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Bibliometric analysis of extracorporeal shock wave therapy for tendinopathy

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Abstract

Background: Extracorporeal shock wave therapy (ESWT) is a mature, conservative treatment modality for tendinopathy. Although many relevant studies have been conducted, systematic bibliometric studies are lacking. This study aimed to identify trends and hotspots in the treatment of tendinopathy using ESWT.

Methods: A literature search was conducted on ESWT for tendinopathy using the Web of Science Core Collection with a search period of 2002 to 2022. Of 559 identified studies, 276 met the inclusion criteria and were analyzed using CiteSpace software.

Results: The results showed that from 2002 to 2022, the publication rate of literature on ESWT for tendinopathy was generally increasing. Research hotspots, such as tendinopathy and calcific rotator cuff deposits, began earlier but continued to receive scholarly attention. Research on animal models and molecular mechanisms has progressed slowly in this field. The combined or comparative effectiveness of injectable and supplement-based treatments with ESWT is a popular research topic.

Conclusion: Pain management in patients with tendinopathy has received considerable attention. Simultaneously, more clinical indicators of energy levels and pulse parameters during ESWT are needed to provide more scientific and accurate treatment for patients.

Abbreviations: AK = author keywords, ESWT = extracorporeal shock wave therapy, IF = impact factor, PDRN = poly dexyribonucelic acid, WOS = Web of Science.

Keywords: bibliometrics, CiteSpace, cluster analysis, extracorporeal shock wave therapy, physical therapy, tendinopathy

1. Introduction

Tendons act as carriers that connect muscles to bones, helping the muscles perform centripetal and centrifugal movements while generating forces that act on the bone and create joint movements. Tendinopathy is a common degenerative disease that primarily affects athletes and physically active workers.[1] The etiology of tendinopathy is diverse, with the most common being the amount of exercise performed or the work environment. Overuse is considered to be the main reason for the high prevalence of this condition. Athletes are the main patients with tendinopathy.[2] For example, patellar tendinopathy is highly prevalent in sports such as basketball, volleyball, and jumping, where the frequency of jumping is high. According to Vetrano et al,[3] the prevalence of patellar tendinopathy in volleyball players is high, especially in elite volleyball players, who have a prevalence of up to 40%. Studies have shown that a high training volume and match frequency are the main risk factors for developing patellar tendinopathy.[4] Similarly, the incidence of Achilles tendinopathy is higher in runners and track and field athletes,[5] whereas the incidence of humeral epicondylitis is higher In tennis and badminton players. This range of tendinopathies affects the performance of good athletes; indeed, more severe cases may prematurely end their careers.[6]

Extracorporeal shock wave therapy (ESWT) is a noninvasive treatment modality.[7] ESWT was initially used in clinical practice in 1980 for the treatment of kidney stones and other diseases, and then rapidly expanded to other areas of medicine. ESWT was first applied to skeletal muscles in 1987 with encouraging results.[8] Recent studies have found that ESWT is effective in the treatment of coronary artery disease in end-stage ischemic heart disease, and ultrasonography has shown significant perfusion in areas with reduced blood flow after ESWT.[9–11] ESWT uses a special type of sound wave with a very high pressure and short duration.[9] which propagates in 3 dimensions. The propagation speed increases with increasing pressure, and the waves reflect and refract between materials with different resistances, attenuating the energy within the materials.[12] The molecular mechanism of ESWT remains unclear, and many researchers believe that its

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therapeutic mechanism mainly focuses on 3 aspects.[13] First, the high energy impact on the painful point of the soft tissue loosens adhesions formed in the soft tissues, thereby relieving pain. Second, high-energy shock waves can cause cavitation in soft tissues, cells, and blood, and regulate macrophage activity to reduce leukocyte infiltration, thus relieving the pain caused by inflammation. Third, ESWT hyperstimulates nerve endings, causing pericellular free radical changes and subsequently reducing pain. In recent years, researchers have found that ESWT has satisfactory positive healing and analgesic effects on bone, skeletal muscle, and tendon, and is a priority treatment modality for athletes suffering from tendinopathy. Compared to surgical treatment, EWST is more efficient, cause less surface trauma, and has a shorter recovery period. As a nonsurgical treatment modality, ESWT has been found to have a positive effect on improving both the pain and functional aspects of calcific rotator cuff tendinitis. Furthermore, ESWT can effectively break down calcific deposits within the rotator cuff.[14]

CiteSpace one of the main media tools in current bibliometric research, is an information visualization software developed in Java.[15] It is primarily based on co-citation theory and uses a Pathfinder algorithm to accurately capture the evolutionary critical paths and knowledge inflection point of the target scientific field.[16] CiteSpace can present the development process and structural relationship of a research topic in the form of images, because it has the dual nature and characteristics of "graph and "spectrum."[17] Therefore, a graphic visualization as well as the network, structure, and derivation of many hidden complex relationships between knowledge units or clusters can be presented.[18] This study used CiteSpace to systematically analyze the literature on ESWT for tendinopathies in terms of publication trends and characteristics of the core authors, highly cited literature, journals, and keywords, to examine research hotspots and trends in ESWT for tendinopathies.

2. Data collection and research methods

2.1. Data collection

The Web of Science Core Collection (WOS) was used to search relevant literature. The search formula was set as author keywords (AK) = (tendon) AND AK = (extracorporeal shock wave therapy), AK = (ligament) AND AK = (extracorporeal shock wave therapy), AK = (tendon-bone) AND AK = (extracorporeal shock wave therapy), AK = (bone-tendon) AND AK = (extracorporeal shock wave therapy), AK = (tendon-enthesis) AND AK = (extracorporeal shock wave therapy), AK = (tendinitis) AND AK = (extracorporeal shock wave therapy), AK = (tendinosis) AND AK = (extracorporeal shock wave therapy), AK = (tendinopathy) AND AK = (extracorporeal shock wave therapy), AND AK = (jumper's knee) AND AK = (extracorporeal shock wave therapy).

The time frame was set from January 1, 2002, to July 1, 2022. Overall, 559 articles were retrieved. The inclusion criteria were: articles written in English that included both "extracorporeal shock wave" and "tendinopathy" as subject terms. Articles written in languages other than English, and those that did not include both "extracorporeal shock wave" and "tendinopathy" as subject terms were excluded. Literature screening was performed by 3 evaluators, as follows: 2 evaluators read the articles' abstracts. If the evaluators were unable to make a judgment regarding the article during the abstract reading process, the full article was read. If neither evaluator was able to decide on an article, a third evaluator made the decision. After screening the 559 articles retrieved by the 3 evaluators, 276 articles were finally included in the study (Fig. 1).

2.2. Research methods

CiteSpace (6.1.R2) was used as the visual analysis software to analyze the author collaboration, keyword co-occurrence, and temporal keyword co-occurrence. Folders were created according to the analysis steps of CiteSpace ("input," "output," "data," and "project"). The WOS database was named "download_XX" for the downloaded TXT format files. CiteSpace was used to de-duplicate the included documents. "Time Slicing" was set to "January 2002 to July 2022. "Years Per Slice' was set to'1." The author, journal, and keyword characteristics were analyzed by selecting "Pathfinder" and "Pruning sliced networks," Analyses of annual publication trends and highly cited literature was performed using the visual analysis function in the WOS database.

3. Results

3.1. Research trend analysis

To some extent, the change in the number of scientific publications over time can, reflect the change in the level of attention paid by researchers in a particular field. From January 1, 2002, to July 1, 2022, 276 articles were published on ESWT for tendinopathy, of which 6 were published between January and July 2022.

Between January 2002—and December 2021, 270 articles were published on ESWT for tendinopathy (Fig. 2). The number of publications increased from 13 in 2002 to 25 in 2021. Figure 2 shows an overall upward trend in research results in related research areas.

3.2. Journal characterization

In total 154 journals were included in this study. The citation frequency of the included journals reflects their influence and importance better than the number of publications.

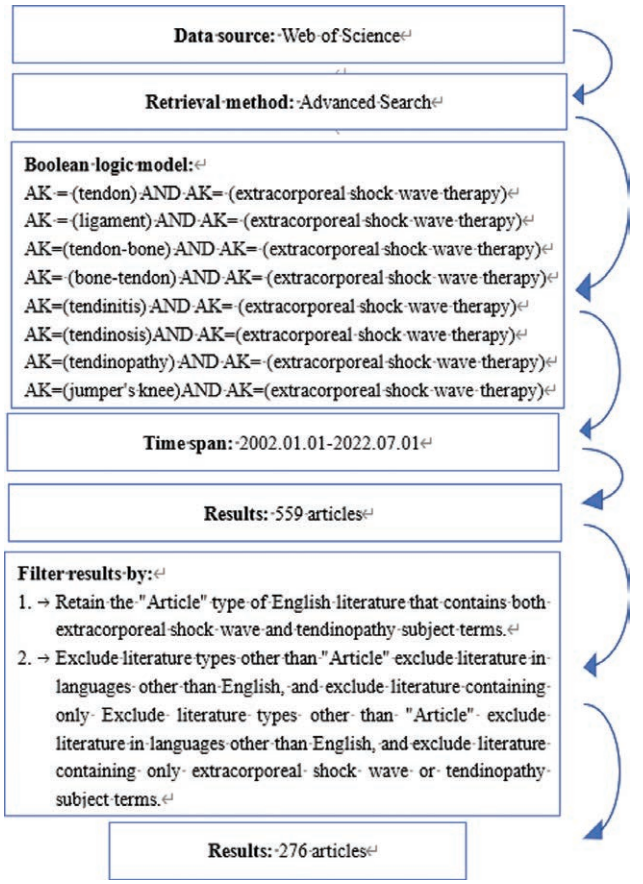

Figure 1. Database search flow chart.

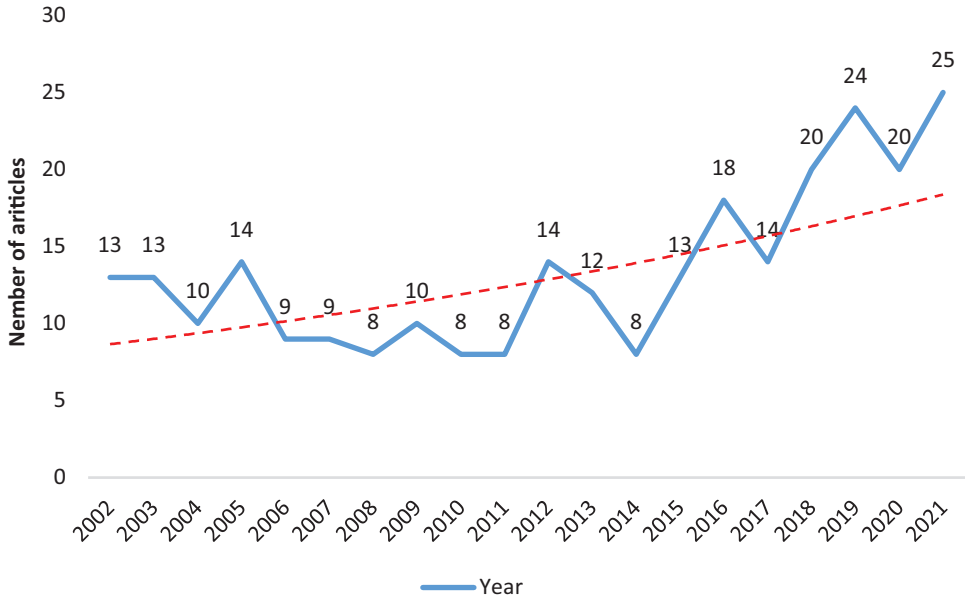

Figure 2. Number of articles published on ESWT of tendinopathy between 2002 to 2021.

The characteristics of journal publications reflect the research trends and directions. Figure 3 shows the results of collating the included journals and using CiteSpace software to perform a co-occurrence analysis of the included journals. The top ten journals were ranked according to their total number of citations and are included in Table 1 for analysis.

Figure 3 shows relatively large networks in the American Journal of Sports Medicine, Journal of Bone and Joint Surgery-British Volume, British Medical Bulletin, Clinical Orthopaedics and Related Research, and Knee Surgery Sports Traumatology Arthroscopy. The colors of the nodes in the co-occurrence map were purple on the inside and red on the outside, indicating that these journals started their research in the field of ESWT for tendinopathies earlier and had considerable influence. Table 1 presents the top ten journals in descending order of citations. The American Journal of Sports Medicine had the highest citation frequency (658) and number of articles (10). JAMA-Journal of the American Medical Association had the highest average number of citations (239) and an impact factor (IF) of 157.335, and is published in the United States. The top ten journals in terms of citations were, from the United States (n = 6), England (n = 2), and Germany (n = 2).

3.3. Core author analysis

By analyzing the collaborative relationships of authors of relevant studies, the main concentrated author collaborative groups were obtained, which could help target the latest results in the field. CiteSpace was used to obtain a clear network of author collaborations (Fig. 4). The size of the author nodes was proportional to the number of author publications in that time frame; more author publications corresponded to a larger node size. The darker the color of the links between authors, the earlier the year of collaboration; conversely, the lighter the color, the closer the collaboration was to 2022. Figure 4 shows the 5 authors with a high influence, Maffulli N (13 articles), Rompe J (7 articles), Maffulli G (6 articles), Padulo J (5 articles), and Luliano E (5 articles). In Figure 4, there are 2 clear and more closely collaborative author groups, one of which is the Maffulli N, Rompe J, and Maffulli G, in the field of ESWT for tendinopathies. The other is a collaborative group with Chen Y, Chou W, and Chang S as the core authors. Three authors, Maffulli N, Schmitz C, and Moretti B, had the highest number of publications. Wang CJ was the author with the highest h-index (46). Maier M was the author with the highest total number of citations (525), as well as the highest average number of citations (75) (Table S1, Supplemental Digital Content, http://links.lww.com/MD/K920).

3.4. Keywords characterization

Figure 5 shows that the keywords with larger nodes were "tendinitis," "calcifying tendinitis" and "shoulder." The darker color in the center of the nodes of these keywords indicated that researchers had examined this topic earlier, whereas "pain," "management" and "extracorporeal shock wave therapy," had a light-colored node center or a small dark-colored center point area and light-colored node periphery, indicating that the research field occurred later.

The most central and frequent keyword was "tendinitis" (0.16 and 60 times), and in the first phase of this field (2002–2012), researchers focused on ESWT with X-ray radiation therapy, transcutaneous point nerve stimulation, ESWT for tendon healing, and the use of three-dimensional (3D) positioning in combination with ESWT for calcific tendonitis of the rotator cuff (Table S2, Supplemental Digital Content, http://links.lww.com/MD/K921). In the second phase of the field, 2013 to 2022, researchers focused on the ESWT treatment efficacy and intensity settings. The keyword "extracorporeal shock wave therapy" used in this search and was therefore excluded from the keyword analysis. The third (centrality 0.11 and 47 times) node center of this research area also appears in dark color in Figure 5, indicating the early start of this research area (2002) (Table S2, Supplemental Digital Content, http://links.lww.com/MD/K921). The years 2018 and 2021 had more relevant studies with the keyword "shoulder." In a 2018 study, researchers compared ESWT with other interventions such as radial extracorporeal shock therapy and intramuscular effect patches. Since 2021, ESWT in combination with other therapeutic strategies has become popular among researchers. Using "shoulder" as the keyword for publication from 2002 to 2021 related research areas included wrap ESWT treatment energy intensity settings, the effects of combining treatment devices such as Kinseio Taping,

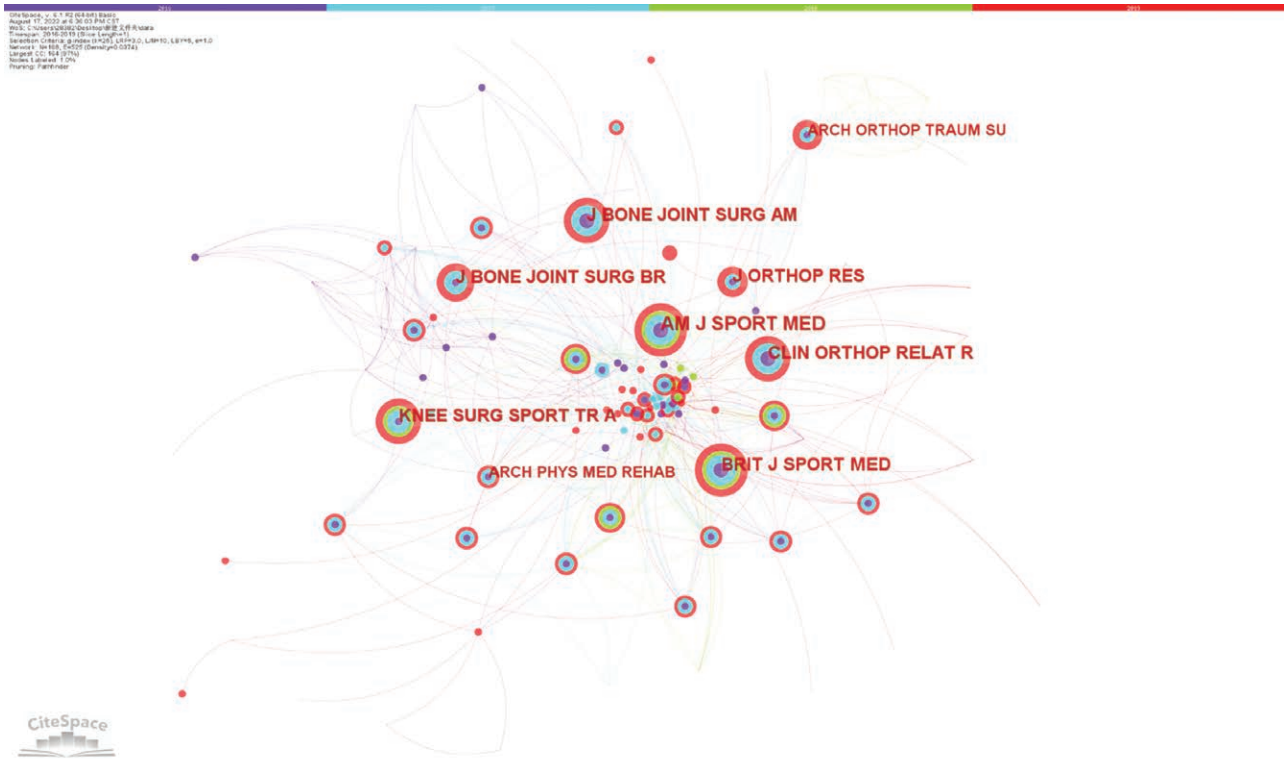

Figure 3. Journals co-occurrence mapping.

Table 1

Top 10 journals by cited frequency.

Rank	Journal	Cited frequency	Publication	Country	IF (2021)
1	*American Journal of Sports Medicine*	658	10	United States	7.010
2	*Journal of Orthopaedic Research*	450	4	England	3.102
3	*Journal of Surgical Research*	333	3	United States	2.417
4	*Knee Surgery Sports Traumatology Arthroscopy*	275	9	Germany	4.114
5	*Journal of Bone and Joint Sugery-British Volume*	248	4	United States	6.588
6	*JAMA-Journal of the American Medical Association*	239	1	United States	157.335
7	*Clinical Orthopaedics and Related Research*	185	3	United States	4.755
8	*Ultrasound in Medicine and Biology*	184	9	England	3.649
9	*Clinical Journal of Sport Medicine*	149	4	United States	3.454
10	*Orthopade*	126	4	Germany	1.004

IF = impact factor.

and the combination with injectable drugs such as injectable deoxyribonucleotides.

3.5. Keyword clustering analysis

Figure 6 shows that the keywords were divided into 11 clusters in order of cluster size: cluster 0 "extracorporeal shockwave therapy," cluster 1 "lateral epicondylitis," cluster 2 "rotator cuff," cluster 3 "extracorporeal shock waves therapy," cluster 4 "extracorporeal shock wave," cluster 5 "painful heel," cluster 6 "differentiation," cluster 7 "jumper's knee," cluster 8 "stifle joint," cluster 9 "horse," and cluster 10 "tendon cells."

Cluster 0, "extracorporeal shockwave therapy" was the largest keyword cluster, and contained 15 keywords, such as "platelet-rich plasma," "rotator cuff tears," "total hip replacement," and "femoral head." Cluster 1, "lateral epicondylitis" mainly contained the keywords "extracorporeal shockwave therapy," "tendon-bone insertion," "energy flux density," "shock wave therapy," "strength fracture," "nonunion," "pseudoarthrosis," and "animal model." Cluster 2, "rotator cuff" mainly contains the keywords: "nuchal ligament," "cervical spine," "rotator cuff," "dietary supplement," "ultrasonic image," "Achilles tendon." Cluster 3, "extracorporeal shock waves therapy" mainly contained the keywords "tennis elbow," "pseudoarthrosis," "calcifying tendinitis," "chronic plantar," and "plantar fasciopathy." Cluster 4, "extracorporeal shock wave" mainly contained the keywords "treatment," "muscle injury," "magnetic resonance imaging," "patellar tendinopathy," "jumper's knee," and "eccentric therapy."

3.6. Analysis of keywords burst

CiteSpace software provides a keyword high burst analysis function, which detected significant changes in keywords within a certain timeframe. Figure 7 was generated in the order of the keyword burst and ended in 2003. During this period, there were 8 papers on painful heel with a strength of 4.92. Shoulder and tennis elbow were also the earliest keywords.

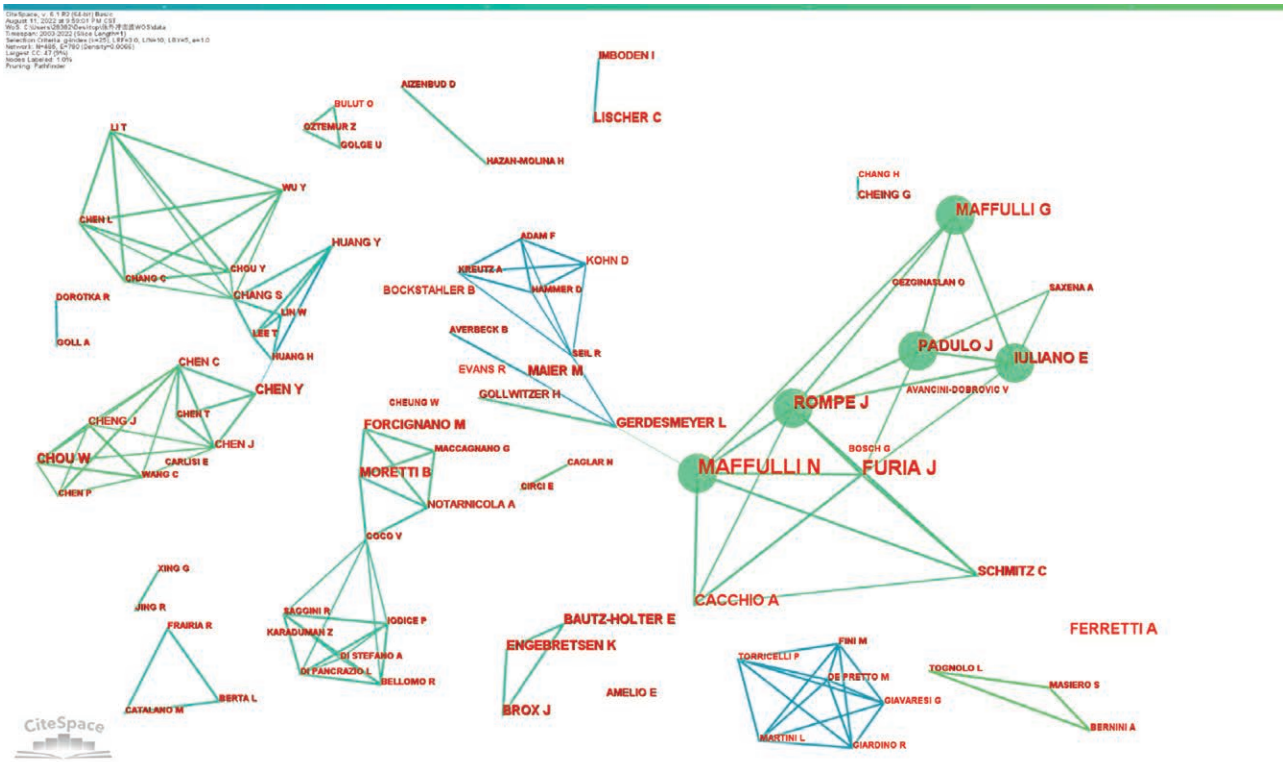

Figure 4. Author collaboration co-occurrence map.

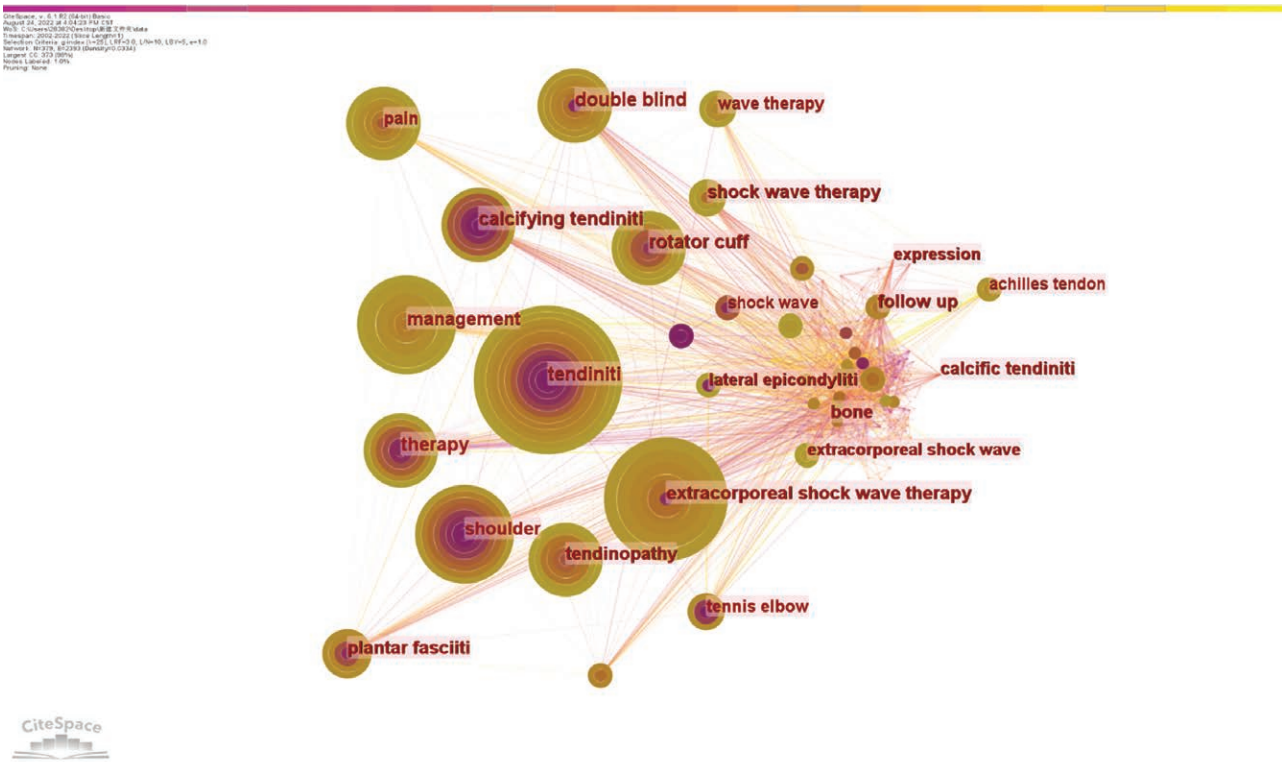

Figure 5. Keyword co-occurrence mapping.

They started in 2002 and ended in 2007. There were 6 papers related to the shoulder with a strength of 4.21 and 1 paper related to tennis elbow with a strength of 3.84. "expression" is the keyword with the longest time span in this study, which began in 2008 and ended in 2016. The total number of articles with the key term "expression" was 8, with a strength of 3.14.

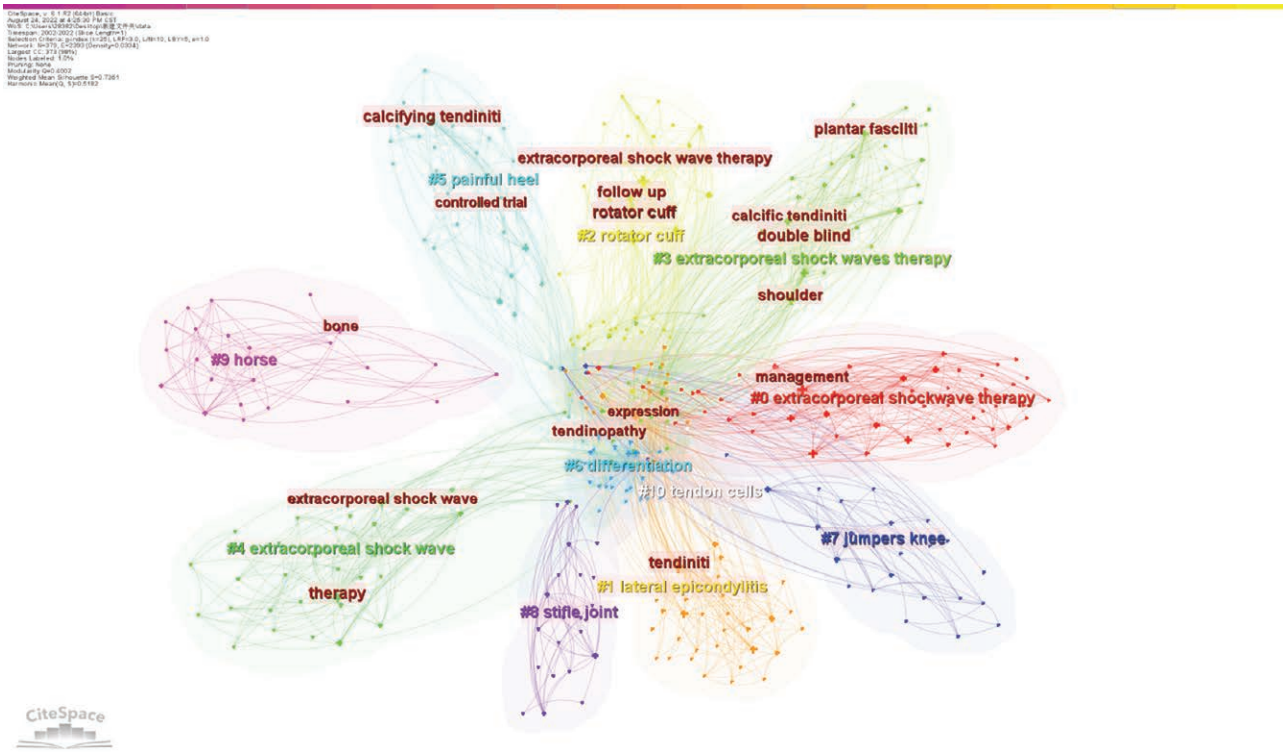

Figure 6. Keyword clustering knowledge graph.

Top 10 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2002 - 2022
painful heel	2002	4.92	**2002**	2003	
shoulder	2002	4.21	**2002**	2007	
tennis elbow	2002	3.84	**2002**	2007	
expression	2002	3.14	**2008**	2016	
differentiation	2002	3.12	**2009**	2013	
management	2002	6.73	**2016**	2020	
extracorporeal shock wave therapy	2002	4.56	**2018**	2020	
wave therapy	2002	3.41	**2018**	2022	
platelet rich plasma	2002	3.16	**2019**	2020	
extracorporeal shock wave	2002	3.14	**2020**	2022	

Figure 7. The strongest keywords burst.

4. Discussion

A total of 276 publications related to ESWT for tendinopathies from January 2002 to July 2022 were compiled using the literature visualization function and Excel spreadsheet available in the WOS for inclusion in the study. The number of publications showed a slow upward trend and t was relatively small from 2006 to 2011. The main study topics in this period included calcific tendinopathy of the shoulder, cellular and collagen mechanisms, gene expression, spinal fusion and animal models. This mainly involved the establishment of animal models and anatomical studies, which may be the reason for the low number of publications in this period.

As for the authors, Maffulli N is the most published author in this field, with 13 articles. Our research focused on various types of tendinopathy treated with extracorporeal shock waves, such as calcific tendinopathy of the shoulder,[19] Achilles tendinopathy,[20,21]

and distal biceps tendinopathy.[22] Studies comparing in vitro shock waves and low molecular weight hyaluronic acid have also been more in-depth.[23] Maffulli N has 2 collaborating authors, one with Gerdesmeyer L's team, which focuses on the short-term and long-term effects of ESWT for calcified shoulder deposits,[19] and the therapeutic effect of electromagnetic transduction therapy combined with ESWT in the treatment of rotator cuff tendinopathy.[24] The other collaborative team included Rompe J and focused on ESWT for Achilles tendinopathy and bursitis of the vertebral body.[19,21,25] These 2 collaborative groups are the largest collaborative groups in the field. The 2 groups had no regional homogeneity, and their study topics had some differences. The Gerdesmeyer et al collaboration focused on the efficacy of ESWT in combination with different devices, confirming the value of ESWT while expanding the range of medical devices that can be used as adjuncts to ESWT. Figure 4 shows that both collaborative groups led by Maffulli N, are relatively recent and have the same purpose, which is to study the short- and medium-term effects of ESWT and the effectiveness of devices, for the treatment of the Achilles tendon,[20,21] patellar tendon,[26] and rotator cuff.[19] The study topic is also practical and novel and may be a new trend and direction for current research on ESWT for tendinopathies. The research of Wang CJ, the author with the highest h-index in this study, focused on collagenase-induced healing of Achilles tendinopathy, targeting ESWT for tendinopathies[27] and the protective effects of ESWT and alendronate sodium on knee tendons and joints.[28]

In terms of the journals, The *American Journal of Sports Medicine* included the most publications related to ESWT of tendinopathies, with 10 relevant articles. Most journals included in this review used animal models as the basis for research of the effects of ESWT treatment.[29,30] In addition, the journal has been interested in the use of ESWT to study the healing effect of the bone-tendon union site.[29] The journal has also paid high attention to the use of ESWT treatment to study the healing effect of bone-tendon junction site, platelet-rich injection treatment and the treatment effect of ESWT with low versus high energy.[31] The *Journal of the American Medical Association* had the highest average citation rate and IF (239 and 157.335, respectively). The article on ultrasound-guided ESWT to improve shoulder function in patients with calcific tendinopathy, by Gerdesmeyer L et al was published in this journal.[32]. It was among the early studies on the efficacy of ESWT, and the combination of IF and citations in this journal also showed a positive correlation between the high number of citations and the quality of the journal.

Keyword analysis revealed that the earliest keywords for ESWT studies on tendinopathy between 2002 and 2022 were "calcifying tendinitis," "therapy" and "tendinitis" suggesting that early researchers had a high interest in ESWT treatment in the area of calcifying tendinitis, which may be related to the migration of clinical results from early ESWT treatment of renal calculi to that of other treatment sites. The rotator cuff, patellar tendon, Achilles tendon, and hip are the most common sites of interest for researchers in this field, and the molecular mechanisms underlying pain management and ESWT treatment have received increasing attention in recent years. The keyword "tendinitis" was the most frequent, with the largest keyword node. The study began in 2002, with darker areas in the node. Calcific tendinitis is a common disease, and the rotator cuff and hip have a high incidence of calcific tendinitis.[33–35] The vast majority of patients in the formative phase can be treated conservatively with pain medications, physical therapy, and steroid injections, whereas patients in the resorptive phase are usually in the self-limiting phase of the disease and experience more pain than those in the formative phase. Nevertheless, the absorption phase is more efficient than the formation phase in breaking down calcified deposits.[34] Daecke et al used ESWT to treat 20 patients with chronic calcific tendonitis and analyzed the results; 15 patients showed a significant reduction in symptoms and magnetic resonance imaging results showed that the rotator cuff was not damaged by the side effects of ESWT treatment.[33] The treatment and pathology of tendonitis have been popular research topics.[36] As later studies divided tendinopathies into specific areas such as the rotator cuff, patellar tendon, and Achilles tendon, the frequency of "tendinitis" began to decrease. However, the outer circle of this keyword node was light-colored, indicating that this area of research is still popular. From 2013–2022 researchers investigated the effects and intensity settings of ESWT treatment. Chen et al conducted a study of adult rats treated with low-energy ESWT for Achilles tendinitis and found that low-energy ESWT treatment reduced the ultimate load and collagen fiber density in the Achilles tendon.[37] The third most frequently used keyword in this study was "shoulder" and calcific tendinitis of the rotator cuff has been a popular issue in ESWT treatment due to the high incidence of calcific tendinopathy in the rotator cuff. In 2002, Daecke et al treated 115 patients with chronic calcific tendonitis of the shoulder using ESWT and achieved positive results.[33] In the same year Schmitt studied the site of ESWT treatment in 50 patients with calcific tendinitis of the rotator cuff and the starting point of the supraspinatus muscle and found that ESWT was more effective for calcification.[36] In recent years, more researchers have investigated areas related to the effects of ESWT treatment in combination with other treatment modalities, Kim et al used ESWT in combination with poly deoxyribonucleic acid (PDRN) to treat chronic traumatic rotator cuff tears in rabbits and found that ESWT in combination with PDRN was more effective and that ESWT prior to PDRN injection resulted in better angiogenesis and cell proliferation.[38] The darker areas of the keywords "calcifying tendinitis" and "therapy" are larger than the lighter areas, indicating that the studies started earlier. This does not mean that these areas of research are outdated but rather reflects new areas of research. Figure 5, displays the keywords "extracorporeal shock wave therapy," and "management," "pain,." The keyword nodes have fewer dark areas, indicating that these research areas started later and have been attracting research attention. This explains why research on "management" and "pain" has been so popular. Comparison between ESWT and other treatment modalities, such as platelet rich injections, steroid injections, and nutritional supplements, is also a popular research area. In addition, exploring the appropriate energy and pulse parameters for ESWT is also worthwhile[32] Gerdesmeyer et al believed that the therapeutic effect of high energy ESWT is better than that of low energy ESWT; however high energy treatment is often accompanied by pain medication, and a better choice of parameters provides better guidance for clinical treatment, which will have great research significance and value.

The top 5 keyword clusters cover most of the research directions of ESWT for tendinopathies and are mainly related to the treatment and healing of calcific tendinitis and tendon injuries. Several studies have been conducted on ESWT for the treatment of bone-tendon sites in animal models. This cluster also includes studies with different ESW energies (mainly moderate and low energies) in combination with other treatment modalities or comparative treatments. Keyword cluster mapping shows that cluster 0 is mainly concerned with studies on the therapeutic effects of ESWT in combination with platelet-rich plasma, ESWT in the treatment of mid-stage Achilles tendinopathy, ESWT in combination with arthroscopic assistance, ESWT for hip femoral dysplasia in dogs, and surgical intervention after ESWT treatment failure. Cluster 1 studies are about animal models, delayed repair of tendon-bone insertion sites, comparison of the effect of ESWT with steroid treatments for costochondritis, comparison of the effect of ultrasound-guided puncture treatment combined with cortisol injection and high-energy ESWT treatment, ESWT for calcific tendonitis of the rotator cuff, the visual analog scale for pain for treatment follow-up, and functional improvement of the rotator cuff after ESWT treatment. Cluster 2 focuses on the biological mechanisms of ESWT combined with platelet-rich injections for rotator cuff tears,[39] ESWT treatment combined

with PDRN for rotator cuff tears,[39] comparison of the effects of Tendisulfur Forte dietary supplementation therapy and ESWT for rotator cuff tendon injuries,[40] ESWT with moderate energy for calcified rotator cuff tendinitis(Moretti et al, 2005), and ESWT combined with arginine in the treatment of Achilles tendinopathy.[41] Cluster 3 focuses on the comparison of the effect of ESWT treatment with surgery for the treatment of humeral epicondylitis,[29] ESWT with low energy and neuromuscular control therapy[42] ESWT versus targeted low-energy ESWT for calcific tendonitis and ESWT with medium energy,[43] and a comparison of ESWT for chronic plantar fasciitis.[44] Cluster 4 focuses on the evaluation of morphology and blood flow using ultrasonography after ESWT for patellar tendinopathy.[45] Research has been conducted on comparing ESWT treatment, ultrasound therapy, and intramuscular patches in the treatment of epicondylitis of the humerus[46] the effect of ESWT on the treatment of ossifying myositis1; the treatment of spasticity of the distal phalangeal joint[47]; and ESWT for patellar tendinopathy.[48]

The keyword emergent mapping showed that "painful heel," "shoulder," and "tennis elbow" were used earlier in this keyword emergent study. These 3 keywords are the main body parts examined in earlier related studies. "Painful heel" was used in the earliest study, and the main research in this field was the analysis of the effect of ESWT in the treatment of Achilles tendinitis or plantar fasciitis.[49,50] The dose-dependent effects of ESWT have been examined.[51] Martitin found that low-energy ESWT significantly improved the metabolic parameters of primary osteoblast cultures, independent of the number of ESWT pulses. Research with the key term "shoulder," which starts at the same time as "painful heel" but ends relatively late, has focused on the treatment and outcome of ESWT for calcific tendonitis of the rotator cuff.[34] In 2002, Hughes suggested that ESWT could be used to treat calcified rotator cuff tendinitis, and he concluded that ESWT was a conservative treatment for calcified rotator cuff tendinitis. However, the treatment results have yet to be elucidated. In 2005, Sabeti et al used computerized 3D navigation with ESWT to treat calcified rotator cuff tendinitis with good results.[52] Since then, many researchers have continued to study and review the intersection of ESWT and calcified rotator cuff tendonitis to obtain more scientific and reliable experimental data and to provide theoretical guidance for clinical treatment. In 2008, Wang et al found that ESWT promoted osteogenesis and fibrocartilage regeneration at the bone-tendon junction and delayed remodeling of the bone-tendon healing junction.[29] Lee et al[53] found that ESWT enhances bone morphogenetic protein 2 expression in spinal fusion. In 2012, Mittermayr et al[54] found that ESWT was effective in recruiting mesenchymal stem cells, stimulating cell proliferation and differentiation, and inhibiting nociception. In 2016, Wang et al[28] found the same protective effects in terms of vascular endothelial factor, soluble vascular cell adhesion molecules, proliferating cell nuclear antigen, and bone morphogenetic protein 2 in a comparison of the effects of ESWT and alendronate in the treatment of knee osteoarthritis in rats. As shown in Figure 7, early researchers have focused on site specific treatment, and the frequent use of "painful heel," "shoulder," and "tennis elbow" demonstrates this point. The keyword "expression" had the longest time span indicating that research on ESWT for tendinopathies has focused on the exploration of its biological molecular mechanism. The time span of "wave therapy" and "extracorporeal shock wave therapy" continues to this day, and they are still a popular research topic.

5. Limitations

This study summarizes topical issues and trends in the field of ESWT for tendinopathy research; therefore, some basic information in this field is explained and illustrated in detail. Because this study mainly involved a bibliometric analysis of this field, other very important but less-studied research areas in this field were not reflected. However, this study can provide a focus for subsequent in-depth research in this field. Specific prospective studies should be conducted to answer more in-depth research questions. We selected literature published from 2002 to 2022 for this study and did not analyze subsequent publications. Another limitation is that CiteSpace can convert some databases for analysis, but the output records of databases such as PubMed do not contain reference formats; therefore, content that can be analyzed is limited. Other databases may have other popular research issues in the field that were not analyzed in this study.

6. Conclusions

The efficacy of ESWT compared to other treatments has been a hot topic in this field of research. Pain scales are increasingly being used as indicators to assess the effectiveness of ESWT. And the ability to reduce patient pain and improve physical function is a new trend in the field of ESWT for tendinopathies. In terms of clinical treatment, setting the energy magnitude and pulse parameters during ESWT is also a relatively weak area of research, and more studies are needed to provide evidence for clinical treatment. At present, no accurate results regarding the molecular mechanisms of ESWT for bone, tendon, or wound healing exist, which is a challenging and significant area of research in ESWT.

Author contributions

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