(42). For example, ultrasound detection of synovial effusion and synovial hypertrophy in knees has obtained good results (43, 44).
Clinical research is a research method to discuss a series of problems such as the diagnosis, treatment, prognosis, prevention of etiology and so on, while ultrasound as a clinical application device, research results can be quickly converted to clinical. Clinical randomized controlled trial is a highly reliable evidence in the field of evidence-based medicine, finally, we searched Clinicaltrials.gov and found 7 documented clinical randomized controlled trial (Table 5), Ultrasound guided knee injections, as a research focus of bone and joint discipline, is also the focus of clinical randomized controlled studies, which is similar to the results in Fig. 7. What is more surprising is that most of the clinical studies we collected are related to nerve block under ultrasound guidance and achieve good therapeutic effect, which provides a direction for the application of ultrasound in treatment to a certain extent. since all the 7 clinical trials were therapeutic, it is reasonable to believe that ultrasound, as a traditional diagnostic tool, has become a trend to be widely used in clinical treatment.

This bibliometric analysis investigated the publications that were extracted from the WOS database. We try to keep the data objective and reliable. However, limitations are inevitable. Due to our inclusion criteria, only English studies have been collected, and some important but non-English studies related to ultrasound have been ignored. In addition, the database is still constantly updated, so our results may be slightly different from the actual results.

Conclusions

The United States was the most productive country for research on ultrasound in orthopaedics, and we predicted that China will surpass the United States in publication over the next two decades. The focus of keywords gradually shifted from treatment research to diagnosis research and epidemiology research. It was also recommended to focus on promising research hotspots, such as MRI, complications and gender. Although the current amount of research is not enough, we believe the growth trend in the future will be rapid. Our study provides profound insights into the research history and current status of ultrasound in orthopaedics, which may indicate its future trend. (Fig. 8)

Abbreviations

WOS: Web of Science; AAY: average appearing year; RRI: relative research interest; GDP: gross domestic product; JCRs: journal citation reports

Declarations

Ethics approval and consent to participate:

Not applicable

Consent for publication:

Not applicable

Availability of data and materials:
All data generated or analysed during this study are included in this published article [and its supplementary information files]

**Competing interests:**

The authors declare that they have no competing interests.

**Funding:**

Not applicable

**Authors’ contributions:**

(I) XSG, WS, XDM and ZZT made the conception and design;

(II) XSG gave the administrative support;

(III) WS, XDM and DWX provided the study materials or patients;

(IV) WS, XDM, WJH, and LL collected and assembled of data;

(V) ZPY, XZR and LL do the data analysis and interpretation;

(VI) All authors took part in the manuscript writing;

All authors read and approved the final manuscript

**Acknowledgements:**

Not applicable

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Figures
Figure 1

Flow diagram of the inclusion process. The detailed process of screening and enrolment.
Figure 2

Contributions of different countries/regions to the research field regarding ultrasound in orthopaedic research. (A) The number of publications, citation frequency ($\times 0.05$), H-index ($\times 5$) and GDP ($\times 5$, per trillion dollar) in the top 10 countries or regions; (B) The number of publications worldwide and the time course of relative research interest of ultrasound in orthopaedics.

Figure 3
The cooperation network of countries/regions in ultrasound in orthopaedics research. The cooperative relations between countries/regions can be visualized.

**Figure 4**

The model fitting curves of growth trends of publications associated with ultrasound in orthopaedic research. (A) Global; (B) USA; (C) England; (D) Japan; (E) Turkey; (F) South Korea; (G) China.

**Figure 5**

The distribution of institutions engaged in research on ultrasound in orthopaedics. (A) The network of institutions by CitesSpace; (B) the network of institutions by VOSviewer.
### Top 16 Keywords with the Strongest Citation Bursts

| Keywords            | Year | Strength | Begin | End  | 2009 - 2020 |
|---------------------|------|----------|-------|------|-------------|
| arthroscopy         | 2009 | 6.9477   | 2009  | 2012 |             |
| low back pain       | 2009 | 6.3451   | 2009  | 2013 |             |
| bone                | 2009 | 5.7301   | 2009  | 2014 |             |
| integrity           | 2009 | 5.2047   | 2009  | 2012 |             |
| articular cartilage | 2009 | 4.6335   | 2009  | 2014 |             |
| thickness           | 2009 | 3.8126   | 2009  | 2014 |             |
| mechanical property | 2009 | 6.418    | 2010  | 2012 |             |
| prevention          | 2009 | 3.46     | 2010  | 2014 |             |
| radiography         | 2009 | 5.1264   | 2011  | 2016 |             |
| therapy             | 2009 | 3.5513   | 2011  | 2014 |             |
| hip                 | 2009 | 3.0541   | 2011  | 2013 |             |
| replacement         | 2009 | 4.263    | 2012  | 2016 |             |
| exercise            | 2009 | 7.4015   | 2013  | 2016 |             |
| metaanalysis        | 2009 | 6.8134   | 2015  | 2018 |             |
| fracture            | 2009 | 3.4734   | 2015  | 2017 |             |
| instability         | 2009 | 4.1026   | 2017  | 2020 |             |

**Figure 7**

The top 16 keywords with the strongest citation bursts from 2009 to 2020. The red bars represent frequently cited keywords during this time period. The green bars represent infrequently cited keywords.