

ORIGINAL ARTICLE

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Examination of orthopedic scientific publications on femoroacetabular impingement using the science mapping method: A bibliometric analysis

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Abstract

Femoroacetabular impingement (FAI) is a significant pathology resulting from structural abnormalities of the hip joint, which can lead to pain and functional loss, particularly in young and active individuals. In recent years, advancements in both diagnostic and surgical approaches have led to a rapid increase in scientific output in this field. The aim of this bibliometric and science mapping study is to evaluate publication trends, collaboration networks, and thematic developments related to FAI over the past 25 years. Publications related to FAI between 2000 and 2024 were retrieved from the Web of Science Core Collection database using predefined search terms. Only articles and reviews were included. The data were analyzed using the Bibliometrix R package and visualized with VOSviewer software. Publication growth rate, citation counts, most productive authors, institutions, and countries were assessed, along with co-authorship networks, keyword co-occurrence, and thematic evolution were analyzed. A total of 1,571 publications were identified, with an average annual growth rate of 5.14%. The United States was the most productive country and occupied a central position in the international collaboration network. Türkiye stood out in recent years with an increasing number of publications and collaborations. Among the most influential journals were The American Journal of Sports Medicine, Arthroscopy, and Clinical Orthopaedics and Related Research. Keyword analysis highlighted “hip arthroscopy,” “cam deformity,” and “labral tear” as prominent topics, while minimally invasive surgery and advanced imaging techniques emerged as trending themes in recent years. Scientific studies in the field of FAI has been steadily increasing, with research priorities evolving in line with clinical advancements and technological integration. These findings reflect both global and local research dynamics and may guide future studies in the field of hip-preserving surgery.

Keywords: Femoroacetabular impingement, hip arthroscopy, bibliometric analysis, science mapping, orthopedic research trends

Introduction

Femoroacetabular impingement (FAI) syndrome is a pathology defined by clinical and radiological findings, resulting from abnormal contact between the acetabulum and the femoral head-neck junction of the hip joint, which can lead to damage of the labrum and articular cartilage [1,2]. This condition is typically classified as cam type, pincer type, or a mixed type combining both [3]. Morphological changes disrupt load distribution in the hip joint, initiating degenerative processes and predisposing to the development of osteoarthritis [4,5].

FAI is frequently observed in young and middle-aged active individuals, with higher prevalence reported among athletes

and occupational groups exposed to repetitive hip flexion [6,7]. Epidemiological studies have shown that the incidence of FAI is particularly increased in the 18–35 age range, with the cam type being more common in males and the pincer type more common in females [8,9]. This underscores the importance of early diagnosis and intervention in preserving hip joint health [10,11].

The diagnostic process involves clinical tests along with advanced imaging modalities such as plain radiography, magnetic resonance imaging (MRI), and computed tomography (CT) [12,13]. These methods not only detect morphological abnormalities but also allow identification of intra-articular soft tissue lesions [14]. Radiological classifications serve as a guide

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in treatment planning and play a critical role in determining surgical indications [15,16].

Treatment approaches include both conservative and surgical methods. Conservative options—such as patient education, activity modification, and physiotherapy protocols—are generally aimed at alleviating symptoms [17,18]. However, surgical interventions, particularly arthroscopic techniques, have gained prominence in recent years for preventing the progression of structural deformities [19,20].

The number of studies on FAI has increased significantly in recent years. Advances in surgical techniques, imaging modalities, and biomechanical analyses have contributed to improved clinical outcomes [3,9,14]. However, the literature remains heterogeneous regarding optimal treatment strategies, long-term outcomes, and complication rates [12,18].

The aim of this study is to examine scientific publications on femoroacetabular impingement using bibliometric and science mapping methods, in order to identify publication trends, collaboration networks, the most frequently studied themes, and potential directions for future research.

Material and Methods

Study Design

This research is a descriptive cross-sectional study based on bibliometric analysis, aimed at evaluating scientific publications on FAI. Publication trends, citation performance, collaboration networks, and thematic development areas were analyzed.

Study Design

Data were obtained from the Web of Science (WoS) Core Collection database. The search strategy targeted FAI-related terms in the title, abstract, and keyword fields:

"Femoroacetabular Impingement" OR "FAI" OR "Hip Impingement" OR "Cam Deformity" OR "Pincer Lesion" OR "Acetabular Overcoverage"

The search was limited to articles and reviews, excluding conference proceedings, editorials, letters, and book chapters. Subject area filters included Orthopedics, Sport Sciences, and Surgery. Publications from 2000 to 2024 were included.

Data Processing

Records obtained from WoS were exported in BibTeX (.bib) format and analyzed using the Bibliometrix R package. Duplicate entries were removed, and author names, institutions, and country information were standardized. Missing metadata were completed using journal records and Digital object identifier (DOI) queries.

Analysis Methods

Performance Analysis

- Number of publications and growth rate by year

- Most productive authors, institutions, and countries
- Most cited publications
- Comparison of local citations (LC) and global citations (GC)

Network Analyses

- Co-authorship analysis: Construction of collaboration networks at the author, institution, and country levels
- Keyword co-occurrence analysis: Identification of co-usage relationships among keywords via co-word analysis
- Network visualizations were performed using VOSviewer software

Thematic Analysis

- Identification of thematic clusters using the Louvain algorithm
- Classification of themes as motor, basic, niche, or emerging based on density and centrality values

Statistical Approach

Analyses were based on descriptive statistics. Publication, citation, and network data were summarized using frequency and percentage distributions. Link strength metrics were used in keyword and collaboration network analyses. No parametric statistical tests were conducted.

Ethical Considerations

Only open-access and publicly available bibliometric data were used in this study. As it does not involve human or animal data, ethical approval was not required.

Result

Publication Performance and Citation Analysis

The literature on FAI showed a marked increase in the number of publications starting from 2001. A total of 1,571 academic publications were identified by 2024, with an average annual growth rate of 5.14%.

- The highest annual number of publications was observed in 2021 (n=155)
- Total citation count: 14,118
- Average citations per article: 33.48
- Number of authors: 4,855
- International collaboration rate: 19.61%

An analysis of the most cited studies in the literature related to FAI syndrome, published between 2000 and 2024, reveals several pioneering publications that have shaped the field (Table 1). During this period, studies by Ganz, Beck, Griffin, and Philippon attracted high citation counts and made influential contributions to the definition, pathophysiology, and clinical management of FAI. Accordingly, these publications represent the most impactful scientific sources in the FAI field between 2000 and 2024.

Table 1. Most cited publications

Author (Year)	Title	Citation Count	Source Journal
Ganz 2003	Femoroacetabular impingement: a cause for osteoarthritis	2412	Clinical Orthopaedics and Related Research
Beck 2005	Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip	1492	J Bone Joint Surg-Br Vol
GRIFFIN 2016	The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement	697	Br J Sports Med
PHILIPPON 2009	Outcomes following hip arthroscopy for femoroacetabular impingement with associated chondrolabral dysfunction: minimum two-year follow-up	647	J Bone Joint Surg-Br Vol

Table 2 presents the H-Index, G-Index, total citations (TC), number of publications (NP), citations per article (TC/NP), and the starting year of publication. Analysis of journals publishing FAI-related studies between 2000 and 2024 revealed that The American Journal of Sports Medicine, Arthroscopy, and Clinical Orthopaedics and Related Research stood out with the highest impact metrics. These journals, based on their H-index, G-index, and M-index values, represent the most productive and influential publication outlets in the field of FAI.

An analysis of the most frequently used keywords in the FAI literature shows that the terms “Femoroacetabular Impingement,” “Hip,” and “Hip Arthroscopy” appear with the highest frequency (Table 3). This reflects the literature’s focus on the primary anatomical structures and surgical approaches. Additionally, the repeated use of terms such as “FAI,” “Femoroacetabular Impingement Syndrome,” and “Impingement” demonstrates conceptual consistency and terminological continuity within the field.

Table 2. Most influential journals

Journal	h_index	g_index	m_index	TC	NP	Year
American Journal Of Sports Medicine	53	88	2.78	9104	189	2007
Arthroscopy-The Journal Of Arthroscopic And Related Surgery	49	83	2.45	8865	227	2006
Clinical Orthopaedics And Related Research	35	78	1.52	7987	78	2003
Journal Of Bone And Joint Surgery-American Volume	22	31	1.04	2430	31	2005
Knee Surgery Sports Traumatology Arthroscopy	22	40	1.15	1851	74	2007
Journal Of Bone And Joint Surgery-British Volume	21	22	0.84	4432	22	2001
Orthopaedic Journal Of Sports Medicine	20	30	1.66	1195	79	2014
Hip International	18	26	0.9	772	45	2006
Journal Of Hip Preservation Surgery	17	26	1.41	987	81	2014
Bone \& Joint Journal	16	22	1.23	578	22	2013

Table 3. Keyword usage frequencies

Keyword	Frequency
Femoroacetabular Impingement	573
Hip	270
Hip Arthroscopy	265
Arthroscopy	123
Fai	115
Femoroacetabular Impingement Syndrome	86
Impingement	75

The graph illustrates the annual distribution of publications on FAI between 2000 and 2024. From 2000 to 2008, the number of articles published in the FAI field was relatively low and fluctuating. Starting in 2009, a noticeable increase occurred, continuing through 2011–2015, marking a significant growth period in the literature. Between 2016 and 2019, there were

minor fluctuations, but the overall trend remained upward. The peak was reached in 2020, and especially in 2021, with approximately 150 publications per year, representing the period of highest research activity in the field. From 2022 to 2024, a clear declining trend in publication numbers is observed. This pattern indicates a rapid rise in scientific interest in FAI during

the 2010s, followed by a potential reduction in research activity in recent years (Figure 1).

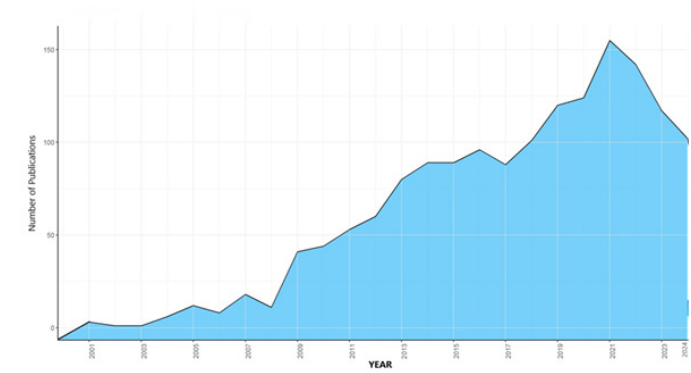


Figure 1. Distribution of publications by year

The flowchart illustrates the bibliometric analysis process applied to the FAI literature (Figure 2). It depicts the filtering of records obtained from the literature search and the subsequent steps of performance, keyword, collaboration, and thematic analyses.

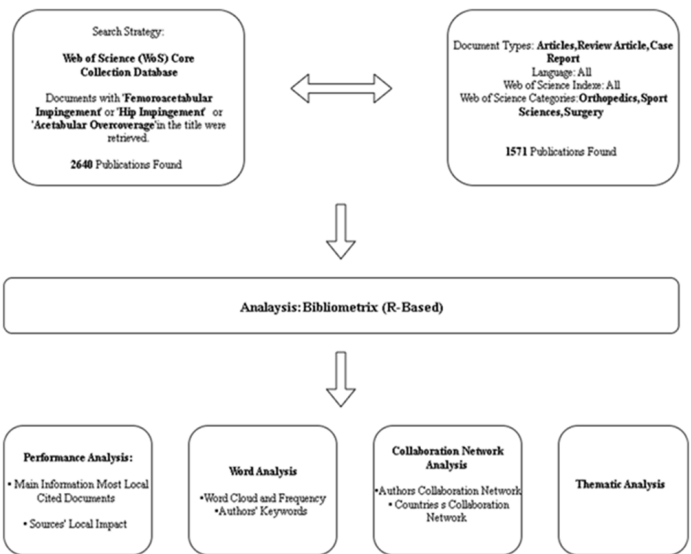


Figure 2. Study flowchart

This figure illustrates the steady increase in scientific output on FAI between 2001 and 2025, with an average annual growth rate of 5.14%. A total of 1,571 publications involved 4,855 authors, highlighting the predominance of collaborative studies with an average of six authors per paper. The international collaboration rate of 19.61% is notable. An average of 33.48 citations per publication indicates the high academic impact of the studies in this field (Figure 3). These data demonstrate that FAI research is both productive and influential.

This trend analysis illustrates the evolution of the FAI literature over time (Figure 4). Between 2003 and 2010, surgical techniques (e.g., surgical dislocation, osteoplasty) and imaging methods (e.g., MR arthrography) were prominent. From 2011 to 2017,

studies increasingly focused on FAI definitions, alpha angle assessment, and clinical outcomes. After 2018, topics such as hip arthroscopy, patient management, and gait analysis became more prominent.



Figure 3. Scientific publication overview on femoroacetabular impingement

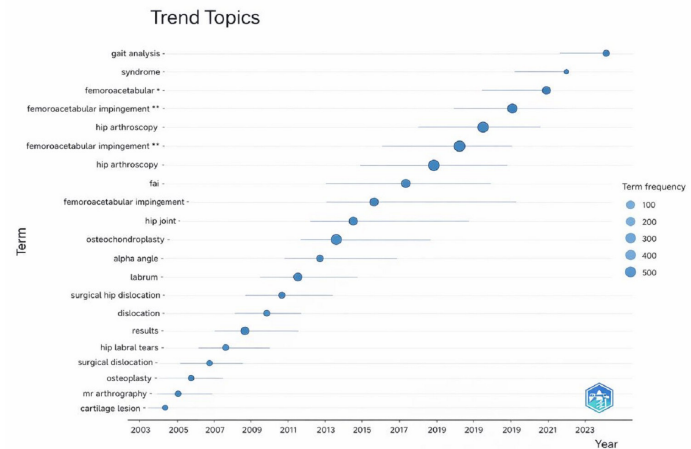


Figure 4. Comprehensive literature overview

This network graph illustrates the collaboration relationships among authors who frequently co-publish in the field of FAI .Nodes (circles) represent individual authors, and node size reflects the author's collaboration intensity, such as the number of publications or centrality within the network. Authors grouped by the same color indicate clusters of closely collaborating researchers. Edges (lines) represent co-authorships between these authors. For example, the largest node typically corresponds to the author with the most connections, appearing in the highest number of joint publications. The clusters depicted in the visualization highlight the prominent research teams and collaborative structures within the FAI literature.

This graph illustrates the distribution of collaborations in the FAI field across different countries. The size of each node represents the number of collaborations for that country. The USA occupies a central position with the highest number of connections. Turkiye is shown to have direct collaborations with countries such as Germany, China, and Italy. Colored nodes and gray connecting lines are used to enhance visual clarity and distinction.

This thematic map presents the main themes in the FAI literature, categorized into four quadrants (Figure 5):

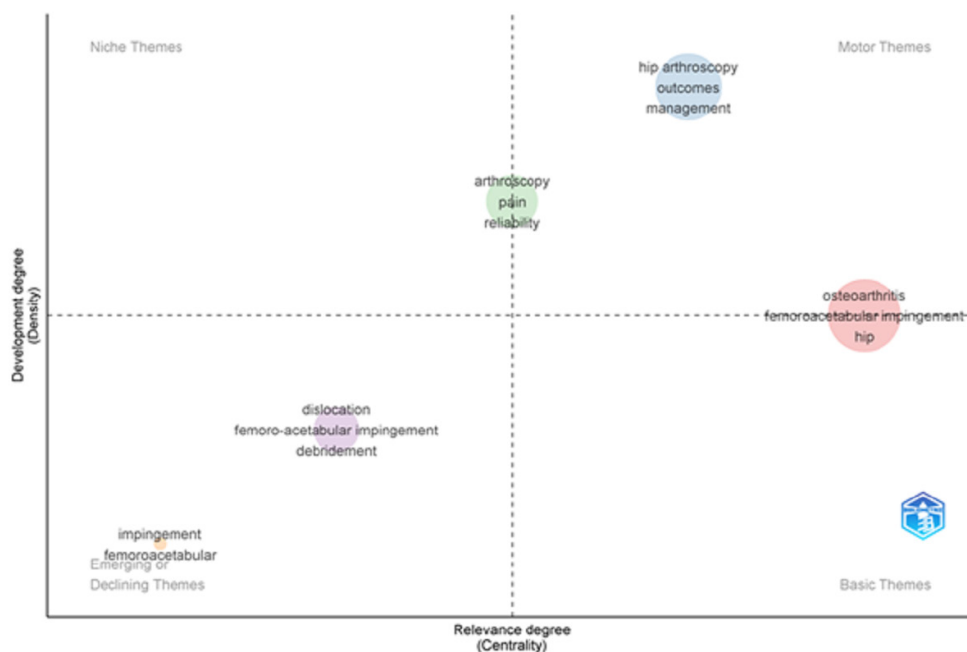


Figure 5. Thematic map

Motor Themes (Upper Right Quadrant)

- Keywords: hip arthroscopy, outcomes, management
- This cluster exhibits high centrality and density, indicating that these themes are both well-developed and critical for the research field. Studies on hip arthroscopy, its outcomes, and management are conceptually mature and strongly connected to other themes in FAI literature. As such, this area represents a core, ongoing theme essential for understanding the clinical aspects of FAI treatment.

Basic Themes (Lower Right Quadrant)

- Keywords: femoroacetabular impingement, hip, osteoarthritis
- This cluster shows high centrality but relatively low development. Concepts like femoroacetabular impingement and osteoarthritis are central discussion topics in the literature; however, studies in these areas remain limited in methodological depth. These themes occupy a central position in FAI research but require further theoretical and empirical exploration.

Niche Themes (Upper Left Quadrant)

- Keywords: arthroscopy, pain, reliability
- These themes have high density but low centrality. Topics such as pain and the reliability of arthroscopic interventions are methodologically detailed but have fewer connections to the broader FAI literature. Their designation as niche themes suggests that these specialized studies are primarily conducted within subfields of expertise.

Emerging or Declining Themes (Lower Left Quadrant)

- Keywords: impingement, femoroacetabular, dislocation, debridement
- This cluster shows low density and centrality, indicating either declining relevance or early-stage development. Terms like “debridement” and “dislocation” have had limited application in the FAI context. These areas could be revitalized through new research questions and investigations.

Overall, the thematic map demonstrates that clinically oriented research, such as hip arthroscopy and its outcomes, dominates the FAI literature. Studies related to osteoarthritis form the foundational framework, while topics like pain and reliability are niche yet detailed. Some themes have either lost relevance or have not yet fully captured researchers' attention.

Discussion

Recent long-term clinical studies in the field of FAI have demonstrated that arthroscopic treatment provides durable symptom control and functional improvements [21]. A contemporary systematic review and meta-analysis summarizing long-term outcomes reported that functional gains are maintained over extended follow-up periods, and revision requirements remain acceptable in selected patient groups [22]. Our analysis, showing a steady increase in publications between 2000 and 2024 and peaking in 2021, aligns with this long-term focus in the literature. However, the decline in publication numbers after 2021 may reflect a maturation phase within the FAI literature or external factors such as the COVID-19 pandemic, which temporarily shifted research priorities in orthopedic surgery.

Reviews on the safety profile of surgery indicate that hip arthroscopy complications are generally low to moderate, with serious adverse events being rare [23]. In our study, themes related to complications and safety have emerged prominently in recent years, gaining visibility within the citation network.

Studies in athlete populations, particularly elite athletes, report high rates of return to sport after arthroscopy, with most athletes regaining pre-injury performance levels [24]. However, literature highlights the need for standardization and objective criteria for measuring return to sport [25]. In our analysis, the central positioning of keywords such as “outcomes” and “return to sport” reflects that this research focus lies at the core of the network.

Regarding technical preferences, studies comparing labral debridement versus repair indicate advantages of labral-preserving approaches for long-term survival and function [26]. Consensus statements standardizing groin pain terminology emphasize the importance of clinical classification for research quality and comparability [27]. Our analysis shows frequent use of terms like “labral tear” and “hip arthroscopy,” reflecting the bibliometric footprint of terminology and technical standardization. In addition, our trend analysis indicates a gradual shift from anatomical characterization to functional and patient-centered approaches, consistent with the increasing clinical emphasis on patient-reported outcomes in orthopedics.

Comparative analyses focusing on demographic determinants suggest that age and sex may significantly influence outcomes [28]. Large cohort studies indicate that functional improvement is generally reproducible in short- to mid-term follow-up, although outcomes may vary in heterogeneous subgroups [29]. Our study shows that topic clusters spread across large populations, supported by collaborative networks.

Systematic reviews summarizing return-to-preinjury levels in athletes suggest that surgery is an important tool for performance recovery, while rehabilitation strategies remain key determinants [30]. Randomized, multicenter trials show that arthroscopy can provide clinical superiority over physiotherapy and activity modification in appropriately selected patients, with patient selection and procedural standardization affecting outcomes [31]. Our network analysis indicates that surgical and rehabilitation themes have concurrently strengthened.

Population-based analyses reveal that the risk of conversion to total hip arthroplasty after hip arthroscopy is low but may increase in specific patient profiles [32]. Large series from national health databases provide distribution of complication types and survival analyses, offering benchmarks for quality improvement initiatives [33]. In our study, publications focusing on long-term follow-up and healthcare utilization formed prominent clusters within the citation network.

The international consensus defining FAI syndrome provides a fundamental reference for clinical and research standardization [34]. Reviews addressing arthroscopy outcomes in the presence of concomitant osteoarthritis emphasize the importance of

patient selection and expectation management [35]. Our thematic map analysis indicates that patient selection and indication determination have emerged as increasingly prominent topics.

Reviews focused on capsular management, integrating anatomy, biomechanics, and technique, highlight the importance of closure and repair strategies for stability and function [36]. Systematic reviews on alpha angle correction examine the impact of morphological correction on clinical outcomes and potential osteoarthritis progression [37]. In our study, the emergence of terms such as “capsulotomy” and “minimally invasive surgery” as rising themes reflects the growing emphasis on technical optimization in the research agenda.

The main limitations of this study include the restricted literature coverage due to reliance on a single database, the dynamic nature of citation metrics over time, and the descriptive nature of the analyses. Nonetheless, the combined evaluation of performance and network indicators allowed objective identification of structural trends in FAI literature. A major limitation of the present study is the exclusive reliance on the Web of Science (WoS) database. The exclusion of other major indexing platforms such as Scopus, PubMed, and Dimensions may have restricted the breadth of the retrieved literature, thereby limiting the generalizability of the findings.

In conclusion, the increase in publication volume, focus on long-term outcomes, emphasis on safety and patient selection, and the need for technical standardization will continue to shape central research axes in FAI. Our findings also suggest that these axes are reflected in local research priorities.

Conclusion

This bibliometric analysis demonstrates that scientific production in the field of FAI has steadily increased over the past 25 years, with clinical, surgical, and technological advancements shaping publication trends. The most influential publications remain pioneering studies focused on defining pathomechanisms and standardizing surgical techniques, while minimally invasive surgery and advanced imaging methods have emerged as rising themes in recent years. The USA maintains its leadership in the literature, whereas Türkiye stands out due to its growing publication volume and visibility within collaboration networks. These findings emphasize the importance of multidisciplinary approaches aimed at improving clinical outcomes in FAI research. Additionally, technological innovations and international collaborations have contributed to the advancement of both diagnostic and treatment strategies. This study identifies current trends and highlights potential areas for future research.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

The authors declare that they have received no financial support for the study.

Ethical Approval

Ethical committee approval was unnecessary for this study.

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