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Original Article

Autologous Minced Cartilage on the Rise: A Bibliometric Mapping of Minced Cartilage Techniques in Cartilage Repair

Burak Menderes Akdogan[1], Cagri Havitcioglu[2], Muhammet Hayat[3], Mehmet Hakan Yilmaz[4], Zafer Atbasi[5], Fatih Barca[6], Mutlu Akdogan[6], Halis Atil Atilla[6]

[1]Department of Orthopaedics and Traumatology, Rize State Hospital, Rize, Türkiye
[2]Department of Orthopaedics and Traumatology, Near East University, Faculty of Medicine, Nicosia, Cyprus
[3]Department of Orthopaedics and Traumatology, Turhal State Hospital, Tokat, Türkiye
[4]Department of Orthopaedics and Traumatology, Gaziler Physical Therapy and Rehabilitation Training and Research Hospital, Ankara, Türkiye
[5]Department of Orthopaedics and Traumatology, Ankara Güven Hospital, Güven Çayyolu Healthy Living Campus, Ankara, Türkiye
[6]Department of Orthopaedics and Traumatology, Ankara Etlik City Hospital, Ankara, Türkiye

ABSTRACT

Objective: Single-stage minced cartilage techniques have emerged as alternatives to two-stage autologous chondrocyte implantation (ACI/MACI) and osteochondral grafting. However, the evolution of different minced cartilage approaches over time, as well as the countries and journals driving this literature, has not been quantified. This study aimed to bibliometrically map the minced cartilage literature from 2000 to 2024, with an additional 2025 snapshot, and to describe temporal trends, technique-specific distributions, including autologous minced cartilage implantation (AMC/MCI), particulated juvenile allograft cartilage (PJAC), and cartilage autograft implantation system (CAIS), and global and journal-level contributions.

Materials and Methods: The Web of Science Core Collection was searched for English-language original articles and notes related to AMC/MCI, PJAC/DeNovo NT, or CAIS published between 2000 and 2024. Reviews, meta-analyses, editorials, letters, and conference proceedings were excluded. Two authors independently screened records and extracted total citations (TC), citations per year (CPY), study type, technique category, country, journal, and Level of Evidence (Levels I–IV). A separate descriptive search using the same strategy covered the period from 1 January to 29 October 2025 as a "2025 snapshot."

Results: Of 219 records, 101 original studies published between 2000 and 2024 were included. Annual output accelerated after 2018, with half of all articles published between 2021 and 2024. Therapeutic, basic science, and technical note designs predominated. In basic science studies, AMC/MCI clearly predominated over PJAC, whereas in therapeutic studies, PJAC still outnumbered AMC/MCI. The United States, Germany, and Switzerland together produced approximately two-thirds of all publications. In the 2025 snapshot, 14 original studies were identified, of which 11 (78.6%) involved AMC/MCI.

Conclusion: Bibliometric evidence demonstrates a shift in the minced cartilage literature from an early emphasis on PJAC toward increasing publication activity related to AMC/MCI, particularly after 2018. AMC/MCI now leads basic science output and has become increasingly represented in recent clinical research. However, bibliometric trends do not establish clinical superiority or broad clinical adoption, and long-term comparative studies are needed to define the effectiveness and role of AMC/MCI across chondral lesion patterns and in combination with matrix or biologic adjuvants.

Keywords: Autologous minced cartilage implantation, bibliometric analysis, minced cartilage, particulated juvenile allograft cartilage, single-stage cartilage procedures.

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Address for correspondence:
Halis Atıl Atilla,
Department of Orthopaedics and Traumatology, Ankara Etlik City Hospital, Ankara, Türkiye
E-mail:
dratilatilla@hotmail.com

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INTRODUCTION

Focal chondral lesions of synovial joints are increasingly recognized as an important cause of pain and functional limitation, particularly in young and active patients. In recent years, the increased diagnosis of chondral lesions has also led to a diversification of treatment approaches.[1] The primary goal of treatment is to restore hyaline or hyaline-like cartilage depending on the size of the defect.[2,3] In medium to large defects, osteochondral autograft transfer (OATS), autologous chondrocyte implantation (ACI), matrix-assisted chondrocyte implantation (MACI), and scaffold-based repair techniques using natural or synthetic materials are the most frequently used options.[3,4] However, the two-stage ACI/MACI approach, which requires in vitro cell expansion, imposes a substantial clinical and economic burden. Although outcomes reported with OATS may be comparable to those of MACI,[5] the limited amount of available autograft tissue and donor-site morbidity are major limitations; when osteochondral allografts are used, issues of availability and cost introduce additional constraints.[6] In recent years, there has been increasing interest in the minced cartilage approach, in which viable autologous cartilage is harvested, minced into small fragments, and reimplanted in a single session. Autologous Minced Cartilage Implantation (AMC/MCI) is defined as intraoperative fragmentation of the patient's own cartilage and its single-stage application to the defect site, usually mixed with a matrix or fibrin glue.[7] Particulated Juvenile Allograft Cartilage (PJAC) is a commercially available allograft product in which cartilage obtained from young juvenile donors is used in the form of small particulated fragments, such as DeNovo NT.[8] The Cartilage Autograft Implantation System (CAIS) is a technique in which autologous cartilage is harvested as cylindrical plugs using a dedicated system and transferred to the defect site.[9] In the minced cartilage technique, the goal is to achieve chondrocyte migration into the biomaterial followed by extracellular matrix (ECM) deposition; the size of the fragments and the degree of mincing may be critical for in vitro ECM production by increasing the surface area in contact with the biomaterial.[10] In addition, the ability to perform the procedure in a single stage without the need for laboratory-based cell expansion has increased the appeal of minced cartilage approaches. Although the clinical evidence in the literature is relatively limited and heterogeneous, satisfactory short-term outcomes and low additional morbidity have been reported, leading to a marked rise in the popularity of these techniques in recent years.[11-14] The aim of this study was to bibliometrically map the minced cartilage literature from 2000 to 2025, delineate annual publication volume and trends, the temporal distribution of techniques, country and journal contributions, and the most influential studies.

MATERIALS AND METHODS

A search was performed in Clarivate Analytics' Web of Science Core Collection database on 29 October 2025 to retrieve all records related to minced cartilage techniques (autologous minced cartilage implantation [AMC/MCI], particulated juvenile allograft cartilage [PJAC], and cartilage autograft implantation system [CAIS]) between 1 January 2000 and 31 December 2024, for the purpose of conducting a bibliometric analysis.

The search covered the SCI-EXPANDED, SSCI, and ESCI indexes and used the following query in titles/abstracts/keywords:

TS=(("minced" NEAR/1 cartilage) OR "minced cartilage implantation" OR ("autologous" NEAR/2 "minced cartilage") OR ("particulated" NEAR/2 cartilage) OR "particulated juvenile articular cartilage" OR "DeNovo NT" OR "cartilage autograft implantation system" OR (CAIS NEAR/3 cartilage) OR PJAC) AND PY=(2000-2024).

The document type was restricted to journal articles and notes (DT=Article OR Note); Reviews, Systematic Reviews/Meta-analyses, Editorials, Letters, and Proceedings Papers were excluded. Duplicate records were removed using DOI, Web of Science accession number, and title. Two investigators independently screened titles and abstracts; records considered potentially eligible were verified against the full text, and any disagreements were resolved by a third reviewer. Because disagreements were infrequent and resolved by consensus with adjudication by a third reviewer, a formal interobserver agreement coefficient was not calculated. All retrieved data were compiled and organized using Microsoft Excel (Microsoft Corp., Redmond, WA, USA).

Data source and search strategy

Records with an original publication date before 1 January 2000 were excluded. During screening, which was conducted independently by two authors, studies whose primary focus was minced cartilage approaches (AMC/MCI, PJAC/DeNovo NT, or CAIS), as well as records evaluating basic science or biomechanical models of these techniques, were included. In contrast, cartilage repair approaches without a minced or particulated component relevant to the study topic—such as isolated microfracture, standalone ACI/MACI procedures, scaffold-only protocols, or stem-cell–only protocols—articles addressing general knee osteoarthritis only peripherally, and studies centered on unrelated concomitant pathologies, such as ACL-focused work, were excluded. Reviews, systematic reviews, and meta-analyses were excluded, whereas technical notes were included as original contributions. Eligibility was assessed independently by two authors through full-text review, and any disagreements were referred to a third author and resolved by consensus.

Records identified in the search were ranked according to total citations (TC). Extracted variables included title, authors, journal, year of publication, country of origin defined as the institution of the corresponding author, or that of the first author when the corresponding author was not specified, technique category (AMC/MCI, PJAC, or CAIS), study type (basic science, therapeutic study, technical note, diagnostic study, prognostic study, or economic study), and citations per year (CPY).

The use of CPY was chosen to partially mitigate temporal bias, whereby older publications tend to appear higher in the ranking solely because they have had a longer period in which to accumulate citations. For clinical studies, the Level of Evidence (LOE) was assigned descriptively as Levels I–IV according to the 2014 JBJS guideline, "Updating the Assignment of Levels of Evidence"; Level V studies, corresponding to systematic reviews and meta-analyses, were excluded from the scope of this study.[18] LOE was reported to provide a general overview of the study-design-hierarchy among clinical articles; no formal methodological quality appraisal or risk-of-bias assessment was performed. Basic science, technical notes, and laboratory studies were not graded with LOE and were reported as a separate category. In addition, to reduce partial-year bias and make the most recent output visible, a separate 2025 search covering the period from 1 January 2025 to 29 October 2025 was performed using the same query and eligibility criteria. This "2025 snapshot" set was reported descriptively and was not included in time-trend or between-period comparison analyses. In the figures, the year 2025 was denoted as a partial year, for example, by hatching, and CPY calculations were based on citations accrued up to the search date. The rationale for this separation was to keep distortions related to the incomplete 2025 calendar year—namely, partial-year and recency bias—outside the primary analyses, thereby enabling fair comparisons among completed years from 2000 to 2024. Nevertheless, the 2025 snapshot makes the most recent momentum in the literature visible at a purely descriptive level.

Ethics

This study is a secondary analysis of publicly available, non-identifiable bibliometric metadata (titles, author/affiliation information, journal, year of publication, total and annual citation counts) retrieved from the Clarivate Analytics Web of Science Core Collection. No intervention or observation involving human participants or animals was performed, and no access was made to patient- or participant-level medical records or personal health data. In line with applicable national regulations and institutional policies, such analyses do not constitute human subjects research and therefore do not require Institutional Review Board (IRB) approval or informed consent. All analyses were reported in aggregate form, in accordance with the licensing conditions of the data source.

RESULTS

In the initial search, 219 records were identified. When restricted to publications in English, 210 records were screened. Following title–abstract and full-text assessment, 47 records (22.4%) not directly related to minced cartilage and 62 records (29.5%) consisting of reviews/systematic reviews/meta-analyses, editorials/letters, or conference proceedings were excluded. Consequently, 101 studies (48.1%) were included in the analysis for the primary window from 2000 to 2024 (Fig. 1). Annual output gained momentum after 2018 and showed a clear peak between 2021 and 2024: 14 articles in 2021, 12 in 2023, and 17 in 2024 (Fig. 2). Publications were sparse and irregular between 2006 and 2010; a steady increase was observed from 2011 to 2015 (n=23), followed by relative stability between 2016 and 2020 (n=21). The years 2021–2024 alone accounted for 51 of 101 publications (50.5%). The year 2025, being a

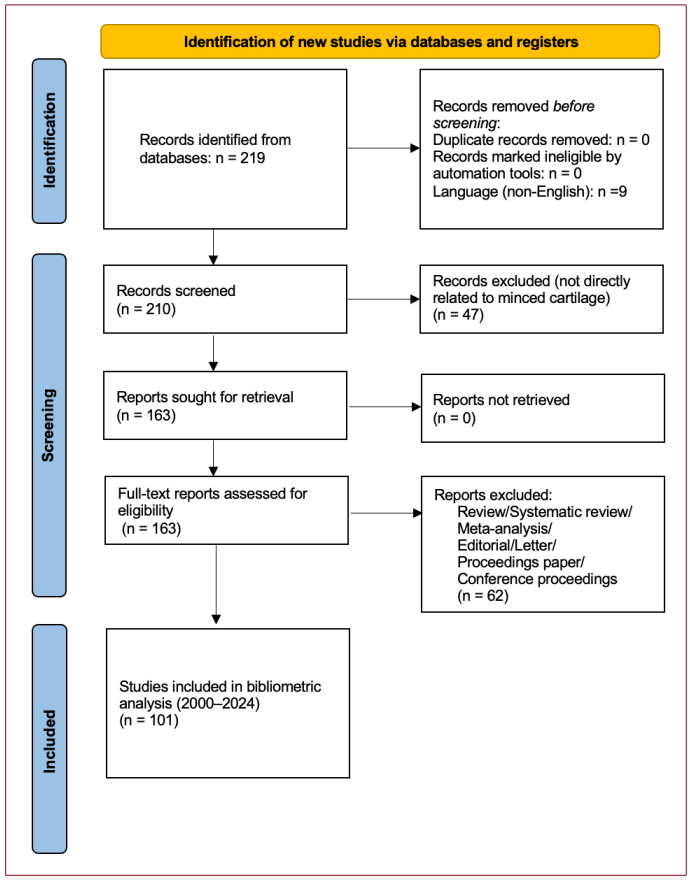

Figure 1. Flow diagram of study identification, screening and inclusion for the minced cartilage bibliometric analysis.

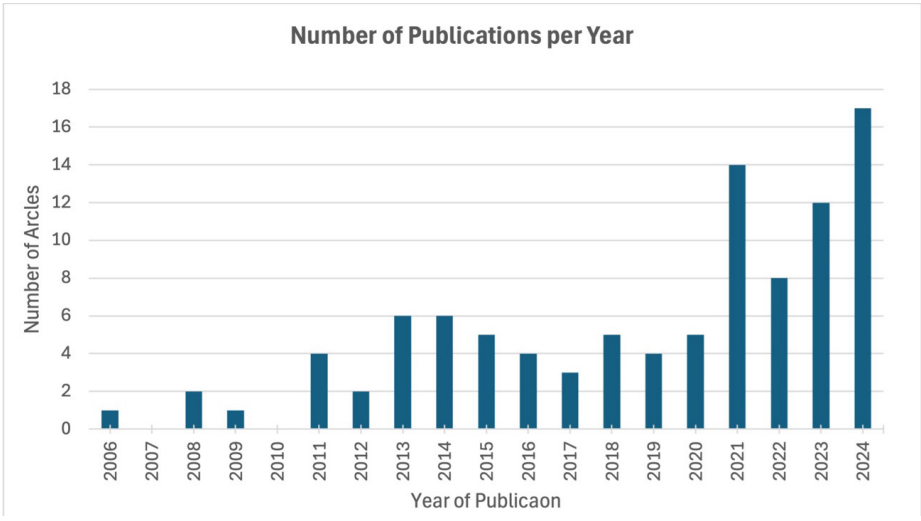

Figure 2. Annual number of minced cartilage–related publications (2000–2024).

Table 1. Top 20 most cited minced cartilage–related original research articles (2000–2024)

Rank	Article title	Publication year	Total citations	Citations per year	Study type
1	Cole BJ, Farr J, Winalski CS, et al. Outcomes after a single-stage procedure for cell-based cartilage repair: a prospective clinical safety trial with 2-year follow-up. Am J Sports Med. 2011;39(6):1170-1179.	2011	184	12.27	Therapeutic, II
2	Lu Y, Dhanaraj S, Wang Z, et al. Minced cartilage without cell culture serves as an effective intraoperative cell source for cartilage repair. J Orthop Res. 2006;24(6):1261-1270.	2006	176	8.8	Basic science
3	Farr J, Tabet SK, Margerrison E, Cole BJ. Clinical, Radiographic, and Histological Outcomes After Cartilage Repair With Particulated Juvenile Articular Cartilage: A 2-Year Prospective Study. Am J Sports Med. 2014;42(6):1417-1425.	2014	131	10.92	Therapeutic, IV
4	Frisbie DD, Lu Y, Kawcak CE, DiCarlo EF, Binette F, McIlwraith CW. In vivo evaluation of autologous cartilage fragment-loaded scaffolds implanted into equine articular defects and compared with autologous chondrocyte implantation. Am J Sports Med. 2009;37 Suppl 1:71S-80S.	2009	96	5.65	Basic science
5	Tompkins M, Hamann JC, Diduch DR, et al. Preliminary results of a novel single-stage cartilage restoration technique: particulated juvenile articular cartilage allograft for chondral defects of the patella. Arthroscopy. 2013;29(10):1661-1670.	2013	82	6.31	Therapeutic, IV
6	Coetzee JC, Giza E, Schon LC, et al. Treatment of osteochondral lesions of the talus with particulated juvenile cartilage. Foot Ankle Int. 2013;34(9):1205-1211.	2013	73	5.62	Therapeutic, IV
7	Marmotti A, Bruzzone M, Bonasia DE, et al. One-step osteochondral repair with cartilage fragments in a composite scaffold. Knee Surg Sports Traumatol Arthrosc. 2012;20(12):2590-2601.	2012	73	5.21	Basic science
8	Massen FK, Inauen CR, Harder LP, Runer A, Preiss S, Salzmann GM. One-Step Autologous Minced Cartilage Procedure for the Treatment of Knee Joint Chondral and Osteochondral Lesions: A Series of 27 Patients With 2-Year Follow-up. Orthop J Sports Med. 2019;7(6):2325967119853773. Published 2019 Jun 13.	2019	70	10	Therapeutic, IV

Table 1. Continue

Rank	Article title	Publication year	Total citations	Citations per year	Study type
9	Farr J, Yao JQ. Chondral Defect Repair with Particulated Juvenile Cartilage Allograft. Cartilage. 2011;2(4):346-353.	2011	66	4.4	Therapeutic, IV
10	Bonasia DE, Martin JA, Marmotti A, et al. Cocultures of adult and juvenile chondrocytes compared with adult and juvenile chondral fragments: in vitro matrix production. Am J Sports Med. 2011;39(11):2355-2361.	2011	63	4.2	Basic science
11	Christensen BB, Foldager CB, Jensen J, Lind M. Autologous Dual-Tissue Transplantation for Osteochondral Repair: Early Clinical and Radiological Results. Cartilage. 2015;6(3):166-173.	2015	55	5	Therapeutic, IV
12	Kruse DL, Ng A, Paden M, Stone PA. Arthroscopic De Novo NT(®) juvenile allograft cartilage implantation in the talus: a case presentation. J Foot Ankle Surg. 2012;51(2):218-221.	2012	53	3.79	Therapeutic, IV
13	Bonasia DE, Marmotti A, Mattia S, et al. The Degree of Chondral Fragmentation Affects Extracellular Matrix Production in Cartilage Autograft Implantation: An In Vitro Study. Arthroscopy. 2015;31(12):2335-2341.	2015	52	4.73	Basic science
14	Levinson C, Cavalli E, Sindi DM, et al. Chondrocytes From Device-Minced Articular Cartilage Show Potent Outgrowth Into Fibrin and Collagen Hydrogels. Orthop J Sports Med. 2019;7(9):2325967119867618. Published 2019 Sep 10.	2019	47	6.71	Basic science
15	Grawe B, Burge A, Nguyen J, et al. Cartilage Regeneration in Full-Thickness Patellar Chondral Defects Treated with Particulated Juvenile Articular Allograft Cartilage: An MRI Analysis. Cartilage. 2017;8(4):374-383.	2017	44	4.89	Diagnostic, IV
16	Lind M, Larsen A. Equal cartilage repair response between autologous chondrocytes in a collagen scaffold and minced cartilage under a collagen scaffold: an in vivo study in goats. Connect Tissue Res. 2008;49(6):437-442.	2008	44	2.44	Basic science
17	Marmotti A, Bonasia DE, Bruzzone M, et al. Human cartilage fragments in a composite scaffold for single-stage cartilage repair: an in vitro study of the chondrocyte migration and the influence of TGF-β1 and G-CSF. Knee Surg Sports Traumatol Arthrosc. 2013;21(8):1819-1833.	2013	43	3.31	Basic science
18	Marmotti A, Bruzzone M, Bonasia DE, et al. Autologous cartilage fragments in a composite scaffold for one stage osteochondral repair in a goat model. Eur Cell Mater. 2013;26:15-32. Published 2013 Aug 4.	2013	42	3.23	Basic science
19	Wang T, Belkin NS, Burge AJ, et al. Patellofemoral Cartilage Lesions Treated With Particulated Juvenile Allograft Cartilage: A Prospective Study With Minimum 2-Year Clinical and Magnetic Resonance Imaging Outcomes. Arthroscopy. 2018;34(5):1498-1505.	2018	37	4.63	Therapeutic, IV
20	Karnovsky SC, DeSandis B, Haleem AM, Sofka CM, O'Malley M, Drakos MC. Comparison of Juvenile Allogenous Articular Cartilage and Bone Marrow Aspirate Concentrate Versus Microfracture With and Without Bone Marrow Aspirate Concentrate in Arthroscopic Treatment of Talar Osteochondral Lesions. Foot Ankle Int. 2018;39(4):393-405.	2018	35	4.38	Therapeutic, III

Table 2. Journals publishing minced cartilage–related research: productivity and citation impact

Rank	Journal	Publication count	Total citations	Median citations per year
1	AMERICAN JOURNAL OF SPORTS MEDICINE	12	592	4.43
2	CARTILAGE	15	293	2.51
3	ARTHROSCOPY-THE JOURNAL OF ARTHROSCOPIC AND RELATED SURGERY	5	180	3.73
4	JOURNAL OF ORTHOPAEDIC RESEARCH	1	176	8.80
5	KNEE SURGERY SPORTS TRAUMATOLOGY ARTHROSCOPY	7	174	3.52
6	FOOT & ANKLE INTERNATIONAL	6	171	3.15
7	ARTHROSCOPY TECHNIQUES	13	137	1.56
8	ORTHOPAEDIC JOURNAL OF SPORTS MEDICINE	5	133	3.89
9	JOURNAL OF FOOT & ANKLE SURGERY	4	94	2.20
10	CONNECTIVE TISSUE RESEARCH	1	44	2.44

partial year, was presented for descriptive purposes only. The most cited articles were identified based on total citations (TC) and citations per year (CPY) (Table 1). While TC reflects the cumulative citation count of an article over its entire lifetime, CPY partially compensates for the advantage of older articles and therefore better captures contemporary visibility. Across the list, both AMC/MCI and PJAC-focused publications showed high visibility, with a mixture of basic science and clinical studies with Levels of Evidence (LOE) II–IV. Among the included publications, clinical studies spanned LOE II–IV, whereas basic science studies, technical notes, and laboratory investigations were reported separately and were not graded. Table 2 summarizes journal-based output and impact. Cartilage ranked first in terms of number of articles, indicating high productivity, whereas The American Journal of Sports Medicine (AJSM) led in total citations, indicating high visibility and impact. Arthroscopy Techniques was the primary outlet for technical notes; because it predominantly publishes method-focused reports, its article count was high, but its typical TC and CPY values were lower than those of clinical journals. This pattern illustrates that the venue of publication, including its channel and target audience, has a substantial influence on the citation profile.

Table 3 shows the distribution of the total 101 publications: therapeutic 40 (39.6%), basic science 38 (37.6%), technical note 19 (18.8%), diagnostic 2 (2.0%), economic 1 (1.0%), and prognostic 1 (1.0%). In the technical breakdown of the basic science group, there were 34 AMC/MCI studies, 9 PJAC studies, and 1 CAIS study, indicating a clear dominance of AMC/MCI in basic research. Among technical notes, AMC/MCI accounted for 9 publications and PJAC for 10, suggesting a slight predominance of PJAC in technique reporting. In therapeutic studies, there were 17 AMC/MCI articles, 22 PJAC articles, and 1 CAIS article; thus, PJAC led in the clinical/therapeutic domain, although AMC/MCI was also substantially represented.

Table 3. Distribution of study types by minced cartilage technique (AMC/MCI, PJAC, CAIS)**

Study type	Number of technique appearances
Basic science	38
AMC/MCI	34
PJAC*	9
CAIS	1
Diagnostic	2
AMC/MCI	2
PJAC*	1
Economic	1
PJAC*	1
Prognostic	1
PJAC*	1
Technical note	19
AMC/MCI	9
PJAC*	10
Therapeutic	40
AMC/MCI	17
PJAC*	22
CAIS	1

*PJAC refers to particulated juvenile allograft cartilage, commercially available as DeNovo® NT (Zimmer Biomet, Warsaw, IN, USA), **Some studies compared more than one minced cartilage technique; therefore, a single article may contribute to multiple technique categories, and row subtotals can exceed the number of unique articles.

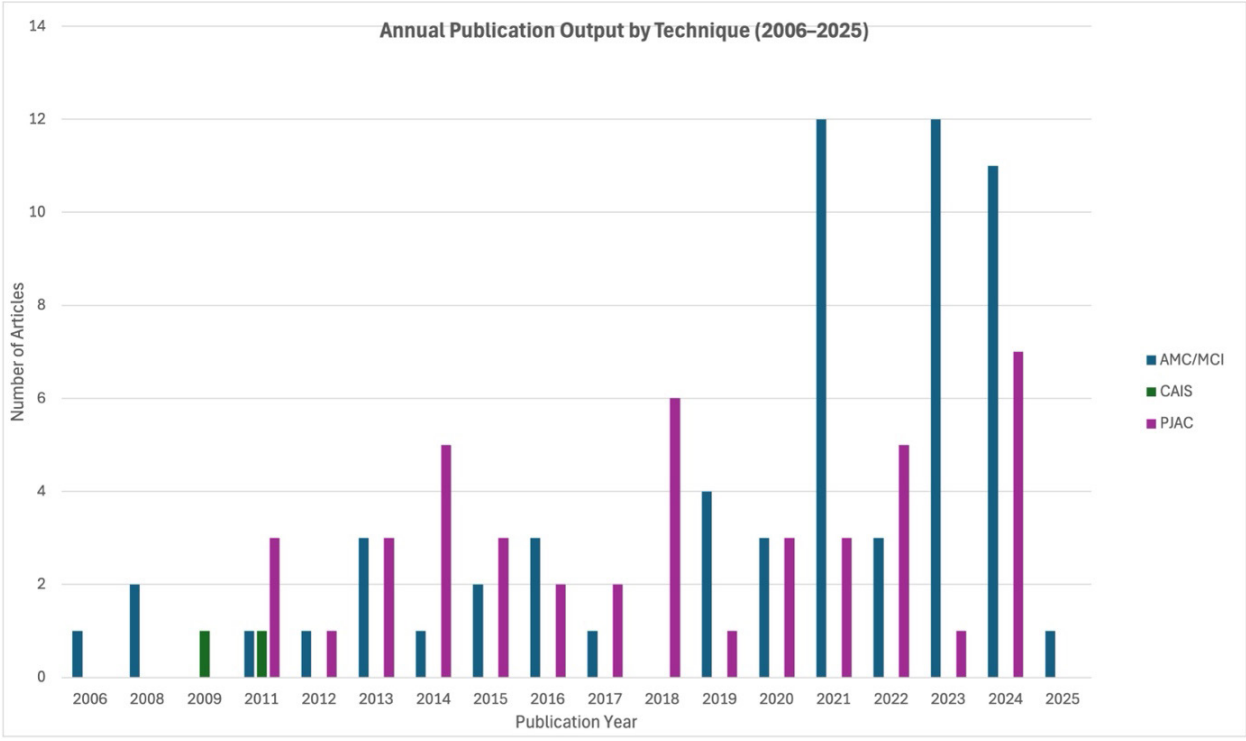

Figure 3. Temporal distribution of minced cartilage techniques (AMC/MCI, PJAC, CAIS) among published studies.

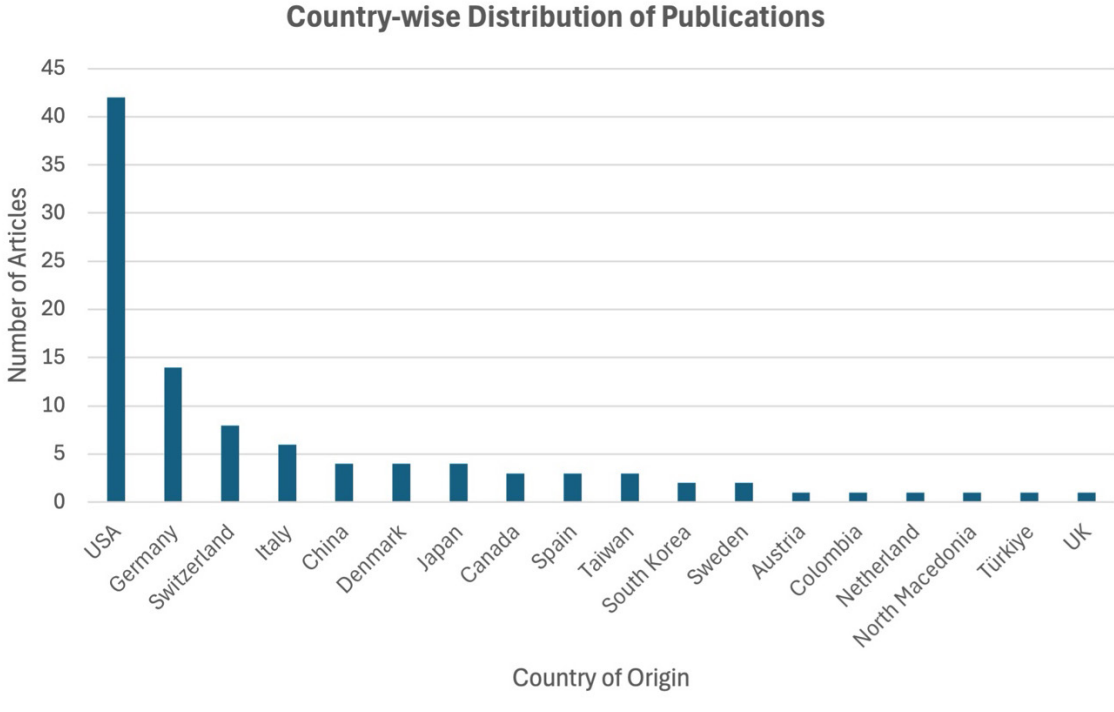

Figure 4. Geographical distribution of minced cartilage–related publications by country.

AMC/MCI publications became clearly predominant from 2021 onwards and reached their highest annual numbers between 2021 and 2024 (Fig. 3). PJAC publications showed an early clustering between 2011 and 2015, with a secondary rise between 2018 and 2024. CAIS publications were rare and appeared only in isolated years. Overall, the pattern suggests a shift from PJAC predominance in the earlier period to AMC/MCI predominance in recent years. The vast majority of publications originated from the United States (n=42), followed by Germany (n=14) and Switzerland (n=8); together, these top three countries accounted for 64 of 101 articles (63.4%). The remaining output formed a broad "long tail" with single-digit numbers, distributed as Italy (n=6), China (n=4), Denmark (n=4), Japan (n=4), Canada/Spain/Taiwan/South Korea (n=3 each), Sweden (n=2), and Austria/Colombia/the Netherlands/North Macedonia/Türkiye/the UK (n=1 each) (Fig.4). Between 1 January and 29 October 2025, 23 records were

Table 4. Minced cartilage–related articles published between 1 January and 29 October 2025 (partial year snapshot)

Article title	Study type
Frings J, Baranowsky A, Korthaus A, et al. Arthroscopic Shaver-based Harvest of Minced Cartilage Results in Reduced Chondrocyte Viability and Reduced Quality of Cartilaginous Repair Tissue Compared With Open Harvest and Conventional Fragmentation. Arthroscopy. 2025;41(3):762-770.	Basic science
Hashiguchi N, Nakasa T, Ishikawa M, et al. Effects of Silk-Elastin and SpheroSeev Mixture and Minced Cartilage on Cartilage Repair in Rabbit Osteochondral Defect Models. Orthop J Sports Med. 2025;13(4):23259671251332620.	Basic science
Barbaret A, Wein F, Jacquet C, Ollivier M. One-stage minced cartilage autograft with platelet-rich plasma improves early clinical outcomes: A multicentric retrospective study. J Exp Orthop. 2025;12(1):e70162.	Therapeutic, III
Mayr J, Warth F, Oehler N, Majewski M, Lutter C, Blanke F. Treatment of large chondral lesions with an autologous minced cartilage technique and synovial flap leads to superior results compared to matrix associated autologous chondrocyte transplantation technique after 24 months: A controlled clinical trial. Knee Surg Sports Traumatol Arthrosc.	Therapeutic, III
Chen Q, Bai L, Wan G, Hao Y, Yang X, Zhang H. Multifunctional MeHA hydrogel for living materials delivery with enhanced cartilage regeneration. Front Bioeng Biotechnol. 2025;13:1545773.	Basic Science
Walker PB, Cope S, Trikha R, Kremen TJ, Jones KJ. Combined Particulated Juvenile Articular Cartilage Allograft Transplantation With Autogenous Bone Graft for Symptomatic Osteochondral Defects in the Tibial Plateau. Arthrosc Tech. 2025;14(8):103689.	Technical Note
Davie R, Ammerman B, Propp B, et al. Comparative Clinical and Imaging Outcomes of Particulated Juvenile Articular Cartilage Implantation in Shouldered and Unshouldered Patellar Cartilage Lesions With Concomitant Stabilization at 2-Year Follow-up. Orthop J Sports Med. 2025;13(9):23259671251369018.	Therapeutic, III
Dai Z, Jiang YH, Liao Y, He L, Yang WJ, Liu JH. Bioinformatic prediction of key genes involved in pro-chondrogenic effect of fragmentated cartilage transplantation. Sci Rep. 2025;15(1):21335.	Basic Science
Bischofreiter M, Hraba C, Breulmann FL, et al. Arthroscopic Minced Cartilage Implantation for Chondral Lesion at the Glenoid in the Shoulder: Technical Note. Arthrosc Tech. 2024;14(2):103218.	Technical Note
Pohl S, Mühler M, Zimmerer A, Schoon J, Wassilew GI, Gebhardt S. Clinical and radiological 2-year results after autologous shaver-based minced cartilage implantation for cartilage lesions of the knee. Arch Orthop Trauma Surg. 2025;145(1):465.	Therapeutic, IV
Wein F, Ferri C, Peduzzi L, Barbaret A, Walbron P. Arthroscopic minced cartilage implantation provides superior clinical and magnetic resonance imaging outcomes compared to microfracture in patellar cartilage defects. Knee Surg Sports Traumatol Arthrosc. Published online July 21, 2025.	Therapeutic, III
Hax J, Leuthard L, Öttl F, et al. Hand-minced cartilage versus microfracture for the repair of articular cartilage defects: A propensity score matched-pair analysis with 2-year follow-up. Knee Surg Sports Traumatol Arthrosc. Published online June 15, 2025.	Therapeutic, III
Schneider S, Linnhoff D, Ilg A, Salzmann GM, Ossendorff R, Holz J. Comparison of Three Different Techniques for the Treatment of Cartilage Lesions-Matrix-Induced Autologous Chondrocyte Implantation (MACI) Versus Autologous Matrix-Induced Chondrogenesis (AMIC) and Arthroscopic Minced Cartilage-A 2-Year Follow-Up on Patient-Reported Pain and Functional Outcomes. J Clin Med. 2025;14(7):2194.	Therapeutic, III
Kühle J, Wagner FC, Beck S, et al. Autologous minced cartilage implantation in osteochondral lesions of the talus-does fibrin make the difference?. Arch Orthop Trauma Surg. 2025;145(1):144.	Therapeutic, III

identified. Three records that were not directly related to minced cartilage and six records consisting of reviews/systematic reviews/meta-analyses, editorials/letters, or conference proceedings were excluded. The remaining 14 studies were analyzed: 4 basic science studies (28.6%), 8 therapeutic studies (57.1%), and 2 technical notes (14.3%). In terms of technique classification, AMC/MCI accounted for 11 of 14 studies (78.6%), whereas PJAC accounted for 3 of 14 studies (21.4%) (Table 4).

DISCUSSION

This bibliometric study shows that, in parallel with the growing popularity of single-stage approaches in cartilage repair, the literature focusing specifically on minced cartilage techniques has gained marked momentum after 2018 and reached a peak between 2021 and 2024. The findings indicate a temporal shift from earlier PJAC-focused publication activity toward increasing recent output on AMC/MCI. The rise of minced cartilage techniques should be viewed as a response to the long-standing use of two-stage methods in cartilage repair, such as ACI/MCI and osteochondral autograft transfer (OATS). Although ACI/MACI approaches have the potential to achieve high-quality hyaline-like cartilage repair, the need for laboratory-based cell expansion, their high cost, and the requirement for the patient to undergo two separate surgical procedures impose substantial clinical and economic limitations.[15] Similarly, although the OATS technique offers a single-stage solution, its use in large defects is limited by the finite amount of available autograft tissue and the risk of donor-site morbidity.[16,17] Minced cartilage techniques aim to mitigate some of the limitations of conventional approaches. In particular, AMC/MCI may reduce the logistical and financial burden associated with ACI/MACI through the use of autologous material, its single-stage nature, and the absence of a requirement for laboratory-based cell expansion. Compared with OATS, it generally allows for a more limited donor site requirement and offers greater flexibility in volumetric defect filling; however, long-term, comparative data remain limited.[18] In our bibliometric analysis, the marked increase in AMC/MCI publications suggests growing interest in these techniques and increasing research attention toward their potential practical advantages; nevertheless, publication trends do not directly prove clinical adoption.

One of the main findings of this study was the predominance of AMC/MCI-related publications during 2021–2024. This pattern suggests increasing research attention toward autologous minced cartilage approaches in the recent literature. The observation that 11 of 14 studies in the 2025 snapshot involved AMC/MCI is consistent with this pattern; however, because the 2025 dataset represents a partial year, these findings should be interpreted as descriptive rather than predictive. While PJAC had greater visibility in the earlier literature, the more recent increase in AMC/MCI publications may reflect growing scientific and clinical interest in autologous single-stage strategies. Nonetheless, bibliometric patterns alone cannot determine whether this shift is driven by biological performance, clinical effectiveness, commercial availability, cost considerations, or broader practice adoption. The early popularity of PJAC was driven by the availability of commercial products such as DeNovo NT and by the biological advantages of juvenile cartilage, including its high chondrocyte density and rich growth factor content.[8,14,19] However, factors such as the potential risk of immunogenicity, donor-related constraints, and high costs associated with allograft use may have steered clinicians toward autologous solutions.[20] AMC/MCI stands out because of advantages such as the absence of immunological risk owing to the use of the patient's own cartilage, its single-stage application, and the lack of need for laboratory-based cell expansion.[12] These characteristics may contribute to the growing interest in AMC/MCI reported in the recent literature.

Our bibliometric analysis revealed a clear predominance of AMC/MCI (n=34) over PJAC (n=9) in basic science studies. This pattern suggests that AMC/MCI has received greater recent attention in preclinical and mechanistic research. The fundamental biological advantage of AMC/MCI is based on the capacity of chondrocytes released from minced cartilage fragments to promote the signalling and migration required for extracellular matrix (ECM) production.[10] The decisive role of fragment size and degree of mincing in enhancing the surface area in contact with the biomaterial—and thereby influencing ECM production—has accelerated basic science research aimed at optimizing this technique.[7,12,21] In therapeutic studies, PJAC (n=22) still has a numerical advantage over AMC/MCI (n=17). This may stem from the longer clinical track record of PJAC and from the early reporting of strong outcomes in specific indications, such as patellofemoral lesions.[14] However, the 2025 snapshot showed that 7 of 8 therapeutic studies involved AMC/MCI. This finding suggests increasing recent publication activity in this area, although partial-year data should be interpreted cautiously and should not be used to infer future research output or clinical dominance. Current clinical literature indicates that the mid-term outcomes of AMC/MCI are satisfactory. In a study by Runer et al.,[11] knee cartilage lesions treated with AMC/MCI demonstrated good postoperative results and low reoperation rates at a minimum of 5-year follow-up. Similarly, in a 2024 study, Schneider et al.[22] reported that AMC/MCI resulted in significant improvements in patient-reported outcome measures (PROMs) at 2-year follow-up. Overall, the

clinical literature was dominated by lower-level evidence designs, which should be considered when interpreting publication growth as a marker of scientific maturity. Our bibliometric analysis showed that *Arthroscopy Techniques* is the main outlet for technical notes and that PJAC holds a slight advantage in technical reporting. This may reflect an early effort to standardize and disseminate the surgical application of PJAC. However, with the rise of AMC/MCI, optimized surgical protocols and novel delivery tools for this technique may increasingly appear in the literature.

For example, a recent trend aimed at enhancing the effectiveness of AMC/MCI is to combine the technique with biological adjuvants, such as platelet-rich plasma (PRP) or bone marrow aspirate concentrate (BMAC).[23,24] These combinations aim to enhance the regenerative potential of the cartilage fragments and to promote the formation of a more robust repair tissue at the defect site. In addition, a study published by Behrendt et al.[25] in 2024 suggested that the AMIC procedure provides superior patient outcomes compared with manually minced autologous cartilage implantation. This finding suggests that future optimization of AMC/MCI may lie in supporting the minced cartilage with a matrix or scaffold. This study is one of the first comprehensive analyses to bibliometrically map the minced cartilage literature, clearly delineating publication trends, the temporal distribution of techniques, and global contributions in this field. In particular, the inclusion of partial-year 2025 data (the "snapshot") is an important strength, as it makes the most recent momentum and shift in focus within the literature visible. This study has several limitations. First, by design, bibliometric analysis evaluates quantitative patterns such as publication counts and citation metrics and does not directly assess clinical effectiveness, biological superiority, or real-world adoption. Second, LOE was reported descriptively for clinical studies, but no formal methodological quality appraisal or risk-of-bias assessment was performed. Third, because the search strategy was limited to the Web of Science Core Collection, relevant studies indexed exclusively in other databases may have been missed. Finally, the 2025 snapshot reflects a partial year and was therefore reported for descriptive purposes only; it should not be interpreted as a basis for forward-looking conclusions.

CONCLUSION

Minced cartilage techniques represent an expanding area within cartilage repair research. This bibliometric analysis demonstrates a temporal shift in the literature from earlier PJAC-focused publication activity toward increased recent output on AMC/MCI, particularly in basic science and partial-year 2025 reporting. These trends should be interpreted as indicators of research attention rather than proof of clinical superiority or widespread adoption. Future studies should focus on long-term comparative clinical outcomes and on clarifying the role of AMC/MCI across different lesion types and adjunctive treatment strategies.

DECLARATIONS

Ethics Committee Approval: This study does not constitute human subjects research and therefore does not require Institutional Review Board approval or informed consent.

Informed Consent: Not required.

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ABBREVIATIONS

ACI: Autologous Chondrocyte Implantation

AJSM: American Journal of Sports Medicine

AMC: Autologous Minced Cartilage

AMC/MCI: Autologous Minced Cartilage / Minced Cartilage Implantation

AMIC: Autologous Matrix-Induced Chondrogenesis

BMAC: Bone Marrow Aspirate Concentrate

CAIS: Cartilage Autograft Implantation System

CPY: Citations per Year

DOI: Digital Object Identifier

ECM: Extracellular Matrix

ESCI: Emerging Sources Citation Index

IRB: Institutional Review Board

LOE: Level of Evidence

MACI: Matrix-Assisted Chondrocyte Implantation

MCI: Minced Cartilage Implantation

OATS: Osteochondral Autograft Transfer System

PJAC: Particulated Juvenile Allograft Cartilage

PROMs: Patient-Reported Outcome Measures

PRP: Platelet-Rich Plasma

SCI-EXPANDED: Science Citation Index Expanded

SSCI: Social Sciences Citation Index

TC: Total Citations

TS: Topic Search

WoS: Web of Science

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