EISSN - 3062-0856

Sports Traumatology & Arthroscopy

STArt

Volume 3
Issue 1
Year 2026

KARE PUBLISHING

Editorial Board

Editor

Ozkan Kose, MD, PhD, Prof.
University of Health Sciences, Antalya Training and Research Hospital, Department of Orthopedics and Traumatology, Antalya, Türkiye

Associate Editors

Ahmet Firat, MD, Prof.
VM Medicalpark Ankara Hospital, Department of Orthopaedics and Traumatology, Ankara, Türkiye
Baris Yilmaz, MD, Prof.
University of Health Sciences, Fatih Sultan Mehmet Training and Research Hospital, Department of Orthopedics and Traumatology, Istanbul, Türkiye
Nicola de Gasperis, MD, Assoc. Prof.
Physical and Rehabilitation Medicine, Department of Life Sciences, Health and Health Professions, Link Campus University, Rome, Italy

Technical Editors

Ahmet Emre Paksoy, MD, Assoc. Prof.
Ataturk University, Medical Faculty, Department of Orthopedics and Traumatology, Erzurum, Türkiye
Halis Atil Atilla, MD, Assoc. Prof.
University of Health Sciences, Ankara Etlik City Hospital, Department of Orthopedics and Traumatology, Ankara, Türkiye
Kerim Oner, MD, Assoc. Prof.
Karadeniz Technical University, Medical Faculty, Department of Orthopedics and Traumatology, Trabzon, Türkiye
Mustafa Tekin, MD, Assoc. Prof.
Cukurova University, Medical Faculty, Department of Orthopedics and Traumatology, Adana, Türkiye
Taha Kizilkurt, MD, Assist. Prof.
Istanbul University, Medical Faculty, Department of Orthopedics and Traumatology, Istanbul, Türkiye

Editorial Board

Ahmet Aslan, MD, Prof.
Alanya Alaaddin Keykubat University, Medical Faculty, Department of Orthopaedics and Traumatology, Alanya, Türkiye
Ahmet Yildirim, MD, Prof.
University of Health Sciences, Konya City Hospital, Department of Orthopedics and Traumatology, Konya, Türkiye
Alper Kaya, MD, Prof.
Department of Orthopedics and Traumatology, Faculty of Medicine, Acibadem Mehmet Ali Aydinlar University, Istanbul, Türkiye
Ali Eraslan, MD
University of Health Sciences, Antalya Training and Research Hospital, Department of Sports Medicine, Antalya, Türkiye
Atacan Atalar, MD, Prof.
Acıbadem Mehmet Ali Aydınlar University, Medical Faculty, Department of Orthopedics and Traumatology, Istanbul, Türkiye
Baran Sarikaya, MD, Prof.
Orthopaedics and Traumatology, Ankara Bilkent City Hospital, Ankara, Türkiye
Baris Kocaoglu, MD, Prof.
Department of Orthopedics and Traumatology, Faculty of Medicine, Acibadem Mehmet Ali Aydinlar University, Istanbul, Türkiye
Burak Akan, MD, Prof.
Department of Orthopedics and Traumatology, Ufuk University, School of Medicine, Ankara, Türkiye
Can Doruk Basa, MD, Assoc. Prof.
Department of Orthopaedics and Traumatology, Tepecik Training and Research Hospital, Izmir, Türkiye
Cemil Erturk, MD, Prof.
Department of Orthopaedics and Traumatology, Kanuni Sultan Süleyman Training and Research Hospital, University of Health Sciences, Istanbul, Türkiye
Derya Celik, PhD, Prof.
Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Istanbul University-Cerrahpasa, Istanbul, Türkiye
Durmus Ali Ocguder, MD, Prof.
Yıldırım Beyazıt University, Ankara City Hospital, Department of Orthopedics and Traumatology, Antalya, Türkiye
Egemen Turhan, MD, Prof.
Hacettepe University, Medical Faculty, Department of Orthopedics and Traumatology, Ankara, Türkiye
Emin Bal, MD, Prof.
Izmir Tınaztepe University, Medical Faculty, Department of Orthopedics and Traumatology, Izmir, Türkiye
Emre Anil Ozbek, MD, Assoc. Prof.
Ankara University, Medical Faculty, Department of Orthopedics and Traumatology, Ankara, Türkiye
Emre Baca, MD, Assoc. Prof.
University of Health Sciences, Bakırköy Dr. Sadi Konuk Training and Research Hospital, Department of Orthopedics and Traumatology, Istanbul, Türkiye
Elcil Kaya Bicer, MD, Assoc. Prof.
Ege University, Medical Faculty, Department of Orthopedics and Traumatology, Izmir, Türkiye
Ertugrul Aksahin, MD, Prof.
Yuksek İhtisas University Medical School Orthopedics and Traumatology Department, Ankara, Türkiye
Gokhan Meric, MD, Prof.
Yeditepe University, Medical Faculty, Department of Orthopedics and Traumatology, Istanbul, Türkiye

Editorial Board

Gokhan Polat, MD, Prof.
Istanbul University, Medical Faculty, Department of Orthopedics and Traumatology, Istanbul, Türkiye
Gul Baltacı, PhD, Prof.
Atlas University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Istanbul, Türkiye
Guzelali Ozdemir, MD, Prof.
Department of Orthopedics and Traumatology, Ankara Bilkent City Hospital, Ankara, Türkiye
Hakan Ozsoy, MD, Prof.
Clinic of Orthopaedic and Traumatology, Memorial Hospital, Ankara, Türkiye
Haluk Oztekin, MD, Prof.
Izmir Kent Hospital, Orthopaedics and Traumatology Clinic, Izmir, Türkiye
Hayri Baran Yosmaoglu, PhD, Prof.
Baskent University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Türkiye
Izzet Bingol, MD, Assoc. Prof.
Department of orthopedics and Traumatology, Health Sciences University, Faculty of Medicine, Ankara Oncology Training and Research Hospital, Ankara, Türkiye
John Nyland, MD, Prof.
Department of Orthopaedic Surgery, University of Louisville, Louisville, Kentucky, USA
Kerem Canbora, MD, Prof.
Uskudar University, Medical Faculty, Department of Orthopedics and Traumatology, Istanbul, Türkiye
Kursat Celik, PhD, Prof.
Akdeniz University, Agricultural Faculty, Department Machinery and Technology Engineering, Antalya, Türkiye
Lena Sonnow, MD
Department of Diagnostic and Interventional Radiology, Hannover Medical School, Hannover, Germany
Levent Sarikcioglu, PhD, Prof.
Akdeniz University, Medical Faculty, Department of Anatomy, Antalya, Türkiye
Mahir Mahirogulları, MD, Prof.
Şişli Memorial Hospital, Department of Orthopedics and Traumatology, Istanbul, Türkiye
Mehmet Akif Altay, MD, Prof.
Department of Orthopedics and Traumatology, Medicine Faculty of Harran University, Sanlıurfa, Türkiye
Mehmet Emin Erdil, MD, Prof.
Department of Orthopaedics and Traumatology, Acibadem Maslak Hospital, Acibadem University, Istanbul, Türkiye
Meric Unal, MD, Assoc. Prof.
Private Meddem Hospital, Orthopedics and Traumatology Clinic, Isparta, Türkiye
Murat Cakar, MD, Assoc. Prof.
University of Health Sciences, Prof. Dr. Cemil Taşcıoğlu City Hospital, Department of Orthopedics and Traumatology, Istanbul, Türkiye
Mustafa Citak, MD, PhD, Prof.
Department of Orthopedics and Traumatology, Helios ENDO-Klinik Hamburg, Holstenstr. 2, 22767, Hamburg, Germany
Muzaffer Sindel, PhD, Prof.
Akdeniz University, Medical Faculty, Department of Anatomy, Antalya, Türkiye
Nuri Aydin, MD, Prof.
Department of Orthopaedics and Traumatology, İstanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine, İstanbul, Türkiye
Nurzat Elmali, MD, Prof.
Department of Orthopedics and Traumatology, Bezmialem Foundation University School of Medicine, Istanbul, Türkiye
Omer Naci Ergin, MD, Assoc. Prof.
Istanbul University, Medical Faculty, Department of Orthopedics and Traumatology, Istanbul, Türkiye
Feza Korkusuz, MD, PhD, Prof.
Hacettepe University, Medical Faculty, Department of Sports Medicine, Ankara, Türkiye
Ramazan Akmese, MD, Prof.
Orthopedics and Traumatology Department, Haliç University, Istanbul, Türkiye
Safa Gursoy, MD, Assoc. Prof.
Acibadem University, Orthopedics and Traumatology, Department, Istanbul, Türkiye
Suleyman Semih Dedeoglu, MD, Prof.
Department of Orthopedics and Traumatology, Health Sciences University Baltalimanı Metin Sabancı Bone Diseases Training and Research Hospital, İstanbul, Türkiye
Tahsin Beyzadeoglu, MD, Prof.
Department of Orthopaedics & Traumatology, Halic University, Istanbul, Türkiye
Tekin Kerem Ulku, MD, Assoc. Prof.
Department of Orthopedic Surgery, Faculty of Medicine, Acibadem University, Istanbul, Türkiye
Tuba Melekoglu, PhD, Assoc. Prof.
Akdeniz University Faculty of Sports Sciences, Department of Movement and Training Sciences, Antalya, Türkiye

Biostatistics Editor
Andreas Ziegler, MD, PhD, Prof.
Cardio-CARE, Medizincampus Davos, Davos Wolfgang, Switzerland

Aims & Scope

Sports Traumatology and Arthroscopy is an international, peer-reviewed journal dedicated to the latest advances and research in sports traumatology, arthroscopy and related surgical techniques. Our aim is to serve as a premier platform for the dissemination of significant new findings and the exchange of evidence-based knowledge and experience that highlight progress in all areas of sports traumatology and arthroscopy. Three issues are released every year in April, August, and December.

Aim

The primary aim of Sports Traumatology and Arthroscopy is to improve the care of patients with sports injuries by promoting the understanding of the pathophysiology of sports injuries, improving diagnostic techniques, and advancing treatment and rehabilitation methods. The journal aims to bridge the gap between sports traumatology research and clinical practice by providing a forum for the exchange of information relevant to clinical orthopedics, sports medicine and the science of sports injury and repair.

Scope of the Journal

The scope of the journal includes, but is not limited to, the following areas

Arthroscopy: Innovative techniques, clinical outcomes, and advances in arthroscopic surgery for the treatment of sports injuries.

Sports Orthopedics: Articles on surgical and non-surgical treatment options for sports injuries, including the use of novel techniques, materials, and implants.

Injury Prevention and Management: Studies on the prevention, diagnosis, treatment, and rehabilitation of sports-related injuries.

Regenerative Medicine: Treatment methods that involve the process of replacing, engineering, or regenerating human cells, tissues, or organs to restore or establish normal function after sports injuries, including ligaments, cartilage, menisci, and bone.

Biomechanics and Kinesiology: The study of the biomechanics of exercise and its effects on the body, with the goal of improving injury prevention strategies and rehabilitation approaches.

Rehabilitation and Physical Therapy: Evidence-based practices for rehabilitating athletes after injury or surgery, including physical therapy techniques and recovery protocols.

Performance Enhancement: Studies on optimizing athletic performance through innovative training techniques, nutrition, and injury prevention strategies.

Musculoskeletal Anatomy: Studies that focus on the anatomical and biomechanical aspects of sports injuries in order to develop better prevention and treatment strategies, such as new surgical techniques and modifications.

Diagnostic Techniques and Imaging: Research on imaging and diagnostic techniques for sports injuries.

Systematic Review and Metanalysis: Comprehensive reviews of the current literature that use explicit, systematic methods to identify, select, and critically appraise relevant research on a specific topic or question.

Case Reports: Detailed reports of individual cases, clinical experiences, and studies that contribute to the understanding of sports injuries and their management.

Sports Traumatology and Arthroscopy invites submissions from researchers, clinicians, and allied health professionals in sports medicine, orthopedic surgery, physical therapy, and related fields. We are committed to providing our readers with high-quality, impactful articles that contribute to the advancement of sports traumatology, arthroscopy, and injury management. Through rigorous peer review and a commitment to excellence, we aim to assist orthopedic surgeons and all physicians who care for patients with sports injuries in improving patient outcomes and advancing the field of sports traumatology and arthroscopy.

Owner: On behalf of the Turkish Sports Traumatology Arthroscopy and Knee Surgery Society:
Prof.Dr. Yavuz KOCABEY
Address: 1420 Street No.67 Floor 1, Kahramanlar/İzmir: +90 (232) 463 00 36 Administrative Office: 2007 Street No.41 Beysukent/Çayyolu/Ankara; **Phone:** +90 (312) 988 02 68; **E-mail:** tusyad@tusyad.org

Publishing House: KARE Publishing; **Graphics Design:** Zeynep KOYUN
Address: Göztepe Mahallesi, Fahrettin Kerim Gökay Caddesi, No: 200, Daire: 2, Göztepe, Kadıköy, İstanbul, Türkiye; **Phone:** +90 216 550 61 11; **Fax:** +90 216 550 61 12; **E-mail:** kare@karepb.com

Instructions for the Authors

Preparation of Manuscripts

The Language

STArt's official language is English. STArt accepts manuscripts written in clear and understandable English, either American or British style. It is strongly recommended that authors who feel that their English language may need correction seek editing and proofreading services.

Manuscript Submission

Please submit your manuscript documents using the "Manuscript Submission" link on the home page. Before submitting, please make sure that all required documents are ready to be uploaded. The submission checklist available from the home page menu 'Author Form' can be used as a guide.

Document Formatting

The main text and tables must be submitted in Microsoft Word document format (.doc or .docx), using 11 pt Times New Roman font, with the main text double-spaced and 2.5 cm margins. Please do not use headers, footers, or endnotes in your paper. Use automatic page numbering to number the pages.

Title Page

This journal follows a blinded peer-review process. Reviewers are blinded to the authors of the paper. Therefore, authors are expected to submit a separate title page. The title page should contain the following information;

Title of the manuscript

All authors' names in order of sequence (Name and Surname)

Academic degree of authors (MD, PhD, Prof.... etc.)

ORCID number (Please see below or refer to https://orcid.org/)

Affiliations of the authors

Contact information of the corresponding author

The name of the **department and institution** in which the work was done

Declarations

Acknowledgments

Ethics approval and consent to participate: The name of the ethical committee or institutional review board, Date of approval, and the number of approvals.

Informed Consent: Conflict of interest statement:

Funding: Availability of data and material.

Authors' contributions: The title page template can be downloaded from the Author Forms at the journal's website.

Attention!

Authors are expected to consider the list of authors carefully before submitting their manuscript and provide the definitive list of authors at the time of the original submission. Any addition, deletion, or rearrangement of author names in the authorship list is not accepted after the submission or during the revisions.

ORCID

ORCID IDs of all authors must be stated during the submission of the manuscript. All IDs will be linked to the authors' pages at https://orcid.org in an online PDF, and the ID of the corresponding author will be added to the details. ORCID IDs will prevent the confusion caused by name similarities and affiliations. All authors can create free accounts on https://orcid.org and get a personal 16-digits number. ORCID also increases the visibility of author and their works by keeping profiles up-to-date.

Abstract

For original articles, a structured abstract of a maximum of 350 words must be submitted on a separate page. The abstract should contain sections describing **the purpose, materials and methods, results, and conclusions**. For case reports, an unstructured abstract of a maximum of 300 words must be submitted.

Keywords

4-6 keywords should be provided for each type of manuscript. Keywords should be chosen from Medical subject headings (MeSH) terms (Please refer to https://www.ncbi.nlm.nih.gov/mesh/)

Level of Evidence

The journal requires authors to categorize all manuscripts with a clinical focus according to the level of evidence. You can find the level of evidence table in the Author Forms Section on the journal page.

Manuscript Text

The main text and tables must be sent in Microsoft Word document format (.doc or .docx), with 11 pt Times New Roman font. The main text should be double-spaced with 2.5cm margins. Please do not use headers, footers, or endnotes in your paper. Use the automatic page numbering function to number the pages. The text of an original article should be divided into the following paragraphs: **Introduction, Materials and Methods, Results, Discussion, and Conclusions**.

Every research paper should adhere to appropriate standards for research reporting. This ensures that editors, peer reviewers, and readers have sufficient information to understand the research methodology and assess the reliability of the results. We recommend the use of standard reporting templates for various studies, which you can find at https://www.equator-network.org/.

Preparation of Declarations in the Abstract Page

Acknowledgements

List all contributors who do not meet the criteria for authorship, such as technical assistants, assistants in data collection and entry, illustrators, writing assistants, or heads of departments who provided only general support. Financial and other material support should be disclosed and acknowledged.

Author Contribution Statement

All authors' contributions to the manuscript should be listed under the authors' contribution categories using their initials (e.g., ML). It should also be noted that all authors have read the final version of the submitted manuscript and agree with its accuracy.

Ethical Approval and Consent to Participate

The institution from which the ethics committee approval was obtained and the date and number of the approval should be reported. For studies where ethics committee approval is not required, the reason why it is not required should be reported. It should also be stated that informed consent was obtained from the participants.

Funding Statement

All authors are required to declare what support they received to carry out their research. Declaring funding sources acknowledges funders' contributions, fulfills funding requirements, and promotes greater transparency in the research process. Each author must individually declare all sources of funding received for the research submitted to the journal. This information includes the name of granting agencies, grant numbers, and a description of each funder's role. If the funder has played no role in the research, this must be stated as well. If no financial support was received, it should be written as 'No financial support was received for this study'.

Conflicts of Interest

Authors are asked to declare any interests that are directly or indirectly related to the work they are submitting for publication. They should report any interests for the past three years from the time the research was conducted and the manuscript was prepared for submission. Any interests beyond this three-year period must also be disclosed if they could potentially be seen as influencing the submitted work. This practice of disclosing interests ensures a transparent and comprehensive process that helps readers make informed judgments about potential bias. It's important to note that disclosure of financial relationships with a sponsoring organization or compensation for consulting does not imply that such relationships are improper.

Data Availability Statement

A data availability statement in an article informs readers about the location and method of accessing data underpinning the findings and analyses. This might encompass links to datasets that are open to the public and were examined or created as part of the research, details about the available data, and/or instructions for obtaining data that isn't openly accessible. We strongly recommend uploading the raw data as a Supplementary file.

References

General Guidelines

Authors should always try to read and cite the original work (the primary source) in the manuscript. In cases where this is not possible, secondary sources citing the primary original source may be cited. However, this situation is undesirable and should be used unexceptionally. Self-citations may be used if the content of the article is related to the submitted manuscript. However, authors, editors, and peer-reviewers should not abuse this option to promote their own papers.

Unpublished studies, unpublished observations, personal communications, and retracted papers cannot be cited. Citations from the predatory or pseudo-journals should be avoided. Please refer to the following list of possible such journals using this link. https://bealllslist.net/.

There is no limit to the number of references. However, authors should cite only the necessary articles.

Style and Format

Reference citations in the text should be identified by numbers in square brackets, such as [5], [7,8], and [4-9, 11]. The reference list should be numbered consecutively.

Journal Article

Grimberg J, Duranthon LD, Bellaïche L, Petrover D, Kalra K. The time for functional recovery after arthroscopic rotator cuff repair: Correlation with tendon healing controlled by computed tomography arthrography. Arthroscopy. 2008;24:25-33.

If there are more than 6 authors, provide first six authors and use 'et al.' at the end of author list. Digital Object Identifier (doi) number should be added to the end of the reference (if available).

Cvetanovich GL, Gowd AK, Liu JN, Nwachukwu BU, Cabarcas BC, Cole BJ, et al. Establishing clinically significant outcome after arthroscopic rotator cuff repair. J Shoulder Elbow Surg. 2019;28:939-48.

Book

Newton ML. Current practice of pain. 1st ed. St. Luis, MO: Mosby; 1990.

Book Chapter

Jurkovich GJ. Duodenum and pancreas. In: Mattox KL, Feliciano DV, Moore EE, editors. Trauma. 4th ed. New York: McGraw-Hill; 2000. pp. 735-62.

Online Document

Cartwright J. Big stars have weather too. IOP Publishing PhysicsWeb. http://physicsweb.org/articles/news/11/6/16/1. Accessed 26 June 2007.

Dissertation

Trent JW. Experimental acute renal failure. Dissertation, University of California; 1975.

Case Reports

New, interesting and rare cases can be reported. They should be unique, describing a great diagnostic or therapeutic challenge and providing a learning point for the readers. Cases with clinical significance or implications will be given priority. These communications could be of up to 1500 words (excluding Abstract and references) and should have the following headings: Abstract (unstructured), Key-words, Introduction, Case report, Discussion, Reference, Tables and Legends in that order. The manuscript could be of up to 1500 words (excluding references and abstract) and could be supported with up to 20 references. Case Reports could be authored by up to 4 authors.

Letter to the Editor

We welcome letters offering commentary on articles we have recently published. This may include constructive criticism, additional insights, related experiences, or discussions that further the conversation initiated by the original article. Letters to the Editor should be concise, focused, and articulate clear points of discussion. While these submissions undergo a peer-review process, they are streamlined compared to full research articles, emphasizing relevance, accuracy, and the potential to contribute constructively to our readers' understanding and engagement.

Tables

All tables should be prepared in Microsoft Word document format (.doc or .docx) and numbered using Arabic numerals. They should be cited consecutively in the text. Each table should have a title or caption that explains its content. Any footnote that contributes to ease the understanding of the table may be added beneath the table body.

Figures

All figures should be properly numbered and uploaded as separate files. Name the figure files accordingly. Cite all figures in the order they appear in the text within parenthesis, such as (Figure 1). Figures with multiple parts should be marked a, b, c, etc., with a description of each panel included in the legend rather than on the figure. Figures must be submitted in **TIFF format**. Color or grayscale photographs should be saved at a minimum of **300 dpi** or higher. Electronic artworks or illustrations should be saved at a minimum of **1200 dpi** or higher. The size of the figure should fit either in one, one and half, or two columns in width (1 column: 8.9 cm, 1.5 columns: 12 cm, two columns: 18 cm in width).

Authors wishing to include figures, photographs, illustrations, diagrams, charts, etc., that have already been published in another journal or book are required to obtain written permission from the copyright owner(s) for both the print and online format and to include evidence that such permission has been granted when submitting their papers. Any document received without permission will be assumed to originate from the authors.

Figure Legends

Figure legends for all images must be included at the end of the manuscript text file, after the References section. Explain what each figure shows. Identify machine settings for magnetic resonance and computed tomography images and give the magnification of all photomicrographs. Define all arrows and other such indicators appearing on the figure.

Abbreviations and Symbols

Use only standard abbreviations; using nonstandard abbreviations can be confusing to readers. Avoid abbreviations in the manuscript's title. The spelled-out abbreviation followed by the abbreviation in parenthesis should be used on the first mention unless the abbreviation is a standard unit of measurement. A list of abbreviations should be included in the manuscript text.

Units of Measurements

Measurements of length, height, weight, and volume should be reported in metric units (meter, kilogram, or liter) or their decimal multiples. Temperatures should be in degrees Celsius, and blood pressure should be in millimeters of mercury unless the journal specifically requires other units. Journals vary in the units they use for reporting hematologic, clinical chemistry, and other measurements. Authors must consult the Information for Authors of the particular journal and should report laboratory information in both local and International Systems of Units (SI). Editors may request that authors add alternative or non-SI units since SI units are not universally used. Drug concentrations may be reported in either SI or mass units, but the alternative should be provided in parentheses where appropriate.

Permissions

Authors wishing to include previously published figures, tables, or excerpts in their manuscripts must obtain permission from the copyright holders for both print and digital publication. They must also provide proof of such permission at the time of submission. Failure to provide such proof will result in the material being assumed to be the author's original work.

Ethics & Policies

Advertisement Policy

The Sports Traumatology and Arthroscopy does not accept advertisements; the journal is sponsored by the Turkish Sports Traumatology Arthroscopy and Knee Surgery Society.

Authorship Policy

All statements and opinions expressed in the manuscripts published in the Sports Traumatology and Arthroscopy reflect the views of the author(s).

Each individual listed as an author should fulfill the authorship criteria recommended by the International Committee of Medical Journal Editors (ICMJE). The ICMJE recommends that authorship should be based on the following 4 criteria:

Substantial contributions to the conception or design of the work, or the acquisition, analysis, or interpretation of data for the work; AND

Drafting the work or revising it critically for important intellectual content; AND

Final approval of the version to be published; AND

Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

In addition to being accountable for their own work, authors should have confidence in the integrity of the contributions of their co-authors and each author should be able to identify which co-authors are responsible for other parts of the work.

All of those designated as authors should meet all four criteria for authorship, and all who meet the four criteria should be identified as authors. Those who provided a contribution but do not meet all four criteria should be recognized separately on the title page and in the Acknowledgements section at the conclusion of the manuscript.

The Sports Traumatology and Arthroscopy requires that corresponding authors submit a signed and scanned version of the authorship contribution form (available for download through) during the initial submission process in order to appropriately indicate and observe authorship rights and to prevent ghost or honorary authorship. Please note that the list of authors on the final manuscript will be presented in the order provided on this form. If the editorial board suspects a case of "gift authorship," the submission will be rejected without further review. As part of the submission of the manuscript, the corresponding author should also send a short statement declaring that they accept all responsibility for authorship during the submission and review stages of the manuscript.

Complaint and Appeal Policy

Appeal and complaint cases are handled within the scope of COPE guidelines by the Editorial Board of the journal. Appeals should be based on the scientific content of the manuscript. The final decision on the appeal and complaint is made by Editor in Chief. An Ombudsperson or the Ethical Editor is assigned to resolve cases that cannot be resolved internally. Authors should get in contact with the Editor in Chief regarding their appeals and complaints via e-mail at kare@karepb.com

Corrections Policy

If the editors or publisher learn from a third party that a published work contains a material error or inaccuracy, the authors must promptly correct or retract the article or provide the journal editors with evidence of the accuracy of the article.

Ethics Policy

The Editorial Board of the Sports Traumatology and Arthroscopy and the Publisher adheres to the principles of the International Council of Medical Journal Editors (ICMJE), the World Association of Medical Editors (WAME), the Council of Science Editors (CSE), the Committee on Publication Ethics (COPE), the US National Library of Medicine (NLM), the World Medical Association (WMA) and the European Association of Science Editors (EASE).

In accordance with the journal's policy, an approval of research protocols by an ethics committee in accordance with international agreements "WMA Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects (last updated: October 2013, Fortaleza, Brazil)", "Guide for the care and use of laboratory animals (8th edition, 2011)" and/or "International Guiding Principles for Biomedical Research Involving Animals (2012)" is required for all research studies. If the submitted manuscript does not include ethics committee approval, it will be reviewed according to COPE's guideline (Guidance for Editors: Research, Audit and Service Evaluations). If the study should have ethical approval, authors will be asked to provide ethical approval in order to proceed the review process. If they cannot provide ethical approval, their manuscript will be rejected and also their institutions and when needed, the related bodies in their country will be informed that such studies must have ethics committee approval. If they provide approval, review of the manuscript will continue.

If the study does not need ethics committee approval after the editorial board's review, the authors will be asked to provide an ethics committee approval or a document given by a related independent committee that indicates the study does not need ethics committee approval according to the research integrity rules in their country. If the authors provide either an approval or a document showing that ethics approval is not needed, the review process can be continued. If the authors cannot provide either documents, the manuscript may be rejected.

For articles concerning experimental research on humans, a statement should be included that shows informed consent of patients and volunteers was obtained following a detailed explanation of the procedures that they may undergo. The journal may request a copy of the Ethics Committee Approval received from the relevant authority. Informed consent must also be obtained for case reports and clinical images.

Studies using human or animal subjects should be approved by the appropriate institutional and local Ministry of Health ethics committees. Ethics approval of research protocols in accordance with international agreements is required for experimental, clinical, and drug studies, as well as for some case reports. Ethics committee reports or an equivalent official document may be requested from the authors. For manuscripts involving experimental research on humans, a statement should be included that shows that written, informed consent of patients and volunteers was obtained. For studies carried out on animals, the measures taken to prevent pain and suffering of the animals should be stated clearly. A statement regarding patient consent, and the name of the ethics committee, the ethics committee approval date, and number should be stated in the Materials and Methods section of the manuscript. It is the authors' responsibility to carefully protect patients' anonymity.

Fee Waiver Policy

There is no fee waiver.

Funding Sources Policy

All authors are required to declare what support they received to carry out their research. Declaring funding sources acknowledges funders' contributions, fulfills funding requirements, and promotes greater transparency in the research process.

Each author must individually declare all sources of funding received for the research submitted to the journal. This information includes the name of granting agencies, grant numbers, and a description of each funder's role. If the funder has played no role in the research, this must be stated as well.

Authors are not required to provide the complete list of every single grant that supports them if the grant is not related to the research published.

Licenses and Copyright Policy

Authors publishing with the journal retain the copyright to their work licensed under the Creative Commons Attribution-NonCommercial 4.0 International license (CC BY-NC 4.0) and grant the Publisher non-exclusive commercial right to publish the work. CC BY-NC 4.0 license permits unrestricted, non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Open Access Policy

The Sports Traumatology and Arthroscopy supports the Budapest Open Access Initiative statement of principles that promotes free access to research literature. The declaration defines open access to academic literature as free availability on the internet, permitting users to read, record, copy, print, search, or link to the full text, examine them for indexing, use them as data for software or other lawful purposes without financial, legal, or technical barriers. Information sharing represents a public good, and is essential to the advancement of science. Therefore, articles published in this journal are available for use by researchers and other readers without permission from the author or the publisher provided that the author and the original source are cited. The articles in the Sports Traumatology and Arthroscopy are accessible through search engines, websites, blogs, and other digital platforms. Additional details on the Budapest Open Access Initiative and their guidelines are available at https://www.budapestopenaccessinitiative.org.

Open Access Policy is based on rules of Budapest Open Access Initiative the Sports Traumatology and Arthroscopy applies the Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) license to articles we publish. If you submit your paper for publication, you agree to have the CC BY-NC 4.0 license applied to your work. Under this Open Access license, you as the author agree that anyone can copy, distribute or reuse the content of your article for non-commercial purposes for free as long as the author and original source are properly cited. The corresponding author must sign the Creative Commons License Agreement after their articles are accepted.

Open Access Statement

The journal is an open access journal and all content is freely available without charge to the user or his/her institution. Except for commercial purposes, users are allowed to read, download, copy, print, search, or link to the full texts of the articles in this journal without asking prior permission from the publisher or the author. This is in accordance with the BOAI definition of open access. The open access articles in the journal are licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) license.

Peer Review Policy

Only those manuscripts approved by its every individual author and that were not published before in or sent to another journal, are accepted for evaluation.

Submitted manuscripts that pass preliminary control are scanned for plagiarism using iThenticate software. After plagiarism check, the eligible ones are evaluated by Editor-in-Chief for their originality, methodology, the importance of the subject covered and compliance with the journal scope. Editor-in-Chief evaluates manuscripts for their scientific content without regard to ethnic origin, gender, sexual orientation, citizenship, religious belief or political philosophy of the authors and ensures a fair double-blind peer review of the selected manuscripts.

The selected manuscripts are sent to at least two national/international referees for evaluation and publication decision is given by Editor-in-Chief upon modification by the authors in accordance with the referees' claims.

Editor-in-Chief does not allow any conflicts of interest between the authors, editors and reviewers and is responsible for final decision for publication of the manuscripts in the Journal.

Reviewers' judgments must be objective. Reviewers' comments on the following aspects are expected while conducting the review.

- Does the manuscript contain new and significant information?
- Does the abstract clearly and accurately describe the content of the manuscript?
- Is the problem significant and concisely stated?
- Are the methods described comprehensively?
- Are the interpretations and consclusions justified by the results?
- Are adequate references made to other Works in the field?
- Is the language acceptable?

Reviewers must ensure that all the information related to submitted manuscripts is kept as confidential and must report to the editor if they are aware of copyright infringement and plagiarism on the author's side.

A reviewer who feels unqualified to review the topic of a manuscript or knows that its prompt review will be impossible should notify the editor and excuse himself from the review process.

The editor informs the reviewers that the manuscripts are confidential information and that this is a privileged interaction. The reviewers and editorial board cannot discuss the manuscripts with other persons. The anonymity of the referees is important.

Plagiarism Policy

All submissions are screened using similarity detection software at least two times: on submission and after completing revisions. In the event of alleged or suspected research misconduct, e.g., plagiarism, citation manipulation, or data falsification/fabrication, the editorial board will follow and act in accordance with COPE guidelines. Plagiarism, including self-plagiarism, that is identified at any stage will result in rejection of the manuscript.

Publication Charges Policy

The Sports Traumatology and Arthroscopy assesses no submission fees, publication fees, or page charges.

Retraction Policy

The publisher will take all appropriate measures to modify the article in question, in close cooperation with the editors, in cases of alleged or proven scientific misconduct, fraudulent publication, or plagiarism. This includes the prompt publication of an erratum, disclosure, or retraction of the affected work in the most severe case.

Together with the editors, the publisher will take reasonable steps to detect and prevent the publication of articles in which research misconduct occurs and will under no circumstances promote or knowingly allow such abuse to occur.

Withdrawal Policy

The Sports Traumatology and Arthroscopy is committed to providing high quality articles and uphold the publication ethics to advance the intellectual agenda of science. We expect our authors to comply with, best practice in publication ethics as well as in quality of their articles.

Withdrawal of a manuscript will be permitted only for the most compelling and unavoidable reasons. For withdrawal of a manuscript authors need to submit an "Article withdrawal Form", signed by all authors mentioning the reason for withdrawal to the Editorial Office. Authors must not assume that their manuscript has been withdrawn until they have received appropriate notification to this effect from the editorial office.

In a case where a manuscript has taken more than five months' time for review process, that allows the author to withdraw manuscript.

Manuscript withdrawal penalty: After receiving the Article withdrawal Form, the Sports Traumatology and Arthroscopy Editorial Board will investigate the reason of withdrawal.

If the reason finds to be acceptable, the author is allowed to withdraw the manuscript without any withdrawal penalty. If not the Sports Traumatology and Arthroscopy will not accept any manuscripts from the same author for one year.

Important notes: Manuscripts may be withdrawn at any stage of review and publication process by submitting a request to the editorial office. Manuscript withdrawal will be permitted after submission only for the most compelling and unavoidable reasons.

If the author wants to withdraw a manuscript, the author needs to submit a completed "Article withdrawal Form", signed by all authors of the manuscript stating the reasons for manuscript withdrawal.

The manuscript will not be withdrawn from publication process until a completed, signed form is received by the editorial office. Authors must not assume that their manuscript has been withdrawn until they have received appropriate notification to this effect from the Sports Traumatology and Arthroscopy editorial office.

TUSYAD STArt

Sports Traumatology & Arthroscopy

Volume: 3 Issue: 1 Year: 2026

Contents

STArt
TUSYAD
Sports Traumatology & Arthroscopy
DOI: 10.14744/STA.2026.11802
Sports Traumatol Arthrosc 2026;3(1):1–3

Editorial

Beyond the Labrum: Rethinking Posterior Impingement and SLAP Lesions in the Elite Tennis Shoulder

Nicola de Gasperis,[1] Ozkan Kose[2]

[1]Department of Life Sciences, Physical and Rehabilitation Medicine, Health and Health Professions, Link Campus University, Rome, Italy
[2]Department of Orthopedics and Traumatology, University of Health Sciences, Antalya Training and Research Hospital, Antalya, Turkiye

Cite this article as:
de Gasperis N, Kose O. Beyond the Labrum: Rethinking Posterior Impingement and SLAP Lesions in the Elite Tennis Shoulder. Sports Traumatol Arthrosc 2026;3(1):1–3.

Address for correspondence:
Ozkan Kose, Department of Orthopedics and Traumatology, University of Health Sciences, Antalya Training and Research Hospital, Antalya, Türkiye
E-mail:
drozkankose@hotmail.com

Available Online: 11.05.2026

Sports Traumatology & Arthroscopy – Available online at www.stajournal.com

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

The modern tennis serve is one of the most violent and biomechanically demanding motions in sport. At peak performance, the shoulder is exposed to extreme abduction and external rotation, rapid deceleration forces, and repetitive torsional stress that test the limits of anatomical tolerance. Yet, paradoxically, most elite players remain asymptomatic for years despite demonstrable structural abnormalities on imaging. This paradox should prompt reflection. Posterior internal impingement (PII) and superior labrum anterior-to-posterior (SLAP) lesions have traditionally been framed as discrete pathological entities, lesions to diagnose, classify, and repair. However, accumulating clinical experience and biomechanical evidence suggest a different interpretation: these conditions are often not isolated structural failures, but rather the biological footprint of a dysfunctional kinetic system. If outcomes in elite tennis players are to be improved, our conceptual framework must evolve accordingly.

Adaptation is not injury—until it is. The overhead athlete's shoulder is defined by adaptation. Increased humeral retroversion, gain in external rotation, posterior capsular tightness, and glenohumeral internal rotation deficit (GIRD) are well-documented findings in high-level players. These changes may enhance performance by allowing greater energy storage and release during the cocking phase. But adaptation has a threshold. The classical descriptions of posterior impingement by Walch et al.[1] and the expanded spectrum proposed by Jobe[2] emphasized contact between the greater tuberosity and the posterosuperior glenoid during abduction and external rotation (ABER). Later, Burkhart et al.[3] highlighted the central role of posterior capsular contracture and the shift in glenohumeral contact point as drivers of pathological impingement. What has become increasingly clear is that posterior internal impingement is rarely purely intra-articular. It reflects a breakdown along the kinetic chain: deficits in lower-limb power transfer, trunk rotation asymmetry, scapular dyskinesis, and neuromuscular imbalance.[4] The shoulder becomes the terminal victim of proximal inefficiency. The key clinical question, therefore, is not simply whether impingement exists but why the adaptive balance has been lost.

Since the original description of SLAP lesions by Stephen J. Snyder[5], the orthopedic community has faced an ongoing dilemma: when does labral pathology require repair, and when is it merely an incidental finding? Advances in magnetic resonance imaging have dramatically increased detection rates. Yet higher diagnostic sensitivity has not translated into uniformly improved outcomes. In the early 2000s, SLAP repair rates surged, particularly in the United States. Subsequent outcome studies, however, revealed sobering realities: persistent pain, unpredictable return-to-play rates, and significant revision rates in overhead athletes.[6,7] The labrum, in many elite tennis players, may represent the endpoint of abnormal biomechanics rather than the primary driver of dysfunction. The "peel-back" mechanism and torsional overload of the biceps anchor occur within a system already stressed by capsular tightness, altered scapular control, and repetitive deceleration demands. Anatomical repair, while intuitively appealing, does not necessarily restore high-level performance or mechanics. This disconnect has fueled growing interest in biceps tenodesis among selected populations, particularly older athletes and revision cases. Yet even tenodesis should not be viewed as a panacea.[8] The broader lesson is sobering: structural normalization does not automatically equate to functional restoration.

Modern imaging has transformed diagnostic precision, but it has also complicated clinical reasoning. Asymptomatic overhead athletes frequently demonstrate articular-sided cuff fraying, posterosuperior labral irregularities, and MRI findings consistent with internal impingement. The mere presence of structural changes does not establish causality. This challenges a surgery-first mentality. The clinical examination, including the assessment of rotational arc symmetry, posterior shoulder tightness, scapular positioning, and kinetic chain sequencing remains indispensable. Imaging must inform, not dictate, decision-making. We must resist the temptation to operate on images rather than patients. The future lies in integration: combining structural imaging with objective biomechanical assessment and load monitoring to distinguish adaptive remodeling from pathological breakdown.

Conservative treatment remains the cornerstone of management in overhead shoulder injuries.[9] However, rehabilitation must evolve beyond generic rotator cuff strengthening. Elite tennis demands explosive lower limb drive, coordinated trunk rotation, scapular stability, and finely tuned neuromuscular timing.[10] Rehabilitation programs must therefore address:

- Restoration of total rotational arc balance
- Targeted posterior capsule mobility
- Quantitative scapular control training
- Core and lower extremity power integration
- Progressive interval serving protocols with load monitoring

The objective is not merely symptom resolution, but restoration of mechanical efficiency. Moreover, prevention strategies deserve equal emphasis. Routine screening for significant GIRD, scapular dyskinesis, and posterior capsule contracture may identify players at risk before structural injury manifests. The greatest gains in athlete longevity may come not from better surgical techniques, but from earlier biomechanical correction.

When nonoperative management fails, surgical intervention must be carefully individualized. Evidence suggests that isolated SLAP repair in high-level overhead athletes carries variable outcomes, particularly beyond the third decade of life.[6,7] Biceps tenodesis has demonstrated promising functional results in selected cases, yet even here, postoperative kinetic chain rehabilitation remains critical.[8] Perhaps the most important responsibility of the surgeon is to be transparent. Return to play at the preinjury level is not guaranteed. Persistent discomfort during high-load serving may remain despite technically successful procedures. Expectations must be realistic, especially in professional or elite players whose performance margins are razor-thin. In this context, restraint may be as important as technical skill.

Current literature remains dominated by single-center case series with heterogeneous reporting of outcomes. Multicenter prospective studies are urgently needed to identify:

- Predictors of success after conservative management
- Biomechanical thresholds distinguishing adaptation from pathology
- Standardized return-to-play criteria
- Long-term comparative outcomes of SLAP repair versus tenodesis in elite tennis populations

Emerging technologies, such as three-dimensional motion capture, wearable load sensors, and artificial intelligence-assisted biomechanical modeling, offer unprecedented opportunities. Machine learning algorithms may soon detect subtle kinetic inefficiencies long before clinical symptoms emerge. Such advances could shift our paradigm from reactive lesion management to proactive preservation of performance.

The elite tennis shoulder is not merely a joint; it is the terminal expression of a highly integrated kinetic chain.[4,10] Posterior internal impingement and SLAP lesions are not isolated enemies to be excised, but signals of system overload. As tennis continues to evolve—with faster serves, greater topspin, and denser competition calendars—the demands on the shoulder will only increase. Our management strategies must evolve as well. The future of overhead shoulder care lies not in more anchors or stronger sutures, but in deeper understanding. If we embrace a systems-based, function-driven model, we may finally align surgical decision-making, rehabilitation science, and performance optimization. The challenge before us is not simply to repair tissue. It is to preserve the extraordinary biomechanical harmony that allows the elite tennis athlete to serve at 220 kilometers per hour again and again.

REFERENCES

1. Walch G, Boileau P, Noel E, Donell ST. Impingement of the deep surface of the supraspinatus tendon on the posterosuperior glenoid rim: an arthroscopic study. J Shoulder Elb Surg 1992;1:238–45. [Crossref]
2. Jobe CM. Posterior superior glenoid impingement: expanded spectrum. Arthroscopy 1995;11:530–6. [Crossref]
3. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology. Part I: Pathoanatomy and biomechanics. Arthroscopy 2003;19:404–20. [Crossref]
4. Kibler WB, Sciascia A, Wilkes T. Scapular dyskinesis and its relation to shoulder injury. J Am Acad Orthop Surg 2012;20:364–72. [Crossref]
5. Snyder SJ, Karzel RP, Del Pizzo W, Ferkel RD, Friedman MJ. SLAP lesions of the shoulder. Arthroscopy 1990;6:274–9. [Crossref]
6. Sayde WM, Cohen SB, Ciccotti MG, Dodson CC. Return to play after Type II superior labral anterior-posterior lesion repairs in athletes: a systematic review. Clin Orthop Relat Res 2012;470:1595–600. [Crossref]
7. Thayaparan A, Yu J, Horner NS, Leroux T, Alolabi B, Khan M. Return to Sport After Arthroscopic Superior Labral Anterior-Posterior Repair: A Systematic Review. Sports Health 2019;11:520–7. [Crossref]
8. Frantz TL, Shacklett AG, Martin AS, Barlow JD, Jones GL, Neviaser AS, et al. Biceps Tenodesis for Superior Labrum Anterior-Posterior Tear in the Overhead Athlete: A Systematic Review. Am J Sports Med 2021;49:522–8. [Crossref]
9. Steinmetz RG, Guth JJ, Matava MJ, Brophy RH, Smith MV. Return to play following nonsurgical management of superior labrum anterior-posterior tears: a systematic review. J Shoulder Elbow Surg 2022;31:1323–33. [Crossref]
10. Kibler WB, Lockhart JW, Cromwell R, Sciascia A. Managing Scapular Dyskinesis. Phys Med Rehabil Clin N Am 2023;34:427–451. [Crossref]

STArt
TUSYAD
Sports Traumatology & Arthroscopy
DOI: 10.14744/start.2026.11290
Sports Traumatol Arthrosc 2026;3(1):4–15

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.

Cite this article as:
Akdogan BM, Havitcioglu C, Hayat M, Yilmaz MH, Atbasi Z, Barca F, et al. Autologous Minced Cartilage on the Rise: A Bibliometric Mapping of Minced Cartilage Techniques in Cartilage Repair. Sports Traumatol Arthrosc 2026;3(1):4–15.

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

Submitted: 28.01.2026
Revised: 08.04.2026
Accepted: 20.04.2026
Available Online: 11.05.2026

Sports Traumatology & Arthroscopy – Available online at www.stajournal.com

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

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

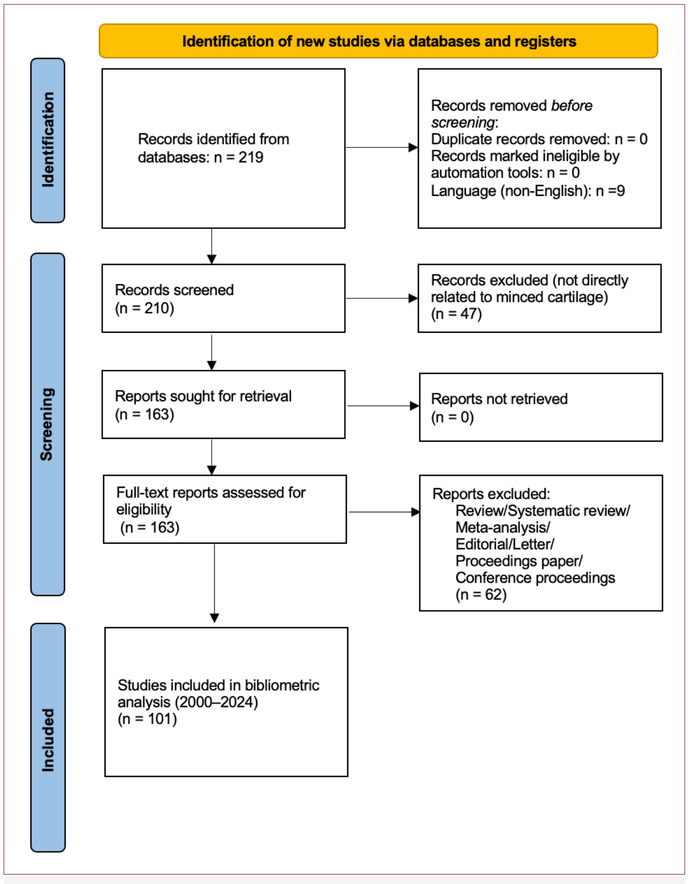

Figure 1. Flow diagram of study identification, screening and inclusion for the minced cartilage bibliometric analysis.

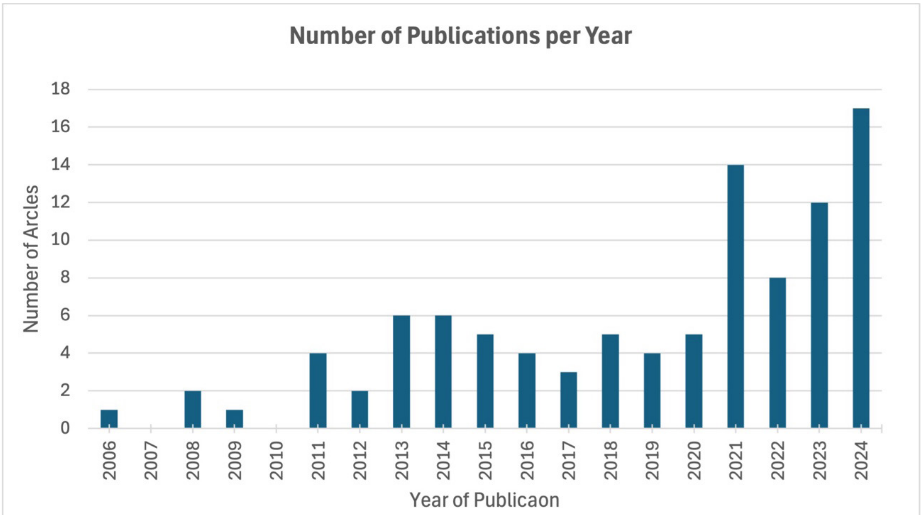

Figure 2. Annual number of minced cartilage–related publications (2000–2024).

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.

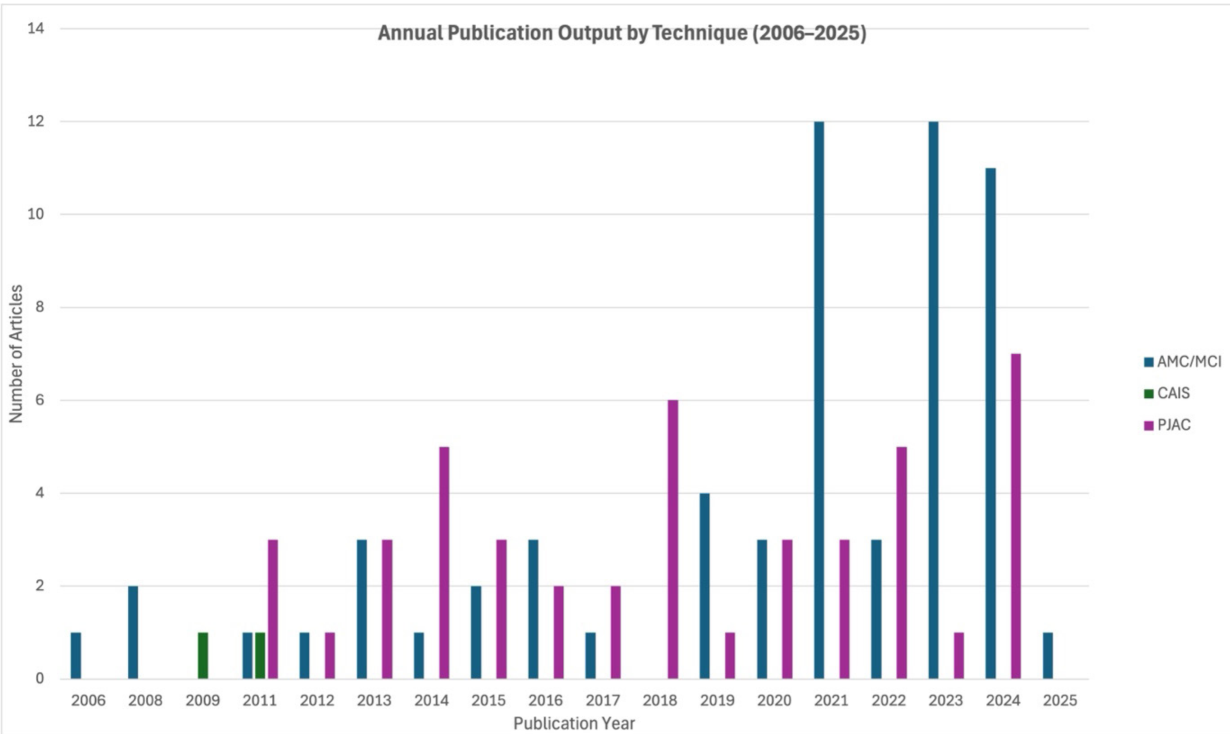

Figure 3. Temporal distribution of minced cartilage techniques (AMC/MCI, PJAC, CAIS) among published studies.

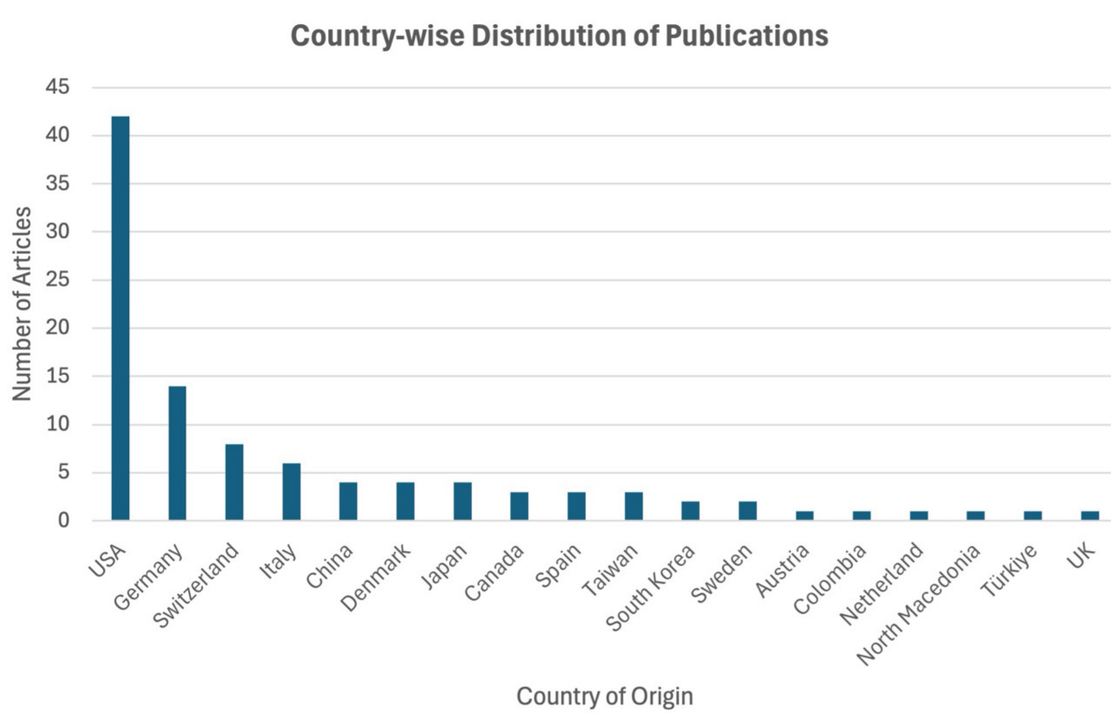

Figure 4. Geographical distribution of minced cartilage–related publications by country.

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.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that they have no relevant or material financial interests that relate to the research described in this paper.

Funding Disclosure: No funding was received for this study.

Data Availability Statement: Data are available from the corresponding author upon reasonable request.

Use of AI for Writing Assistance: The authors declared that they did not use any generative artificial intelligence for the writing of this manuscript, nor for the creation of images, graphics, tables, or their corresponding captions.

Author Contributions: Concept: B.M.A., C.H., H.A.A.; Design: B.M.A., C.H., H.A.A.; Supervision: H.A.A., M.A.; Data Collection and/or Processing: B.M.A., M.H.Y., Z.A., F.B.; Analysis and/or Interpretation: M.H.Y., Z.A., F.B.; Literature Search: B.M.A., C.H., M.H.Y.; Writing: B.M.A., C.H.; Critical Reviews: H.A.A.A, M.A., M.H.Y., Z.A. All authors have read and agreed to the published version of the manuscript.

Peer-review: Externally peer-reviewed.

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

REFERENCES

1. Dekker TJ, Aman ZS, DePhillipo NN, Dickens JF, Anz AW, LaPrade RF. Chondral Lesions of the Knee: An Evidence-Based Approach. J Bone Joint Surg Am 2021;103:629–5. [CrossRef]
2. Evenbratt H, Andreasson L, Bicknell V, Brittberg M, Mobini R, Simonsson S. Insights into the present and future of cartilage regeneration and joint repair. Cell Regen 2022;11:3. [CrossRef]
3. Chimutengwende-Gordon M, Donaldson J, Bentley G. Current solutions for the treatment of chronic articular cartilage defects in the knee. EFORT Open Rev 2020;5:156–63. [CrossRef]
4. Filardo G, Andriolo L, Angele P, Berruto M, Brittberg M, Condello V, et al. Scaffolds for Knee Chondral and Osteochondral Defects: Indications for Different Clinical Scenarios. A Consensus Statement. Cartilage 2021;13:1036S–46S. [CrossRef]
5. Richter DL, Schenck RC Jr, Wascher DC, Treme G. Knee Articular Cartilage Repair and Restoration Techniques: A Review of the Literature. Sports Health 2016;8:153–60. [CrossRef]
6. Soubih HO, Al-Saed AM, Ghazaly SAE, Sobhy MH, Kamel ME, Ebied WF, et al. Fresh osteochondral allograft transplantation for knee full-thickness articular cartilage lesions using femoral head of living donors: short-term results. Arch Orthop Trauma Surg 2024;144:3479–89. [CrossRef]
7. Lu Y, Dhanaraj S, Wang Z, Bradley DM, Bowman SM, Cole BJ, et al. Minced cartilage without cell culture serves as an effective intraoperative cell source for cartilage repair. J Orthop Res 2006;24:1261–70. [CrossRef]
8. Farr J, Yao JQ. Chondral Defect Repair with Particulated Juvenile Cartilage Allograft. Cartilage 2011;2:346–53. [CrossRef]
9. 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;37:71S–80S. [CrossRef]
10. Bonasia DE, Marmotti A, Mattia S, Cosentino A, Spolaore S, Governale G, et al. The Degree of Chondral Fragmentation Affects Extracellular Matrix Production in Cartilage Autograft Implantation: An In Vitro Study. Arthroscopy 2015;31:2335–41. [CrossRef]
11. Runer A, Ossendorff R, Öttl F, Stadelmann VA, Schneider S, Preiss S, et al. Autologous minced cartilage repair for chondral and osteochondral lesions of the knee joint demonstrates good postoperative outcomes and low reoperation rates at minimum five-year follow-up. Knee Surg Sports Traumatol Arthrosc 2023;31:4977–87. [CrossRef]
12. Salzmann GM, Ossendorff R, Gilat R, Cole BJ. Autologous Minced Cartilage Implantation for Treatment of Chondral and Osteochondral Lesions in the Knee Joint: An Overview. Cartilage 2021;13:1124S–36S. [CrossRef]
13. Gebhardt S, Hofer A, Wassilew GI, Sobau C, Zimmerer A. Minced Cartilage Implantation in Acetabular Cartilage Defects: Case Series with 2-Year Results. Cartilage 2023;14:393–9. [CrossRef]
14. Wang T, Belkin NS, Burge AJ, Chang B, Pais M, Mahony G, 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;34:1498–505. [CrossRef]
15. 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;14:2194. [CrossRef]
16. LaPrade RF, Botker JC. Donor-site morbidity after osteochondral autograft transfer procedures. Arthroscopy 2004;20:e69–73. [CrossRef]
17. Andrade R, Vasta S, Pereira R, Pereira H, Papalia R, Karahan M, et al. Knee donor-site morbidity after mosaicplasty - a systematic review. J Exp Orthop 2016;3:31. [CrossRef]
18. Runer A, Salzmann GM. Moving towards single stage cartilage repair—is there evidence for the minced cartilage procedure? Journal of Cartilage & Joint Preservation 2022;2:100053. [CrossRef]
19. Hatic SO 2nd, Berlet GC. Particulated juvenile articular cartilage graft (DeNovo NT Graft) for treatment of osteochondral lesions of the talus. Foot Ankle Spec 2010;3:361–4. [CrossRef]

20. Görtz S, Bugbee WD. Fresh osteochondral allografts: graft processing and clinical applications. J Knee Surg 2006;19:231–40. [CrossRef]
21. Levinson C, Cavalli E, Sindi DM, Kessel B, Zenobi-Wong M, Preiss S, et al. Chondrocytes From Device-Minced Articular Cartilage Show Potent Outgrowth Into Fibrin and Collagen Hydrogels. Orthop J Sports Med 2019;7:2325967119867618. [CrossRef]
22. 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;145:465. [CrossRef]
23. Bozkurt M, Nayda D, Şahin A, Yavaşoğlı K, Veizi E. Osteoperiosteal Cylindrical Iliac Bone Graft and Minced Cartilage as an Osteochondral Autograft for a Large Osteochondral Lesion. Arthrosc Tech 2024;13:103135. [CrossRef]
24. Blanke F, Warth F, Oehler N, Siegl J, Prall WC. Autologous platelet-rich plasma and fibrin-augmented minced cartilage implantation in chondral lesions of the knee leads to good clinical and radiological outcomes after more than 12 months: A retrospective cohort study of 71 patients. J Exp Orthop 2024;11:e70051. [CrossRef]
25. Behrendt P, Eggeling L, Lindner A, von Rehlingen-Prinz F, Krause M, Hoffmann M, et al. Autologous matrix-induced chondrogenesis provides better outcomes in comparison to autologous minced cartilage implantation in the repair of knee chondral defects. Knee Surg Sports Traumatol Arthrosc 2024;32:3023–30. [CrossRef]

STArt
Sports Traumatology & Arthroscopy
DOI: 10.14744/start.2026.42987
Sports Traumatol Arthrosc 2026;3(1):16–22

Original Article

Isolated Root Repair Versus Root Repair Combined with Meniscal Centralization for Medial Meniscus Posterior Root Tears with Extrusion: Clinical and Radiographic Outcomes

Kerim Oner, Fevzi Gurkan Aslan

Department of Orthopedics and Traumatology, Karadeniz Technical University, Trabzon, Turkiye

ABSTRACT

Objective: Medial meniscus posterior root tears (MMPRTs) disrupt hoop stress transmission and knee biomechanics and are commonly associated with medial meniscus extrusion (MME) and osteoarthritis progression. This study aimed to determine whether adding meniscal centralization to transtibial pull-out posterior root repair improves clinical outcomes and radiographic osteoarthritis severity compared with isolated root repair in patients with MMPRTs.

Materials and Methods: This retrospective comparative study included patients who underwent arthroscopic surgery for MMPRTs and were allocated to either isolated transtibial pull-out root repair or root repair combined with meniscal centralization. Patients with advanced osteoarthritis (Kellgren–Lawrence [K–L] grade ≥3) or varus malalignment >5° were excluded. Clinical outcomes were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC) subjective score, Lysholm score, and Tegner activity scale. Radiographic evaluation was performed using the K–L grading system on preoperative and postoperative standing radiographs. Between-group comparisons were performed using the independent-samples t-test or Mann–Whitney U test, and within-group comparisons were analyzed using the Wilcoxon signed-rank test.

Results: Twenty patients were included (isolated root repair group, n=10; root repair with meniscal centralization group, n=10). The groups were comparable in age, body mass index, and follow-up duration. Postoperative patient-reported outcome scores were similar between groups for KOOS (78.0±2.6 vs. 79.0±2.1; p=0.356), IKDC (73.2±1.9 vs. 74.0±1.1; p=0.270), Lysholm (89.8±3.1 vs. 90.3±1.8; p=0.666), and Tegner (4.2±0.4 vs. 4.3±0.5; p=0.628). No statistically significant progression in K–L grade was detected within either group, and postoperative K–L grades did not differ significantly between groups.

Conclusion: In patients with MMPRTs without advanced osteoarthritis or marked varus malalignment, the addition of meniscal centralization to posterior root repair did not demonstrate superior short- to mid-term clinical outcomes or radiographic osteoarthritis severity compared with isolated root repair. Larger prospective randomized studies with longer follow-up are needed to better define the indications for meniscal centralization.

Keywords: Medial meniscus posterior root tear, meniscal centralization, transtibial pull-out repair, meniscal extrusion, knee osteoarthritis.

Cite this article as:
Oner K, Gurkan Aslan F. Isolated Root Repair Versus Root Repair Combined with Meniscal Centralization for Medial Meniscus Posterior Root Tears with Extrusion: Clinical and Radiographic Outcomes. Sports Traumatol Arthrosc 2026;3(1):16–22.

Address for correspondence:
Fevzi Gurkan Aslan, Department of Orthopedics and Traumatology, Karadeniz Technical University, Trabzon, Turkiye
E-mail:
fevzigurkanaslan@yahoo.com

Submitted: 23.01.2026
Revised: 10.03.2026
Accepted: 06.04.2026
Available Online: 11.05.2026

Sports Traumatology & Arthroscopy – Available online at www.stajournal.com

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

INTRODUCTION

Medial meniscus posterior root tears (MMPRTs) are characterized by disruption of the meniscal root attachment to the tibial plateau and have a substantial negative impact on knee biomechanics. Loss of root integrity compromises hoop stress transmission, increases tibiofemoral contact pressure and may accelerate the progression of osteoarthritis (OA).[1] Accordingly, MMPRTs are considered biomechanically comparable to a functional total meniscectomy.[2] Once regarded as a vestigial structure, the meniscus is now recognized as essential for joint stability, load transmission, and cartilage protection.[3,4] Nonoperative management has been associated with unfavorable clinical outcomes, rapid OA progression, and higher arthroplasty rates, leading to the development of surgical techniques aimed at restoring native meniscal anatomy and biomechanics.[5,6]

Recently, medial meniscus extrusion (MME) has received increasing attention in association with MMPRTs. MME may result not only from root disruption but also from injury to the meniscotibial attachments, concomitant cartilage degeneration, and lower-limb malalignment.[7] Varus alignment, increased age, and higher body mass index have been linked to greater extrusion and medial compartment overload, suggesting that MME may contribute independently to OA development.[8] Importantly, MME can progress shortly after symptomatic MMPRTs and may persist despite surgical repair, and persistent extrusion has been reported as a strong predictor of OA progression.[9-11]

These observations raise the question of whether isolated root repair is sufficient to restore meniscal position and adequately control extrusion. Meniscal centralization has therefore been proposed as an adjunct to transtibial pull-out repair for repositioning the meniscus closer to its anatomic location. However, the reported effectiveness of centralization remains controversial, with conflicting clinical and radiological findings in the literature.[12,13]

The purpose of this study was to evaluate whether adding meniscal centralization to posterior root repair improves clinical and radiographic outcomes compared with isolated root repair in patients with MMPRT. We hypothesized that adjunctive meniscal centralization would provide superior postoperative patient-reported outcomes and better radiographic preservation.

MATERIALS AND METHODS

Patients and Study Design

This retrospective comparative study was conducted after approval was obtained from the institutional ethics committee (approval no. 2025/288), and written informed consent was obtained from all patients. Patients who underwent arthroscopic surgery between 2022 and 2025 for MMPRTs treated with a transtibial pull-out repair technique were retrospectively reviewed.

All included patients demonstrated MME ≥3 mm on preoperative MRI. In all cases, transtibial pull-out posterior root repair was performed as the primary procedure. After completion of the root repair, the degree of extrusion was reassessed intraoperatively. The meniscal body was reassessed arthroscopically by the senior surgeon using a probe to evaluate its reducibility relative to the edge of the medial tibial plateau. No formal millimeter-based intraoperative measurement or predefined threshold was used. Meniscal centralization was added when the meniscus remained visibly extruded and could not be satisfactorily reduced after root repair alone.

Accordingly, patients were allocated into two groups based on the final procedure performed: isolated posterior root repair and posterior root repair combined with meniscal centralization.

Inclusion criteria were as follows: (1) diagnosis of MMPRT confirmed by MRI and arthroscopic findings, (2) preoperative MME ≥3 mm, (3) treatment with transtibial pull-out root repair with or without additional meniscal centralization, and (4) minimum clinical follow-up of 24 months. Exclusion criteria were advanced osteoarthritis (Kellgren–Lawrence grade ≥3), varus malalignment greater than 5°, previous surgery on the same knee, concomitant ligament injuries or fractures, inflammatory arthritis, and incomplete clinical or radiographic data (Fig. 1).

Surgical Technique

All procedures were performed arthroscopically through standard anterolateral and anteromedial portals. Transtibial pull-out posterior root repair was performed in all patients. The torn root footprint was debrided to expose a bleeding bony surface. Sutures were passed through the posterior root using a standardized suture configuration, and a tibial tunnel was created to allow transtibial passage of the repair sutures. The sutures were then tensioned and secured over the anteromedial tibial cortex to restore the anatomic position of the root. In patients undergoing centralization, an all-suture anchor was inserted onto the medial tibial plateau with the knee in full flexion. The peripheral meniscal rim was then centralized and secured onto the tibial plateau using the anchor sutures, with the aim of reducing persistent meniscal extrusion (Fig. 2).

Postoperative Rehabilitation

All patients followed the same standardized postoperative rehabilitation protocol regardless of whether meniscal centralization was performed. Brace immobilization in full

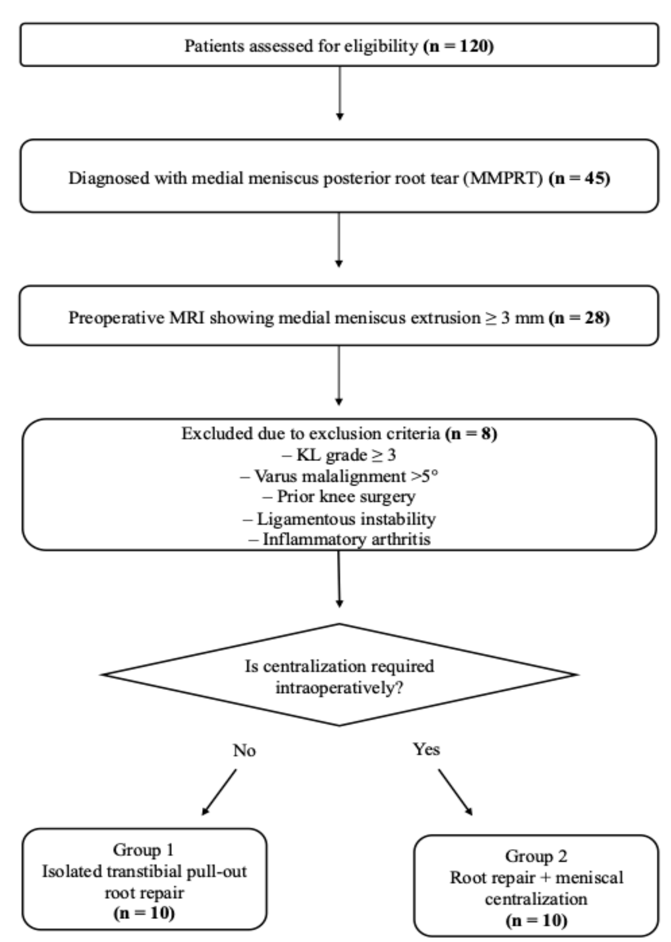

Figure 1. Flowchart demonstrating patient selection and allocation to treatment groups.

extension was maintained for the first four weeks, with toe-touch weight-bearing allowed during this period. Range-of-motion exercises were initiated gradually, and weight-bearing was progressively advanced thereafter according to clinical tolerance.

Outcome Measures

Clinical outcomes were assessed postoperatively using the Knee Injury and Osteoarthritis Outcome Score (KOOS), the International Knee Documentation Committee (IKDC) subjective score, the Lysholm score, and the Tegner activity scale. Radiographic evaluation included preoperative and postoperative weight-bearing standing knee radiographs, and osteoarthritis severity was graded according to the Kellgren–Lawrence classification. Lower-limb alignment was assessed on full-length standing anteroposterior lower-extremity radiographs using the hip-knee-ankle (HKA) angle based on the mechanical axis. Kellgren–Lawrence grading was performed by an experienced orthopaedic surgeon who was not involved in the surgical procedures and was blinded to treatment allocation. Interobserver and intraobserver reliability analyses were not performed.

Statistical Analysis

Statistical analyses were performed using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed before analysis. Between-group comparisons were performed using the independent-samples t-test or the Mann–Whitney U test, as appropriate. Within-group comparisons of preoperative and postoperative Kellgren–Lawrence grades were performed using the Wilcoxon signed-rank test. A p-value <0.05 was considered statistically significant. For descriptive interpretation of between-group differences in postoperative patient-reported outcome measures, standardized effect sizes and 95% confidence intervals for mean differences were calculated.

RESULTS

Twenty patients were included and divided into two groups according to the surgical technique: isolated transtibial pull-out root repair (Group 1, n=10) and root repair combined with meniscal centralization (Group 2, n=10). The two groups were comparable in terms of age (54.2±2.0 vs. 55.3±2.0 years; p=0.234), body mass index (25.7±1.4 vs. 24.9±0.9 kg/m^2; p=0.190), and follow-up duration (25.9±1.2 vs. 25.6±1.2 months; p=0.579). Laterality distribution was also similar between the two groups (Table 1).

At final follow-up, patient-reported outcome measures were comparable between the two groups. Mean KOOS scores were

Table 1. Demographic and baseline characteristics of the patients

Variable	Group 1: Isolated root repair (n=10)	Group 2: Root repair + centralization (n=10)	p
Age (years), mean± SD	54.2±2.0	55.3±2.0	0.23
BMI (kg/m^2), mean±SD	25.7±1.4	24.9±0.9	0.19
Follow-up (months), mean±SD	25.9±1.2	25.6±1.2	0.57
Sex (F/M)	6/4	3/7	0.37
Side (Right/Left)	6/4	7/3	0.87

Values are presented as mean±standard deviation or number of patients. A p-value<0.05 was considered statistically significant.

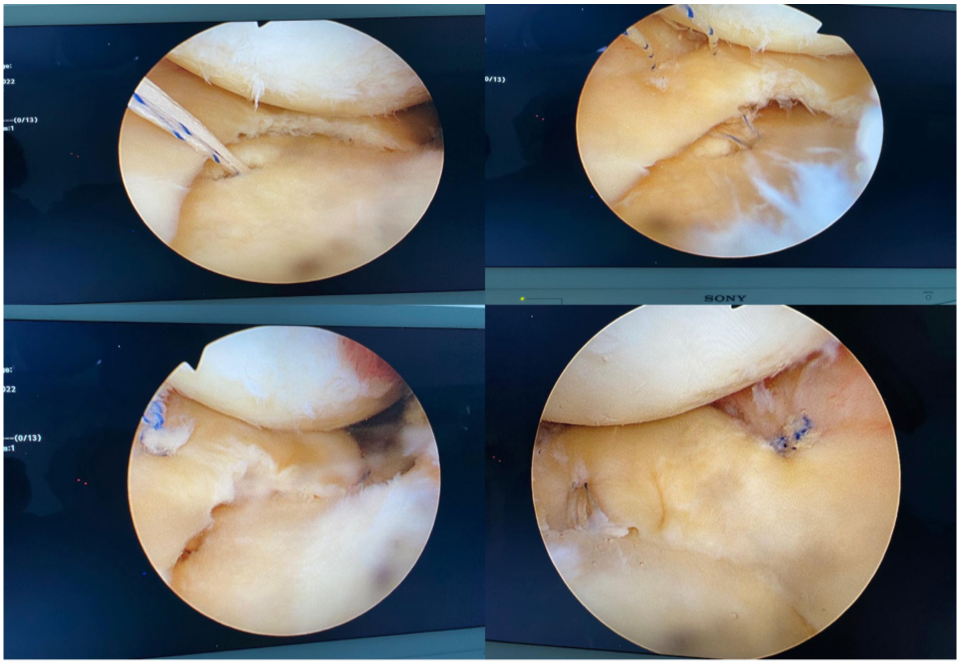

Figure 2. Intraoperative arthroscopic views demonstrating meniscal centralization performed with the all–suture anchor technique. After transtibial pull-out fixation of the medial meniscus posterior root, a single all–suture anchor was inserted into the medial tibial plateau, and peripheral meniscal tissue was centralized toward the anatomic footprint to reduce extrusion.

78.0±2.6 in Group 1 and 79.0±2.1 in Group 2 (p=0.356). Similarly, IKDC (73.2±1.9 vs. 74.0±1.1; p=0.270), Lysholm (89.8±3.1 vs. 90.3±1.8; p=0.666), and Tegner activity scores (4.2±0.4 vs. 4.3±0.5; p=0.628) did not differ significantly between groups (Table 2). Effect size analysis suggested only small between-group differences in the main postoperative patient-reported outcomes.

Table 2. Comparison of postoperative patient-reported outcome measures between the two groups

Outcome score	Group 1: Isolated root repair (n=10)	Group 2: Root repair + centralization (n=10)	p
KOOS total	78.0±2.6	79.0±2.1	0.35
IKDC subjective score	73.2±1.9	74.0±1.1	0.27
Lysholm score	89.8±3.1	90.3±1.8	0.66
Tegner activity level	4.2±0.4	4.3±0.5	0.62

Values are presented as mean±standard deviation. KOOS: Knee injury and Osteoarthritis Outcome Score; IKDC: International Knee Documentation Committee. A p-value<0.05 was considered statistically significant.

Preoperative Kellgren–Lawrence (K–L) grades were comparable between the two groups. Within-group analysis demonstrated no statistically significant progression of K–L grade from preoperative assessment to final follow-up in either group (Wilcoxon signed-rank test, both p=0.317). Postoperative K–L grades were also similar between the groups (Mann–Whitney U test, p=0.734) (Table 3).

Table 3. Distribution of Kellgren–Lawrence grades before and after surgery

	KL 0/1/2	p
Group 1 (Isolated root repair)		
Preoperative	1/4/5	
Postoperative	1/3/6	0.317
Group 2 (Root repair + centralization)		
Preoperative	1/5/4	
Postoperative	1/4/5	0.338
Postoperative between-group comparison		0.734

KL: Kellgren–Lawrence. Values are presented as number of patients. Statistical significance was set at p<0.05.

DISCUSSION

The principal finding of the present study is that, in patients with MMPRTs accompanied by preoperative MME ≥3 mm, posterior root repair combined with meniscal centralization did not result in superior short- to midterm patient-reported outcomes or radiographic osteoarthritis severity compared with isolated posterior root repair. Postoperative KOOS, IKDC, Lysholm, and Tegner scores were comparable between groups, and no statistically significant progression in Kellgren–Lawrence grade was detected during a mean follow-up of 26 months. These findings suggest that any potential biomechanical advantages of centralization may not have translated into detectable short- to mid-term clinical benefit in this cohort; however, this interpretation should be made cautiously in light of the study's methodological limitations.

MME has been increasingly recognized as a key pathomechanical factor associated with altered tibiofemoral contact mechanics and osteoarthritis progression. Debieux et al.[14] demonstrated that extrusion exceeding 4 mm reduces medial compartment contact area and increases contact pressures, while also highlighting the stabilizing role of peripheral meniscotibial structures. In clinical settings, extrusion has been associated with cartilage damage, varus alignment, osteophyte formation, higher Kellgren–Lawrence grades, and an increased risk of progression to arthroplasty. These observations have supported the rationale for adjunctive procedures to correct extrusion, including meniscal centralization.

Several studies have reported that centralization can reduce extrusion and may improve structural outcomes. Choi et al.[15] showed that transtibial pull-out repair yields substantial mid-term improvements in functional outcomes, while knees with decreased extrusion demonstrated less joint-space narrowing and a lower rate of Kellgren–Lawrence progression. Similarly, Zhou et al.[16] reported comparable short-term functional improvements between isolated repair and repair with centralization but noted greater extrusion reduction and a more favorable distribution of postoperative Kellgren–Lawrence grades in the centralization group. In contrast, our findings indicate that, in a cohort without advanced osteoarthritis or marked varus malalignment, adding centralization did not confer a measurable advantage in patient-reported outcomes or radiographic grading during early follow-up. This is particularly relevant because previous studies have suggested that centralization may improve extrusion-related structural parameters even when short-term patient-reported outcomes remain comparable between treatment groups.

From a clinical standpoint, these results suggest that isolated posterior root repair may provide satisfactory short- to mid-term outcomes in appropriately selected patients, and that meniscal centralization may not be necessary as a routine adjunct for all MMPRT cases. However, it remains possible that centralization may be beneficial in specific subgroups, such as patients with marked extrusion, compromised peripheral meniscotibial stabilizers, or a higher risk of persistent extrusion and structural deterioration. Longer-term follow-up is required to determine whether subtle structural benefits of centralization translate into clinically meaningful differences in osteoarthritis progression and survivorship.[17-20]

This study has several limitations. First, the sample size was small, which may have limited the statistical power to detect small but clinically relevant between-group differences; therefore, the absence of statistically significant differences should not be interpreted as evidence of equivalence. Second, the retrospective design and nonrandomized treatment allocation may have introduced selection bias, as meniscal centralization was selectively performed in knees with persistent residual extrusion after root repair. Consequently, the centralization group may have included more challenging cases and may also have had more severe baseline extrusion, although quantitative comparison of preoperative extrusion severity between the groups was not available. Third, routine postoperative MRI was not performed; therefore, residual extrusion and the structural effect of centralization could not be quantitatively assessed during follow-up. Finally, the mean follow-up duration of approximately 26 months may have been insufficient to reliably evaluate radiographic osteoarthritis progression.

CONCLUSION

In patients with medial MMPRTs without advanced osteoarthritis or marked varus malalignment, posterior root repair combined with meniscal centralization did not demonstrate superior short- to mid-term patient-reported outcomes or radiographic osteoarthritis severity compared with isolated posterior root repair. These findings suggest that meniscal centralization may not be required as a routine adjunct in all MMPRT cases, and that its use should be individualized based on patient- and knee-specific factors. Further prospective randomized studies with larger cohorts and longer follow-up are warranted to clarify optimal indications for meniscal centralization.

DECLARATIONS

Ethics Committee Approval: The Karadeniz Technical University, Faculty of Medicine Scientific Research Ethics Committee approved this study. (Date: 17/12/2025, Number: 2025/288).

Informed Consent: Written informed consent was obtained from all patients.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that they have no rel-

evant or material financial interests that relate to the research described in this paper.

Funding Disclosure: No funding was received for this study.

Data Availability Statement: Data are available from the corresponding author upon reasonable request.

Use of AI for Writing Assistance: The authors declared that they did not use any generative artificial intelligence for the writing of this manuscript, nor for the creation of images, graphics, tables, or their corresponding captions.

Author Contributions: Concept – FGA; Design – FGA; Supervision – KO; Data collection and/or processing – FGA; Analysis and/or interpretation – FGA; Literature search – KO; Writing – KO; Critical review – KO; References and fundings – KO; Materials – KO. All authors have read and agreed to the published version of the manuscript.

Peer-review: Externally peer-reviewed.

ABBREVIATIONS

BMI: Body Mass Index

CI: Confidence Interval

HKA: Hip-Knee-Ankle angle

IKDC: International Knee Documentation Committee

K–L: Kellgren–Lawrence

KOOS: Knee Injury and Osteoarthritis Outcome Score

MME: Medial Meniscus Extrusion

MMPRT: Medial Meniscus Posterior Root Tear

MRI: Magnetic Resonance Imaging

OA: Osteoarthritis

PROs: Patient-Reported Outcomes

SD: Standard Deviation

SPSS: Statistical Package for the Social Sciences

REFERENCES

1. Moon HS, Choi CH, Jung M, Chung K, Jung SH, Kim YH, et al. Medial Meniscus Posterior Root Tear: How Far Have We Come and What Remains? Medicina (Kaunas) 2023;59:1181. [Crossref]
2. Allaire R, Muriuki M, Gilbertson L, Harner CD. Biomechanical Consequences of a Tear of the Posterior Root of the Medial Meniscus. The Journal of Bone and Joint Surgery-American Volume. 2008;90:1922–31. [Crossref]
3. Langhans MT, Lamba A, Saris DBF, Smith P, Krych AJ. Meniscal Extrusion: Diagnosis, Etiology, and Treatment Options. Curr Rev Musculoskelet Med 2023;16:316–27. [Crossref]
4. LaPrade CM, James EW, Cram TR, Feagin JA, Engebretsen L, LaPrade RF. Meniscal Root Tears. Am J Sports Med 2015;43:363–9. [Crossref]
5. Furumatsu T, Kodama Y, Kamatsuki Y, Hino T, Okazaki Y, Ozaki T. Meniscal Extrusion Progresses Shortly after the Medial Meniscus Posterior Root Tear. Knee Surg Relat Res 2017 ;29:295–301. [Crossref]
6. Krych AJ, Reardon PJ, Johnson NR, Mohan R, Peter L, Levy BA, et al. Non-operative management of medial meniscus posterior horn root tears is associated with worsening arthritis and poor clinical outcome at 5-year follow-up. Knee Surg Sports Traumatol Arthrosc 2017;25:383–9. [Crossref]
7. Papalia GF, Za P, Saccone L, Franceschetti E, Zampogna B, Vasta S, et al. Meniscal extrusion: risk factors and diagnostic tools to predict early osteoarthritis. Orthop Rev (Pavia). 2023;15: 74881. [Crossref]
8. Willinger L, Lang JJ, von Deimling C, Diermeier T, Petersen W, Imhoff AB, et al. Varus alignment increases medial meniscus extrusion and peak contact pressure: a biomechanical study. Knee Surg Sports Traumatol Arthrosc 2020;28:1092–8. [Crossref]
9. Kından Baltacı P, Toker M, Ozbek EA. Meniscus Root Tears: Current Concepts in Anatomy, Diagnosis, and Treatment Strategies. Sports Traumatol Arthrosc 2025;2:134-41. [Crossref]
10. Moon HS, Choi CH, Jung M, Lee DY, Hong SP, Kim SH. Early Surgical Repair of Medial Meniscus Posterior Root Tear Minimizes the Progression of Meniscal Extrusion: 2-Year Follow-up of Clinical and Radiographic Parameters After Arthroscopic Transtibial Pull-out Repair. Am J Sports Med 2020;48:2692–702. [Crossref]
11. Ozeki N, Muneta T, Kawabata K, Koga H, Nakagawa Y, Saito R, et al. Centralization of extruded medial meniscus delays cartilage degeneration in rats. Journal of Orthopaedic Science. 2017;22:542–8. [Crossref]
12. Daney BT, Aman ZS, Krob JJ, Storaci HW, Brady AW, Nakama G, et al. Utilization of Transtibial Centralization Suture Best Minimizes Extrusion and Restores Tibiofemoral Contact Mechanics for Anatomic Medial Meniscal Root Repairs in a Cadaveric Model. Am J Sports Med 2019;47:1591–600. [Crossref]
13. Takase R, Ohsawa T, Hashimoto S, Kurihara S, Yanagisawa S, Hagiwara K, et al. Insufficient restoration of meniscal extrusion by transtibial pullout repair for medial meniscus posterior root tears. Knee Surg Sports Traumatol Arthrosc 2023;31:4895–902. [Crossref]
14. Debieux P, Jimenez AE, Novaretti JV, Kaleka CC, Kriscenski DE, Astur DC, et al. Medial meniscal extrusion greater than 4 mm reduces medial tibiofemoral compartment contact area: a biomechanical analysis of tibiofemoral contact area and pressures with varying amounts of

meniscal extrusion. Knee Surg Sports Traumatol Arthrosc 2021;29:3124–32. [Crossref]

15. Choi CJ, Choi YJ, Lee JJ, Choi CH. Magnetic Resonance Imaging Evidence of Meniscal Extrusion in Medial Meniscus Posterior Root Tear. Arthroscopy 2010;26:1602–6. [Crossref]

16. Zhou Y, Yang Q, Kang J, Xu J, Chen M, Wu C. Clinical effect of medial meniscus posterior root repair combined with centralization technique in the treatment of medial meniscus posterior root tears. BMC Musculoskelet Disord 2024;25:982. [Crossref]

17. Berthiaume MJ, Raynauld JP, Martel-Pelletier J, Labonté F, Beaudoin G, Bloch DA, et al. Meniscal tear and extrusion are strongly associated with progression of symptomatic knee osteoarthritis as assessed by quantitative magnetic resonance imaging. Ann Rheum Dis 2005;64:556–63. [Crossref]

18. Boksh K, ET Shepherd D, M Espino D, Ghosh A, Aujla R, Boutefnouchet T. Centralization reduces meniscal extrusion, improves joint mechanics and functional outcomes in patients undergoing meniscus surgery: A systematic review and meta-analysis. Knee Surgery Sports Traumatology Arthroscopy 2025;33:888–906. [Crossref]

19. Chung KS, Ha JK, Ra HJ, Nam GW, Kim JG. Pullout Fixation of Posterior Medial Meniscus Root Tears: Correlation Between Meniscus Extrusion and Midterm Clinical Results. Am J Sports Med 2017;45:42–9. [Crossref]

20. Kahat DH, Nouraee CM, Smith JS, Santiago CC, Floyd ER, Zbyn S, et al. The Relationship Between Medial Meniscal Extrusion and Outcome Measures for Knee Osteoarthritis: A Systematic Review. Orthop J Sports Med 2024;12: 23259671241248457. [Crossref]

TUSYAD STArt Sports Traumatology & Arthroscopy
DOI: 10.14744/start.2026.66437
Sports Traumatol Arthrosc 2026;3(1):23–30

Original Article

Clinical and Radiological Outcomes Following Open Reduction and Screw Fixation via a Posterior Approach for Tibial PCL Avulsion Fractures

Emre Mucahit Kartal,[1] Murat Yuncu[2]

[1]Department of Orthopedics and Traumatology, Antalya City Hospital, Antalya, Turkiye
[2]Department of Orthopedics and Traumatology, Elmalı State Hospital, Antalya, Turkiye

ABSTRACT

Objective: Tibial avulsion fractures of the posterior cruciate ligament (PCL) are uncommon injuries that may lead to persistent posterior instability and functional limitations if not anatomically reduced and rigidly fixed. This study aimed to evaluate the clinical and radiological outcomes of open reduction and screw fixation of tibial PCL avulsion fractures performed through a posterior knee approach.

Materials and Methods: We retrospectively reviewed 33 patients who underwent open reduction and screw fixation for tibial PCL avulsion fractures via a posterior knee approach. The cohort included 29 males (87.9%) and 4 females (12.1%), with a mean age of 34.9±12.9 years (range, 14–65). The right knee was involved in 19 cases (57.6%) and the left knee in 14 (42.4%). The most common injury mechanisms were motorcycle accidents (45.5%) and falls (36.4%), followed by bicycle accidents (9.1%) and sports injuries (9.1%). In 25 patients (75.8%), the fracture was isolated, whereas 8 (24.2%) had associated periarticular fractures involving the patella, femur, tibia, or combinations of these structures. Radiological follow-up averaged 31.9±29.4 months (range, 12–120), and functional follow-up averaged 54.1±39.5 months (range, 12–120). Outcome measures included the Lysholm knee score, the IKDC score, range of motion, and the visual analog scale (VAS) for pain.

Results: At the final follow-up, the mean Lysholm score was 73.0±15.5 (range, 37–100), and the mean IKDC score was 70.6±16.1 (range, 32–98). The mean knee flexion deficit was 21.2°±15.0° (range, 0–45), and the mean extension lag was 10.0°±10.0° (range, 0–30). The mean VAS pain score was 2.2±1.5 (range, 0–6), indicating generally low pain levels during daily activities. All fractures united.

Conclusion: Open reduction and screw fixation through a posterior approach consistently achieved fracture union with low residual pain. However, functional outcomes were moderate, and residual range-of-motion deficits were observed, indicating that successful osseous healing does not necessarily translate into optimal clinical recovery in this heterogeneous trauma cohort.

Keywords: Fracture fixation, internal fixation, knee injuries, open reduction, posterior cruciate ligament, tibial fractures, treatment outcome.

Cite this article as:
Kartal EM, Yuncu M. Clinical and Radiological Outcomes Following Open Reduction and Screw Fixation via a Posterior Approach for Tibial PCL Avulsion Fractures. Sports Traumatol Arthrosc 2026;3(1):23–30.

Address for correspondence:
Murat Yuncu,
Department of Orthopedics and Traumatology, Elmalı State Hospital, Antalya, Turkiye
E-mail:
m-yuncu@yandex.com

Submitted: 13.03.2026
Revised: 23.04.2026
Accepted: 24.04.2026
Available Online: 11.05.2026

Sports Traumatology & Arthroscopy – Available online at www.stajournal.com

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

INTRODUCTION

The posterior cruciate ligament (PCL) is one of the key structures providing posterior stabilization to the knee joint and forms the primary resistance mechanism against posterior tibial displacement.[1] PCL injuries account for approximately 3–20% of acute knee ligament injuries. Tibial avulsion fractures represent a distinct clinical entity within this injury spectrum.[1,2]

Tibial avulsion fractures of the PCL typically result from high-energy trauma. Dashboard injuries, caused by a posteriorly directed force applied to the knee in flexion, and motorcycle accidents are among the most common injury mechanisms.[1,3] Concomitant intra-articular or periarticular pathologies have been reported in 20–30% of cases and may adversely influence postoperative functional outcomes.[1,3,4] Previous comparative studies have demonstrated that associated meniscal or ligamentous injuries may influence both surgical planning and rehabilitation protocols.[5]

Displaced PCL avulsion fractures, that are not anatomically reduced and adequately stabilized can lead to permanent posterior instability, impaired knee biomechanics, and early degenerative changes.[3,5] Persistent posterior laxity has also been shown to increase patellofemoral contact pressures and accelerate cartilage degeneration.[5,6] Although conservative treatment may be considered in cases with minimal displacement, anatomical reduction and stable internal fixation are recommended, especially in Meyers–McKeever type II and III fractures.[7]

Both open surgical techniques and arthroscopic methods have been described for the surgical treatment of tibial PCL avulsion fractures. Arthroscopic methods are advantageous because they are minimally invasive and allow for the simultaneous treatment of accompanying intra-articular lesions.[2] However, achieving adequate reduction in large fragments or comminuted fractures can be technically challenging. It has been reported that arthroscopy-assisted fixation may have a steep learning curve and requires specialized instrumentation, potentially limiting its applicability in certain centers.[8] Open posterior approaches, on the other hand, allow for direct visualization of the fracture bed, anatomical reduction, and rigid fixation with screws or plates.[7] Recent comparative series have shown that open posteromedial fixation techniques provide comparable union rates and functional outcomes to arthroscopic methods, with shorter operative times in some reports.[9]

Meta-analyses and comparative series have consistently demonstrated similar functional and radiological outcomes between open and arthroscopic fixation techniques. Despite the growing body of literature, the optimal surgical technique for displaced tibial PCL avulsion fractures remains controversial.[10] Moreover, there remains ongoing debate regarding the optimal fixation strategy for large or comminuted fragments, particularly in trauma settings.[2] Clinical practice is thus still influenced by research assessing the mid-term clinical results of practical and repeatable surgical procedures.

Despite existing studies on tibial PCL avulsion, most reports focus on relatively homogeneous cohorts or isolated injuries. In contrast, real-world clinical practice frequently involves heterogeneous trauma patterns, including cases with associated periarticular fractures. Therefore, evaluating outcomes in such heterogeneous populations remains clinically relevant.

The aim of this study was to evaluate the mid-term clinical and radiological outcomes of open reduction and screw fixation for tibial PCL avulsion fractures using a posterior knee approach.

MATERIALS AND METHODS

Study Design and Patient Population

This retrospective study evaluated patients who underwent open reduction and screw fixation through a posterior knee approach for tibial posterior cruciate ligament (PCL) avulsion fractures. Patients treated at our institution between January 2015 and December 2024 were retrospectively reviewed. Thirty-three consecutive patients who met the inclusion criteria were included in the final analysis.

The study protocol was approved by the Antalya Training and Research Hospital Scientific Research Ethics Committee (Approval No: 20/5; Date: November 27, 2025; Project No: 2025-437). The study was conducted in accordance with the principles of the Declaration of Helsinki. Due to the retrospective design of the study, the requirement for informed consent was waived by the ethics committee. The inclusion criteria were patients aged 14 to 65 years with closed physes who underwent surgical fixation for a tibial PCL avulsion fracture, had a minimum follow-up of 6 months, and had complete clinical and radiological records available. The exclusion criteria were patients with multiligament knee injuries requiring primary ligament reconstruction, patients with open physes, and those with incomplete medical records or follow-up shorter than 6 months.

Surgical Technique

All patients underwent open reduction and internal fixation using a posterior knee approach. Patients were placed in the prone position under either spinal or general anesthesia. A posterior incision was made in the popliteal region, and the interval between the medial head of the gastrocnemius and the semimembranosus tendon was developed to expose the posterior aspect of the proximal tibia while carefully protecting the neurovascular structures.

Following exposure of the fracture site, the avulsed fragment was identified and anatomically reduced under direct visualization. When required, temporary fixation was achieved using reduction clamps or Kirschner wires. Intraoperative fluoroscopy was used to confirm adequate fracture reduction and appropriate screw placement. Definitive fixation was performed using screws to achieve stable interfragmentary compression and restore the anatomic attachment of the posterior cruciate ligament. The number and type of screws were determined intraoperatively according to the operating surgeon's preference and based on fragment size, fracture morphology, and bone quality. Because the primary aim of this study was to evaluate the overall clinical and radiological outcomes of open posterior reduction and screw fixation, implant-specific comparisons were not performed.

The operations were performed by experienced orthopedic surgeons proficient in the posterior knee approach. In all cases, the same posteromedial interval between the medial head of the gastrocnemius muscle and the semimembranosus tendon was used.

Postoperative Rehabilitation

In the postoperative period, patients were treated using a standard rehabilitation protocol based on fracture stability and the presence of associated pathologies. An angle-adjustable knee brace was used in the early postoperative period. Range of motion was gradually increased under supervision, and rehabilitation exercises were initiated. Weight-bearing was gradually permitted according to clinical and radiological evaluations. Physiotherapy was performed to restore knee mobility and function.

Outcome Assessment

Clinical and radiological evaluations were performed during follow-up. Functional outcomes were assessed using the Lysholm Knee Score and the International Knee Documentation Committee (IKDC) score. Pain levels were evaluated using the visual analog scale (VAS). Knee range of motion was assessed clinically, and loss were recorded as flexion deficit and extension lag. Fracture healing and union were assessed using radiographic examinations. Full extension was defined as 0°, and maximal physiological flexion was defined as 135°.

Statistical Analysis

Statistical analyses were performed using SPSS software (IBM SPSS Statistics, version 26.0; IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean±standard deviation and range, while categorical variables were expressed as numbers and percentages.

RESULTS

A total of 33 patients were included in the study. The cohort consisted of 29 males (87.9%) and 4 females (12.1%), with a mean age of 34.9±12.9 years (range, 14–65). The right knee was involved in 19 patients (57.6%), whereas 14 patients (42.4%) had injuries of the left knee. The most common injury mechanisms were motorcycle accidents (45.5%), followed by falls (36.4%), bicycle accidents (9.1%), and sports injuries (9.1%). Fractures were isolated in 25 patients (75.8%), while 8 patients (24.2%) had associated periarticular fractures involving the patella, femur, tibia, or combined femoral and tibial injuries. The mean time from injury to surgery was 4.1±3.4 days (range, 1–20). Demographic characteristics are summarized in Table 1. Representative preoperative computed tomography images demonstrating a tibial PCL avulsion fracture are shown in Figure 1.

Table 1. Demographic and clinical characteristics of the study population

Variables	Data
Age (years±SD)	34.9±12.9 (14-65)
Sex (n, %)	
Female	4 (12.1%)
Male	29 (87.9%)
Side (n, %)	
Right	19 (57.6%)
Left	14 (42.4%)
Weight (kg±SD)	79.7±13.4 (47-108)
Height (cm±SD)	174.6±6.0 (162-186)
BMI (kg/m2±SD)	26.1±4.5 (15.6-38.1)
Mechanism of Injury	
Motorcycle accident	15 (45.5%)
Fall	12 (36.4%)
Bicycle Accident	3 (9.1%)
Sports Injury	3 (9.1%)
Isolated fractures (n, %)	25 (75.8%)
Associated fractures (n, %)	8 (24.2%)
Time to surgery (days±SD)	4.1±3.4 (1-20)
Accompanying fractures (n, %)	
None	25 (75.8%)
Patella	3 (9.1%)
Femur	3 (9.1%)
Tibia	1 (3.0%)
Femur + Tibia	1 (3.0%)

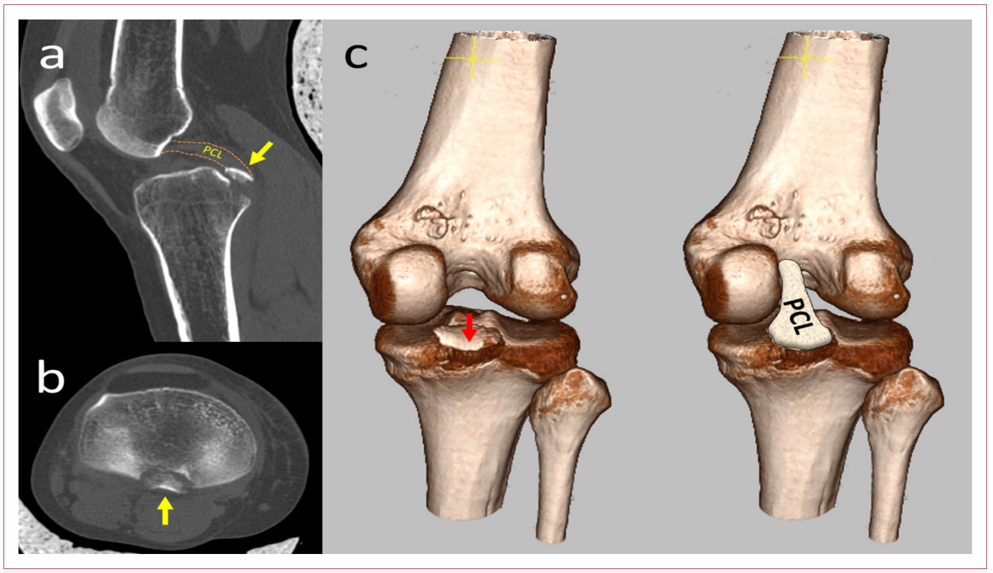

Figure 1. Typical preoperative CT scans showing an avulsion fracture of the tibial posterior cruciate ligament (PCL).

At the final follow-up, fracture union was achieved in all patients (100%). Figure 2 displays representative postoperative radiographs demonstrating various screw fixation techniques. Functional evaluation revealed a mean Lysholm Knee Score of 73.0±15.5 (range, 37–100) and a mean IKDC score of 70.6±16.1 (range, 32–98). Pain levels were generally low, with a mean VAS score of 2.2±1.5 (range, 0–6). Regarding knee range of motion, the mean flexion deficit was 21.2°±15.0° (range, 0–45), and the mean extension deficit was 10.0°±10.0° (range, 0–30). The mean radiological follow-up period was 31.9±29.4 months (range, 12–120), while the mean clinical follow-up duration was 54.1±39.5 months (range, 12–120). Functional outcomes are summarized in Table 2. Descriptive subgroup comparison showed broadly similar functional scores and range-of-motion deficits between the isolated and associated injury groups.

No major complications, such as nonunion, deep infection, neurovascular injury, or revision surgery, were observed. Despite complete fracture union, residual motion deficits were observed in a substantial proportion of patients, indicating that full functional recovery was not consistently achieved across the cohort.

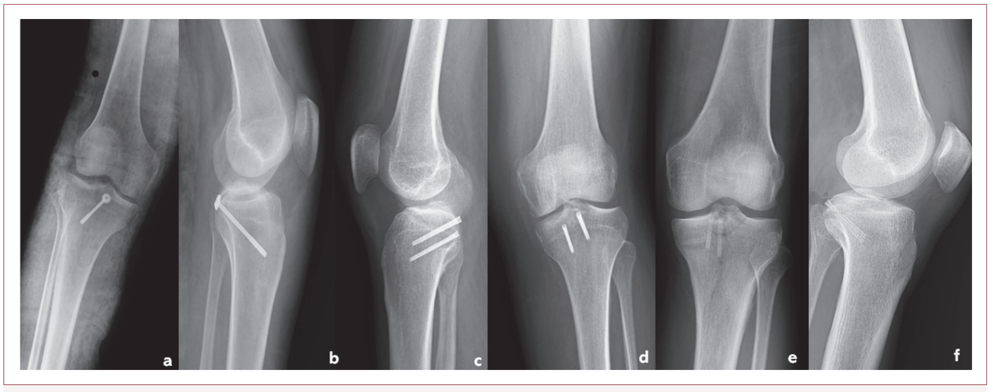

Figure 2. Tibial posterior cruciate ligament avulsion fractures treated with open reduction and internal fixation with various screw types are shown in representative postoperative radiographs. **(a,b)** Anteroposterior and lateral views of cannulated screw fixation. **(c,d)** Anteroposterior and lateral views of headless compression screw fixation. **(e,f)** Anteroposterior and lateral images of magnesium screw fixation.

Table 2. Clinical and radiological outcomes of the overall cohort and descriptive subgroup comparison by injury pattern

Variables	Overall (n=33)	Isolated (n=25)	Associated (n=8)
Lysholm knee score	73.0±15.5	73.2±13.6	72.1±20.5
IKDC	70.6±16.1	71±14.6	69.1±20.4
VAS (postop)	2.2±1.5	2.1±1.4	2.5±2.1
Knee flexion deficit (°)	21.2±15.0	23.0±14.1	15.6±15.9
Knee extension deficit (°)	10.0±10.0	10±10.4	10.0±9.3
Union (n, %)	33 (100%)	25 (100%)	8 (100%)

IKDC: International Knee Documentation Committee; VAS: Visual Analogue Scale

DISCUSSION

The tibial PCL avulsion fractures are uncommon but clinically important injuries, as untreated or inadequately reduced lesions may lead to residual posterior instability, pain, and functional impairment. Current evidence supports surgical treatment as the preferred management strategy for displaced fractures. Nevertheless, in selected acute and isolated cases with minimal displacement, nonoperative treatment may still be considered; Yoon et al. reported that conservative treatment may be feasible in acute isolated PCL avulsion fractures with displacement of less than 6.7 mm.[11] In the present series, all patients underwent surgical fixation, indicating that the injuries were displaced and required operative management. The achievement of fracture union in all cases further supports the appropriateness of this treatment approach.

In the present study, open reduction and screw fixation through a posterior approach resulted in a 100% fracture union rate and low pain levels, consistent with the existing literature. Fracture union was achieved in all cases, and the mean VAS score of 2.2 indicated that pain during daily activities was generally limited. However, the mean Lysholm score (73.0±15.5) and mean IKDC score (70.6±16.1) were lower than those reported in many published series of isolated injuries. Open surgical series involving isolated tibial PCL avulsion fractures have generally reported more favorable functional outcomes; for example, Joshi et al. reported a mean Lysholm score of 97±7.6 and a mean knee flexion of 121.7°±9.2°, whereas Khalifa et al. reported a mean Lysholm score of 93.4±3.9 and a mean flexion of 120.7°±4.3.[12,13] Similarly, Schmidt-Hebbel et al. reported a mean Lysholm score of 85.17 after open screw fixation.[14] The relatively moderate IKDC and Lysholm scores observed in our cohort indicate that satisfactory fracture healing does not necessarily translate into optimal functional recovery, a finding that has also been reported in other knee surgical contexts.[15]

The moderate functional outcomes observed in this study may be related to multiple factors, including injury severity, high-energy trauma mechanisms, and the presence of associated injuries. However, the exact contribution of these factors could not be determined due to the descriptive design of the study. In our study, 24.2% of patients had associated periarticular fractures, and a substantial proportion of injuries resulted from high-energy trauma, both of which may have adversely affected patient-perceived knee function. This interpretation is supported by previous studies, such as the study by Xiong et al.; however, it could not be directly evaluated in the present cohort due to the descriptive nature of the study.[4] In addition, the mean flexion loss of 21.2° and the mean extension lag of 10° observed in our series suggest that, despite successful osseous healing, functional recovery may remain limited in terms of range of motion. Considering that maximal flexion was defined as 135° and full extension as 0° in our study, the observed deficits correspond to an average knee flexion of approximately 114°. Importantly, IKDC and Lysholm scores do not merely reflect fracture union but rather represent multidimensional outcome measures encompassing knee motion, daily function, and activity level. Therefore, the lower functional scores and restricted range of motion observed in our cohort may be attributed to the combined effects of high-energy trauma, associated osseous and soft-tissue injuries, and a tendency toward postoperative stiffness.

The timing of surgery may also influence the clinical outcomes of tibial PCL avulsion fractures. In the present study, the mean interval from injury to surgery was relatively short, at 4.1±3.4 days. Early surgical intervention may facilitate fracture reduction and help prevent scar formation and soft-tissue contracture around the avulsed fragment. Previous studies have suggested that delayed treatment may be associated with poorer functional outcomes. For instance, Xiong et al.[4] reported that patients undergoing delayed surgery for tibial PCL avulsion fractures had significantly worse functional scores than those treated earlier. Therefore, although the functional outcomes in our cohort may have been adversely influenced by the severity and heterogeneity of injury mechanisms, the relatively early timing of surgery may have contributed to the high union rate observed in this series, which is consistent with previous reports suggesting that delayed surgery may adversely affect outcomes.[4]

With regard to the surgical approach, the current literature has not demonstrated a clear superiority of the open posterior technique over arthroscopic methods. Systematic reviews by Hooper et al.[10] and Song et al.[16] have shown that open posterior fixation and arthroscopic fixation generally provide comparable clinical outcomes, union rates, and restoration of stability. Likewise, in the comparative study by Sabat et al.,[17] no substantial differences were observed between the open posterior approach and arthroscopic single-tunnel suture fixation in short-term outcomes. However, in a more recent retrospective study, Li et al.[18] reported that, after matching, the arthroscopic group achieved better Lysholm, IKDC, and KT-1000 results than the open group. Nevertheless, one of the most recent meta-analyses, by Rajnish et al.[19] in 2025, concluded that arthroscopic and open techniques are broadly comparable in terms of outcomes and complications. Taken together, the current evidence suggests that the choice of approach should not be based solely on whether the procedure is open or arthroscopic but rather on factors such as fragment morphology, associated intra-articular pathology, surgeon experience, and institutional technical resources. Although fracture union was consistently achieved, functional recovery was moderate, and motion deficits remained. These findings indicate that anatomic healing alone does not guarantee optimal functional outcomes.

From the standpoint of fixation method, screw fixation is particularly suitable for large, single-fragment avulsions amenable to compression, as it allows direct visualization, anatomic reduction, and stable interfragmentary compression. In contrast, hook plates, pin-hook constructs, or suture-based techniques may offer advantages in small or comminuted fragments. Qi et al.,[19] for example, compared hook plate fixation with hollow lag screw plus gasket fixation and reported favorable results with both techniques, while suggesting that hook plates may provide potential advantages in selected cases.[7] Similarly, Liu et al.[5] reported comparably satisfactory outcomes using a hook plate through an inverted L posteromedial approach and arthroscopic Endobutton fixation. By contrast, Schmidt-Hebbel et al.,[14] in a series treated with a posterior approach and cannulated screws, reported fracture union in all cases, a mean side-to-side posterior translation difference of 2.6 mm, and a mean range of motion of 1°–118°. Likewise, in our series, fracture union was achieved in all patients treated with screw fixation, supporting the effectiveness of this method when fragment morphology is appropriate. In the present study, the primary objective was not to compare implant-specific performance but to evaluate the overall clinical outcomes of this surgical strategy in routine clinical practice. Therefore, the heterogeneity in screw types should be interpreted as a reflection of intraoperative decision-making rather than a variable specifically investigated in this analysis. However, our functional scores and range-of-motion findings also indicate that union alone does not necessarily guarantee an optimal clinical outcome.

This study has several limitations. A major limitation is the absence of a standardized objective postoperative stability assessment, such as stress radiographs or arthrometric evaluation. First, the retrospective design and lack of a control group preclude definitive conclusions regarding the superiority of posterior open screw fixation over arthroscopic or alternative open techniques. Second, the inclusion of both isolated cases and cases with associated periarticular fractures resulted in a heterogeneous cohort. Third, objective methods for quantifying residual instability, such as stress radiographs, KT-1000 arthrometry, or similar quantitative assessments, were not used. This represents an important limitation, since objective assessments of posterior stability, such as stress radiographs, have been used in previous studies to quantify postoperative posterior translation.[14] Future prospective comparative studies incorporating standardized rehabilitation protocols are needed to better clarify the effects of associated fractures, surgical delay, and postoperative stiffness on outcomes. Another limitation is that postoperative rehabilitation protocols were not analyzed in a standardized manner. Because this was a retrospective outcome study, the focus was placed on the final clinical and radiological results of the surgical treatment rather than on the comparative effects of rehabilitation strategies. Variations in postoperative management may therefore have influenced functional recovery and range-of-motion outcomes. The wide range of follow-up durations may have introduced additional heterogeneity in outcome assessment. The difference between radiological and clinical follow-up durations reflects the retrospective nature of the study and the variability in long-term patient follow-up.

CONCLUSION

In conclusion, open reduction and screw fixation through a posterior approach achieved reliable fracture union with low residual pain in patients with tibial PCL avulsion fractures. However, the presence of flexion loss, extension lag, and relatively lower Lysholm and IKDC scores indicates that successful osseous healing does not necessarily translate into optimal functional recovery. These findings suggest that, beyond stable fixation, preservation of knee range of motion and appropriate postoperative rehabilitation remain important determinants of overall clinical recovery.

DECLARATIONS

Ethics Committee Approval: This study was approved by the Antalya Training and Research Hospital Scientific Research Ethics Committee (Approval No: 20/5; Date: 27 November 2025; Project No: 2025-437). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent: Not applicable.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure:

Funding Disclosure: The authors declared that no fund was received for this study.

Data Availability Statement: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Use of AI for Writing Assistance: The authors declare that no artificial intelligence–assisted tools were used in the preparation of this manuscript.

Author Contributions: Concept – EMK, MY; Design – EMK, MY; Control/Supervision – MY; Data Collection and/or Processing – EMK, MY; Analysis and/or Interpretation – EMK, MY; Literature review – EMK, MY; Writing – EMK, MY; Critical Review – EMK, MY; References and Fundings – MY; Materials – EMK, MY.

Peer-review: Externally peer-reviewed.

ABBREVIATIONS

PCL: Posterior Cruciate Ligament
IKDC: International Knee Documentation Committee
VAS: Visual Analogue Scale
ROM: Range of Motion
ORIF: Open Reduction and Internal Fixation
SD: Standard Deviation
CT: Computed Tomography
SPSS: Statistical Package for the Social Sciences

REFERENCES

1. Katsman A, Strauss EJ, Campbell KA, Alaia MJ. Posterior Cruciate Ligament Avulsion Fractures. Curr Rev Musculoskelet Med 2018;11:503–9. [CrossRef]
2. Zhou Z, Wang S, Xiao J, Mao Y, Li L, Xu W, et al. The degree of fracture reduction does not compromise the clinical efficacy of arthroscopic reduction and fixation of tibial posterior cruciate ligament avulsion fractures: A retrospective study. Medicine (Baltimore) 2023;102:e35356. [CrossRef]
3. Ghoti SD, Shah NZ, Marfatia A, Punekar A, Ghag NS, Soheil M. Posterior Cruciate Ligament Avulsion Fracture of Tibia: Fixation with Screw and Augmentation Using Ethibond Suture for Improved Clinical Outcomes. J Orthop Case Rep 2024;14:194–201. [CrossRef]
4. Xiong HZ, Yang HJ, Du LR, Liu XQ, Sun L, Jin Y, et al. The effect of posterior cruciate ligament tibial avulsion fracture on functional outcomes in knees with concomitant ipsilateral lower limb fractures: a matched-cohort analysis. BMC Musculoskelet Disord 2023;24:404. [CrossRef]
5. Liu H, Liu J, Wu Y, Ma Y, Gu S, Mi J, et al. Outcomes of tibial avulsion fracture of the posterior cruciate ligament treated with a homemade hook plate. Injury. 2021;52:1934–8. [CrossRef]
6. Pu JS, Zheng L, Jian CC. Clinical efficacy of suture bridge versus hollow screw fixation for PCL tibial avulsion fractures: a comparative study. BMC Surg 2025;25:180. [CrossRef]
7. Qi H, Lu Y, Li M, Ren C, Xu Y, Ma T, et al. Open reduction and internal fixation of the tibial avulsion fracture of the posterior cruciate ligament: which is better, a hollow lag screw combined with a gasket or a homemade hook plate? BMC Musculoskelet Disord 2022;23:143. [CrossRef]
8. Tang J, Zhao J. Arthroscopic Suture-to-Loop Fixation of Posterior Cruciate Ligament Tibial Avulsion Fracture. Arthrosc Tech 2021;10:e1595–602. [CrossRef]
9. Guo H, Zhao Y, Gao L, Wang C, Shang X, Fan H, et al. Treatment of avulsion fracture of posterior cruciate ligament tibial insertion by minimally invasive approach in posterior medial knee. Front Surg 2023;9:885669. [CrossRef]
10. Hooper PO 3rd, Silko C, Malcolm TL, Farrow LD. Management of Posterior Cruciate Ligament Tibial Avulsion Injuries: A Systematic Review. Am J Sports Med 2018;46:734–42. [CrossRef]
11. Yoon KH, Kim SG, Park JY. The amount of displacement can determine non-operative treatment in posterior cruciate ligament avulsion fracture. Knee Surg Sports Traumatol Arthrosc 2020;28(9):2838–44. [CrossRef]
12. Joshi S, Bhatia C, Gondane A, Rai A, Singh S, Gupta S. Open Reduction and Internal Fixation of Isolated Posterior Cruciate Ligament Avulsion Fractures: Clinical and Functional Outcome. Knee Surg Relat Res 2017;29:210–6. [CrossRef]
13. Khalifa AA, Elsherif ME, Elsherif E, Refai O. Posterior cruciate ligament tibial insertion avulsion, management by open reduction and internal fixation using plate and screws through a direct posterior approach. Injury 2021;52:594–601. [CrossRef]
14. Schmidt-Hebbel A, Reyes JT, O'Connell L, Valderrama J, Tuca MJ, Carredano X, et al. Fracturas avulsivas tibiales

del ligamento cruzado posterior fijadas con tornillos: un estudio clínico y radiológico. Rev Chil Ortop Traumatol 2021;62:11–8. [CrossRef]

15. Yuncu M, Kose O, Aykanat F, Egerci OF, Dogruoz F, Yapar A. The role of tranexamic acid use in primary anterior cruciate ligament reconstruction: a prospective comparison. Arch Trauma Res 2025;14:1–8. [CrossRef]
16. Song JG, Nha KW, Lee SW. Open Posterior Approach versus Arthroscopic Suture Fixation for Displaced Posterior Cruciate Ligament Avulsion Fractures: Systematic Review. Knee Surg Relat Res 2018;30:275–83. [CrossRef]
17. Sabat D, Jain A, Kumar V. Displaced Posterior Cruciate Ligament Avulsion Fractures: A Retrospective Comparative Study Between Open Posterior Approach and Arthroscopic Single-Tunnel Suture Fixation. Arthroscopy 2016;32:44–53. [CrossRef]
18. Li X, Ma Q, Zheng Q, Dou Q, Zhou L, Sun L, et al. Modified arthroscopic repair of a posterior cruciate ligament tibial avulsion fracture improves IKDC and Lysholm score compared to open reduction. J Orthop Surg Res 2024;19:362. [CrossRef]
19. Rajnish RK, Yadav SK, Srivastava A, Gupta AP, Gupta S, Elhence A. Arthroscopic fixation versus open reduction and internal fixation for displaced tibial side posterior cruciate ligament avulsion fractures: A systematic review and meta-analysis. J Orthop 2025;66:271–81. [CrossRef]

DOI: 10.14744/start.2025.66437
Sports Traumatol Arthrosc 2026;3(1):31–35

Case Report

Myositis Ossificans in Adductor Longus Muscle in a Recreational Football Player: A Case Report

Murat Yuncu

Department of Orthopedics and Traumatology, Elmalı State Hospital, Antalya, Türkiye

ABSTRACT

Myositis ossificans (MO) is a rare benign pathology characterized by heterotopic bone formation within skeletal muscle, typically following trauma. Although MO is uncommon in the adductor muscle group, it may occur in athletes after direct muscular injury. We present the case of a 21-year-old male amateur football player who developed persistent groin pain after sustaining a direct blow. Initial radiographs were normal, and conservative treatment was initiated. However, the symptoms persisted for eight months. Follow-up imaging revealed a full-thickness tear of the adductor longus and mature ossification consistent with MO. Despite the presence of a palpable ossified mass, the patient declined surgical intervention and continued with conservative management. This case illustrates the diagnostic challenges of MO in atypical locations and underscores the importance of follow-up imaging in athletes with unresolved symptoms. It also raises awareness of the potential risks associated with biologic agents, such as platelet-rich plasma (PRP), in the context of muscle injury.

Keywords: Adductor longus, conservative treatment, Myositis ossificans, Platelet-rich plasma (PRP), sports injury.

Level of Evidence: Level IV

Cite this article as:
Yuncu M. Myositis Ossificans in Adductor Longus Muscle in a Recreational Football Player: A Case Report. Sports Traumatol Arthrosc 2026;3(1):31–35.

Address for correspondence:
Murat Yuncu,
Department of Orthopedics and Traumatology, Elmalı State Hospital, Antalya, Türkiye
E-mail:
m-yuncu@yandex.com

Submitted: 24.04.2025
Revised: 13.06.2025
Accepted: 14.06.2025
Available Online: 11.05.2026

Sports Traumatology & Arthroscopy – Available online at www.stajournal.com

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

INTRODUCTION

Myositis ossificans (MO) is a benign condition characterized by the formation of heterotopic bone within skeletal muscle, typically following trauma.[1–3] Although it most commonly affects the quadriceps and brachialis muscles, involvement of the adductor muscle group, particularly the adductor longus, is rare but increasingly reported, especially among athletes engaged in kicking sports such as football and rugby.[3–5] Among these less common locations, the adductor longus muscle presents unique diagnostic and therapeutic challenges, particularly in athletes. The adductor longus is susceptible to strain and partial tearing due to its critical role in hip adduction and dynamic stabilization of the lower limb. Trauma-induced hematoma and subsequent inflammation may trigger abnormal osteogenic activity, ultimately leading to MO.[1]

Early diagnosis can be challenging, as initial radiographs are often unremarkable, and the clinical presentation may mimic other conditions such as muscle strain, hematoma, infection, or soft tissue tumors. Thus, advanced imaging modalities, including MRI and CT, are essential for identifying mature ossification and distinguishing MO from other pathologies.[2,6] As treatment options evolve, increasing attention has been directed toward the role of biological agents in muscle healing. While most MO cases respond well to conservative treatment, surgical excision may be warranted in patients with persistent symptoms or significant functional limitations. Treatment decisions should consider symptom severity, lesion maturity, and patient preference. Recently, the use of biological agents such as platelet-rich plasma (PRP) and autologous conditioned plasma (ACP) has increased in the management of muscle injuries; however, their safety in the context of heterotopic ossification remains under debate.[7]

In this report, we present a rare case of adductor longus MO that developed following a kick sustained during amateur football and was diagnosed late. This case underscores the importance of clinical vigilance and timely imaging in patients with persistent groin pain, while also highlighting a scenario in which conservative management was effective despite radiographic evidence of mature ossification.

CASE REPORT

A 21-year-old male presented to the emergency department with sudden-onset groin pain after attempting a forceful kick while playing football. Although initial symptom relief was noted, the pain eventually recurred. He had no relevant medical history or prior injury. On physical examination, marked tenderness was observed along the adductor muscles from the symphysis pubis to the medial aspect of the left thigh. Pain was also elicited during resisted hip adduction. Initial pelvic radiographs revealed no abnormalities (Fig. 1). The patient was prescribed conservative treatment consisting of rest, ice, and nonsteroidal anti-inflammatory drugs (NSAIDs), and close follow-up was advised.

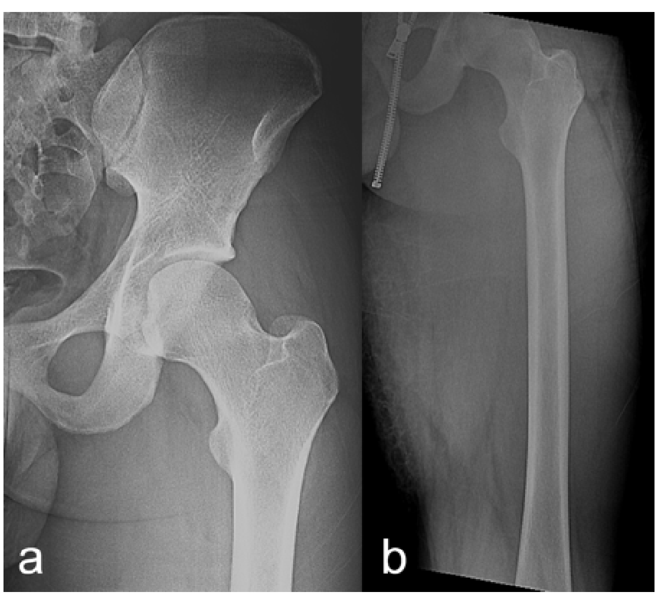

Figure 1. Anteroposterior radiographs of the pelvis **(a)** and left femur **(b)** were obtained at the initial presentation to the emergency department. No acute bony abnormalities or fractures were identified.

As the symptoms persisted, the patient presented to the orthopedic clinic at another facility. After six months of unresolved complaints, he received an ACP injection. Although the symptoms initially seemed to improve, the pain eventually recurred.

Eight months later, the patient re-presented with ongoing groin pain. On examination, a mobile, firm mass was palpable along the medial thigh, corresponding to the course of the adductor muscles. Repeat radiographs (Fig. 2) and MRI (Fig. 3) revealed a complete rupture of the adductor longus with

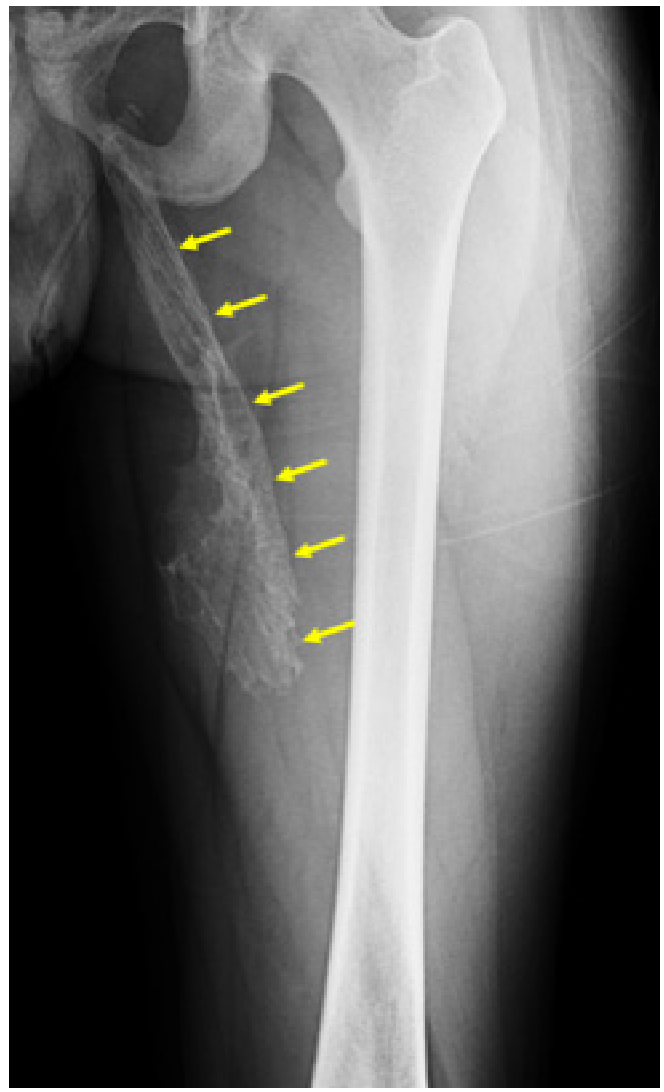

Figure 2. The follow-up anteroposterior radiograph of the left hip and proximal femur was obtained eight months after the initial injury. Mature, linear, and trabeculated ossification is visible along the course of the adductor longus muscle (yellow arrows), consistent with myositis ossificans.

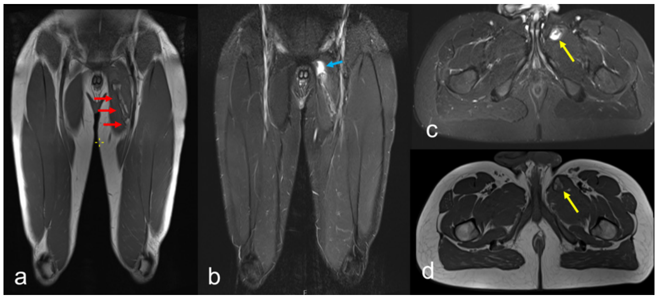

Figure 3. Magnetic resonance imaging (MRI) of the pelvis and proximal thighs showing findings consistent with complete adductor longus rupture and associated myositis ossificans. **(a)** Coronal T1-weighted image demonstrating discontinuity and retraction of the adductor longus muscle fibers (red arrows). **(b)** Coronal fat-suppressed T2-weighted image showing hyperintense edema and fluid at the proximal rupture site with a hypointense ossified lesion within the muscle belly (blue arrow). **(c)** Axial fat-suppressed T2-weighted image revealing a well-demarcated ossified mass within the adductor longus muscle (yellow arrow). **(d)** Axial T1-weighted image showing mature ossification with signal intensity similar to cortical bone (yellow arrow).

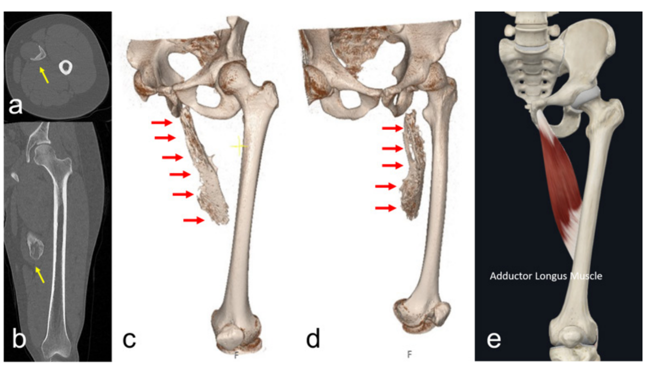

Figure 4. Computed tomography (CT) and three-dimensional (3D) volume-rendered reconstructions demonstrating mature heterotopic ossification within the adductor longus muscle. **(a)** Axial CT image showing a well-circumscribed, corticated, ossified mass within the adductor compartment (yellow arrow). **(b)** Coronal CT image confirming the linear configuration of the ossified lesion along the course of the adductor longus muscle (yellow arrow). **(c, d)** 3D volume-rendered CT reconstructions from anterolateral and anteromedial views, respectively, illustrating extensive mature ossification with a trabecular pattern along the typical trajectory of the adductor longus (red arrows). **(e)** Anatomical illustration showing the normal position and orientation of the adductor longus muscle for reference.

intramuscular myositis ossificans. To further delineate the lesion and assist with surgical planning, a CT scan (Fig. 4) was obtained, demonstrating mature, heterotopic ossification within the adductor longus. Although surgical excision was recommended, the patient declined surgery. Conservative treatment was continued, and his symptoms gradually regressed. He returned to low-energy sports activities, such as walking and cycling, and had no pain during daily activities, although he avoided running and competitive sports.

Written consent was obtained from the patient for the publication of the images and clinical information used in this case report.

DISCUSSION

MO is a benign post-traumatic condition characterized by heterotopic bone formation, typically resulting from direct trauma, strain, or avulsion injuries involving large muscle groups.[1,2,8] It most commonly affects the quadriceps and brachialis muscles. Involvement of the adductor muscle group, particularly the adductor longus, is uncommon.[5,9,10] However, cases involving these muscles are increasingly reported, particularly in athletes exposed to repetitive kicking trauma in sports such as football and rugby. The case presented by Çetin et al. is one of the earliest in the literature to report MO of the adductor brevis in an amateur football player.[11]

The increasing use of biological agents in muscle injury management has generated significant debate.[5,9,11] Similar clinical scenarios have been documented previously. In the present case, the patient sustained an acute injury after a direct kick and continued to experience groin pain thereafter. The diagnosis was delayed. Kanakaraddi et al. described a case in which MO of the adductor longus mimicked symptoms of hip pseudoankylosis.[12] Iorio et al. reported a case of bilateral MO in which symptoms appeared on only one side, emphasizing that diagnosis cannot rely on symptom presentation alone.[13]

Although initial radiographs revealed no abnormalities, advanced imaging techniques such as MRI and CT played a decisive role in recognizing and characterizing the lesion.[2] The critical importance of these modalities has been consistently highlighted in the literature. A limitation of this case is the absence of histopathological confirmation. However, the presence of a lesion displaying a radiological zonal maturation pattern and well-defined trabecular structure supported the diagnosis of MO and allowed differentiation from malignancy or focal myositis. This imaging-based approach enabled a definitive diagnosis and helped avoid unnecessary surgical intervention.[1]

Once the diagnosis is established, treatment planning should take into account factors such as symptom severity, lesion maturity, the degree of functional limitation, and the patient's preferences. Conservative treatment, including NSAIDs, rest, and activity modification, is typically the first-line approach. However, in some cases, chronic symptoms may necessitate surgical intervention.[2,14,15] De Smet et al.[16] reported successful excision of an 8-cm MO lesion, resulting in full functional recovery and return to sport. Likewise, Talbot et al.[9] documented a rugby player who failed conservative therapy but achieved permanent recovery following surgical intervention. Conversely, Zarro et al.[5] demonstrated that nonoperative management could also result in pain reduction and functional improvement. In the present case, although mature MO was identified radiologically, the patient opted against surgery and showed progressive symptom improvement with conservative care alone. This outcome aligns with similar cases in which favorable results were achieved without operative treatment.

The increasing use of biological agents in the management of muscle injuries, particularly PRP, has generated significant debate.[7,17] While PRP has shown promising effects on tissue healing, there is growing concern about its potential to induce heterotopic ossification (HO).[7,14] In a large cohort study conducted by Poor et al.[14], the incidence of HO was significantly higher in athletes who received PRP for core muscle injuries. This finding highlights the osteogenic potential of growth factors introduced through PRP. Although PRP was not administered in our case, the patient received autologous conditioned plasma (ACP), a similar biologic agent that is rich in growth factors but has a lower leukocyte concentration.[7,14,18] Both therapies aim to promote tissue regeneration and reduce inflammation; however, their use in injured tissue must be approached with caution due to the possible risk of HO development.[7]

This case contributes to the growing literature on the diagnosis and management of adductor longus MO, a rare and often underrecognized condition. Advanced imaging modalities, awareness of the risks associated with biological treatments, and personalized treatment strategies are crucial for achieving optimal clinical outcomes. Further research is needed to clarify the relationship between biological agents and HO, as well as to define the appropriate timing and indications for surgical intervention in chronic cases of MO.

Although rare, MO of the adductor longus should be included in the differential diagnosis of athletes presenting with chronic groin pain, particularly when initial radiographs are unremarkable. Early clinical suspicion, prompt use of advanced imaging, and individualized treatment planning are key to minimizing morbidity. In today's clinical landscape, where biological agents are frequently used, careful consideration of their risks is essential. Surgical treatment should be reserved for patients with persistent and functionally limiting symptoms that are unresponsive to conservative measures. This case underscores the importance of clinical vigilance and supports the efficacy of conservative management in selected MO cases.

DECLARATIONS

Ethics Committee Approval: This is a case report; therefore, formal ethics committee approval was not required in accordance with institutional policies.

Informed Consent: Written informed consent was obtained from the patient.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that they have no relevant or material financial interests that relate to the research described in this paper.

Funding Disclosure: No funding was received for this study.

Data Availability Statement: Data are available from the corresponding author upon reasonable request.

Use of AI for Writing Assistance: The authors declared that they did not use any generative artificial intelligence for the writing of this manuscript, nor for the creation of images, graphics, tables, or their corresponding captions.

Author Contributions: The senior author has read and agreed to the published version of the manuscript.

Peer-review: Externally peer-reviewed.

ABBREVIATIONS

ACP: Autologous conditioned plasma

CT: Computed Tomography

HO: Heterotopic ossification

MO: Myositis Ossificans

MRI: Magnetic Resonance Imaging

NSAID: Nonsteroidal anti-inflammatory drugs

PRP: Platelet-rich plasma

REFERENCES

1. Walczak BE, Johnson CN, Howe BM. Myositis Ossificans. J Am Acad Orthop Surg 2015;23:612–22. [CrossRef]
2. Hanisch M, Hanisch L, Fröhlich LF, Werkmeister R, Bohner L, Kleinheinz J. Myositis ossificans traumatica of the masticatory muscles: etiology, diagnosis and treatment. Head Face Med 2018;14:23. [CrossRef]
3. Landolsi M, Mrad T. Traumatic myositis ossificans circumscripta (MOC). BMJ Case Rep 2017;2017:bcr2017219422. [CrossRef]
4. Sokunbi G, Fowler JR, Ilyas AM, Moyer RA. A case report of myositis ossificans traumatica in the adductor magnus. Clin J Sport Med 2010;20:495–6. [CrossRef]

5. Zarro M, Tamberrino K, Bane EM. Myositis Ossificans of the Adductor Longus in a Soccer Player. J Orthop Sports Phys Ther 2020;50:586. [CrossRef]
6. Al-Qattan MM, Al-Fahdil L, Al-Shammari HM, Joarder AI. Management of Myositis Ossificans of the Hand: A Case Report and a Review of the Literature. J Hand Surg Am. 2017;42:576.e1-e4.
7. Kaux JF, Le Goff C, Seidel L, Péters P, Gothot A, Albert A, et a. Étude comparative de cinq techniques de préparation plaquettaire (platelet-rich plasma) [Comparative study of five techniques of preparation of platelet-rich plasma]. Pathol Biol (Paris) 2011;59:157–60. [CrossRef]
8. Nieuwenhuizen CJ, van Veldhoven PLJ, van Oosterom RF. Rare case of a traumatic myositis ossificans in the tibialis anterior muscle. BMJ Case Rep 2020;13:e233210. [CrossRef]
9. Talbot JC, Bismil Q, Barwick T, Robinson P, Benjamin M, Schilders E. Partial rupture of the adductor longus complicated by myositis ossificans. Injury Extra 2006;37:274-6. [CrossRef]
10. Rajakulendran K, Field RE. Late formation of heterotopic bone following an adductor origin avulsion injury. Injury 2012;43:530–2. [CrossRef]
11. Cetin C, Sekir U, Yildiz Y, Aydin T, Ors F, Kalyon TA. Chronic groin pain in an amateur soccer player. Br J Sports Med 2004;38:223–4. [CrossRef]
12. Kanakaraddi S V., Dileep KS, Vidyasagar JVS, Jayaprasad PS. Myositis ossificans traumatica of the hip adductors with pseudoankylosis. Curr Orthop Pract 2010;21:E20–22. [CrossRef]
13. Iorio R, Massafra C, Viglietta E, Mazza D, Ferretti A. Bilateral Post Traumatic Myositis Ossificans of Adductor Longus in a Young Soccer Player: A Case Report and Literature Review. Curr Sports Med Rep 2021;20:584–7. [CrossRef]
14. Poor AE, Zoga AC, Warren A, Waters LC, Vilotti L, Bentz GP, et al. Heterotopic Ossification and Platelet-Rich Plasma in Core Muscle Injuries: A Single-Institution Experience Over 6 Years. Am J Sports Med 2024;52:54–9. [CrossRef]
15. Devilbiss Z, Hess M, Ho GWK. Myositis Ossificans in Sport: A Review. Curr Sports Med Rep.2018;17:290–5. [CrossRef]
16. de Smet GHJ, Buijk SE, Weir A. Surgical excision of post-traumatic myositis ossificans of the adductor longus in a football player. BMJ Case Rep 2020;13:e233504. [CrossRef]
17. Auerbach A, Fanburg-Smith JC, Wang G, Rushing EJ. Focal myositis: a clinicopathologic study of 115 cases of an intramuscular mass-like reactive process. Am J Surg Pathol 2009;33:1016–24. [CrossRef]
18. Filardo G, Di Matteo B, Kon E, Merli G, Marcacci M. Platelet-rich plasma in tendon-related disorders: results and indications. Knee Surg Sports Traumatol Arthrosc 2018;26:1984–99. [CrossRef]

TUSYAD STArt Sports Traumatology & Arthroscopy

DOI: 10.14744/start.2026.85449
Sports Traumatol Arthrosc 2026;3(1):36–46

Review

Posterior Tibial Slope-Modifying Osteotomies: Current Concepts in Biomechanics, Indications, Surgical Techniques and Outcomes

Omer Faruk Sevim,[1] Muhammed Yusuf Afacan,[2,3] Mahmut Enes Kayaalp[4]

[1]Kartal Dr. Lutfi Kırdar City Hospital, Istanbul, Turkiye
[2]Department of Orthopaedics and Traumatology, Istanbul Physical Therapy and Rehabilitation Training and Research Hospital, Istanbul, Turkiye
[3]Department of Anatomy, Istanbul University–Cerrahpasa, Institute of Graduate Studies, Cerrahpasa Faculty of Medicine, Istanbul, Turkiye
[4]Department of Orthopaedics and Traumatology, University of Health Sciences, Istanbul Fatih Sultan Mehmet Training and Research Hospital, Istanbul, Turkiye

ABSTRACT

The posterior tibial slope (PTS) is a key determinant of knee biomechanics, influencing anterior and posterior cruciate ligament (PCL) function, joint stability and load distribution. Abnormal PTS values predispose to instability and ligament reconstruction failures. This review aims to synthesize current evidence regarding the biomechanical, clinical, and surgical principles of PTS-modifying osteotomies, emphasizing their indications, techniques and outcomes. A comprehensive narrative review of the literature was conducted focusing on the definition, measurement methods, biomechanical implications, surgical approaches, and clinical results of PTS-reducing and PTS-increasing tibial osteotomies. Key data were extracted from biomechanical, radiologic, and clinical studies evaluating PTS correction and its effect on knee stability and success of ligamentous reconstruction. Measurement of PTS varies significantly among studies due to inconsistent radiological methods, i.e. radiograph versus magnetic resonance imaging or reference points and tibial axis definitions. PTS-reducing osteotomies effectively decrease anterior tibial translation, improving stability in ACL-deficient knees, while PTS-increasing procedures restore stability in PCL insufficiency and genu recurvatum deformities. Both techniques demonstrate substantial postoperative improvements in functional scores (Lysholm, IKDC, Tegner) with reported success rates up to 80–85%. Common complications include hinge fractures, patellar maltracking, and loss of correction, mitigated by accurate planning and fixation. PTS-modifying osteotomies represent valuable tools for managing ligamentous knee instability secondary to abnormal PTS. Optimal outcomes depend on precise radiologic assessment, appropriate surgical selection, and structured rehabilitation. Further longitudinal studies are warranted to determine their long-term effects on joint preservation and osteoarthritis progression.

Keywords: Anterior cruciate ligament, high tibial osteotomy, knee biomechanics, posterior cruciate ligament, posterior tibial slope, revision ligament reconstruction, slope-increasing osteotomy, slope-reducing osteotomy

Cite this article as:
Sevim OF, Afacan MY, Kayaalp ME. Posterior Tibial Slope-Modifying Osteotomies: Current Concepts in Biomechanics, Indications, Surgical Techniques and Outcomes. Sports Traumatol Arthrosc 2026;3(1):36–46.

Address for correspondence:
Muhammed Yusuf Afacan, Department of Orthopaedics and Traumatology, Istanbul Physical Therapy and Rehabilitation Training and Research Hospital, Istanbul, Türkiye
E-mail:
drmyaorto@gmail.com

Submitted: 07.01.2026
Revised: 17.02.2026
Accepted: 06.04.2026
Available Online: 11.05.2026

Sports Traumatology & Arthroscopy – Available online at www.stajournal.com

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

INTRODUCTION

The posterior tibial slope (PTS) plays a critical role in knee biomechanics, influencing both the stability and function of the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL).[1,2] Therefore, PTS-modifying osteotomies, either increasing or decreasing the slope, represent surgical techniques developed to correct knee instability related to abnormal PTS angles. PTS-increasing osteotomies are generally performed to correct posterior knee instability [3,4], especially in cases of PCL insufficiency, whereas PTS-decreasing osteotomies are applied to reduce anterior tibial translation (ATT) in ACL-deficient knees [5,6]. In this extensive review, both procedures are discussed in the context of their biomechanical role, clinical indications, various operative approaches, and outcomes.

The biomechanical importance of PTS has been well established. Increased PTS results in greater ATT under axial loading, thereby increasing strain on the ACL and contributing to both primary injury and graft failure.[7,8] Conversely, decreased PTS is associated with increased posterior tibial translation and greater mechanical demand on the posterior cruciate ligament, leading to posterior instability.[9] These alterations in sagittal alignment influence tibiofemoral contact mechanics, joint loading patterns, and ligament forces, underscoring the central role of PTS in knee stability and kinematics.[8,10] It is important to differentiate between two distinct clinical concepts related to PTS correction. In many cases, changes in PTS occur as a secondary consequence of high tibial osteotomy performed primarily for coronal plane deformities or medial compartment osteoarthritis. In contrast, the PTS-modifying osteotomies described in this review refer to procedures intentionally performed in the sagittal plane to correct abnormal PTS in the setting of ligamentous instability, particularly ACL or PCL deficiency.

This narrative review was conducted to summarize the current evidence regarding PTS-modifying osteotomies of the proximal tibia. A literature search was performed using PubMed, Scopus, and Web of Science databases to identify relevant publications related to PTS and slope-modifying osteotomy techniques.

The search strategy included combinations of the following keywords: “posterior tibial slope,” “tibial slope correction,” PTS-modifying osteotomy,” “anterior closing wedge osteotomy,” “posterior opening wedge osteotomy,” “anterior opening wedge osteotomy,” and “high tibial osteotomy.” Eligible publications included clinical studies, biomechanical investigations, systematic reviews, and technical reports focusing on the biomechanics, indications, surgical techniques, complications, and clinical outcomes of PTS-modifying osteotomies. Articles published in English and considered relevant to the topic were reviewed. In addition, the reference lists of selected studies were manually screened to identify further relevant publications. The aim of this review was to synthesize the available literature and provide a comprehensive overview of the biomechanical principles, clinical indications, surgical techniques, and reported outcomes associated with PTS-modifying osteotomies.

Definition and Measurement of PTS

The literature on PTS measurement reveals inconsistencies, leading to discrepancies in reported PTS values. Some studies have evaluated either the lateral or medial PTS individually, while others have not distinguished between the two.[7,11,12] Additionally, differences in the chosen tibial length on radiographs significantly affect PTS measurements.[13,14] Variations in the measurement approach are noteworthy because medial and lateral plateau PTS values can differ within individuals.[15,16] Studies have shown that using a 10 cm tibial length often leads to an overestimation of PTS by an average of 3 degrees compared to the mechanical axis.[17]

Several researchers have used different tibial diaphyseal levels to define the anatomical axis.[5,18,19] Some findings suggest that using the anatomical axis of the proximal tibia provides the most accurate PTS measurement compared to the mechanical axis of the tibia.[20] The widely accepted PTS cutoff value of 12 degrees was established using landmarks located 5 and 15 cm distal to the tibial joint line. A recent consensus report on revision ACL reconstruction also supports this methodology.[21] Full-length lateral tibial radiographs measured along the tibial mechanical axis are considered the most accurate method for determining PTS. However, patient-specific anatomy, such as tibial bowing, may affect PTS measurements, potentially influencing surgical decision-making.[17,22,23]

Studies have adopted various techniques to determine the tibial axis, including the anterior cortical line[24], the posterior cortical line [25], or an intermediate line[26] (Fig. 1). The anterior cortical line tends to overestimate PTS, while posterior referencing underestimates it.[27] Accurate lateral radiographic views with minimal posterior femoral condyle overlap (ideally <6 mm) are essential for accurate PTS measurements.[28] Research suggests that aligning the distal femoral surfaces of both condyles has a more significant impact on accuracy than aligning the posterior condyles.[29]

Despite its relevance, the influence of tibial rotation on measurements, particularly axial rotation and lateral tilting, is often neglected.[16] MRI and computed tomography (CT) scans provide greater precision in distinguishing between medial and lateral PTS.[15,30] However, there is no established MRI protocol for determining the optimal tibial length for PTS measurements. MRI-based approaches typically focus

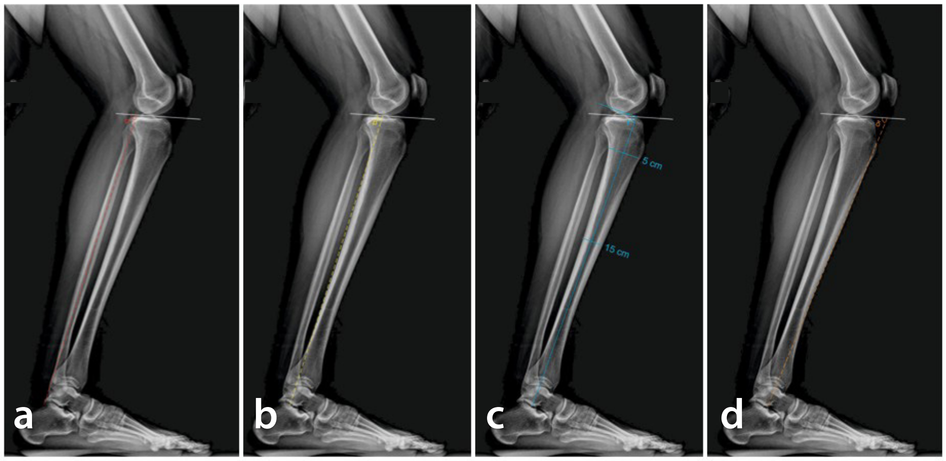

Figure 1. Commonly used reference methods for measuring posterior tibial slope (PTS) on a lateral knee radiograph. The figure illustrates four commonly described methods for determining the posterior tibial slope of the medial tibial plateau according to the tibial reference axis used. **(a)** Measurement based on the fibular diaphyseal axis, with PTS calculated as 90° – α. **(b)** Measurement based on the anterior tibial cortex axis, with PTS calculated as 90° – β. **(c)** Measurement based on the tibial proximal anatomic axis, the most commonly used reference method, with PTS calculated as 90° – γ. **(d)** Measurement based on the posterior tibial cortex axis, with PTS calculated as 90° – δ. Blue lines indicate the selected tibial reference axis and the tangent to the medial tibial plateau used for angle determination.

on the proximal tibia and may underestimate PTS. MRI-based approaches focusing on the proximal tibia may underestimate PTS, with studies reporting discrepancies of up to 4.9° compared to lateral knee radiographs.[31] For surgical decision-making, MRI- and CT-based PTS measurements should be avoided. Instead, lateral knee radiographs with at least 15 cm of the tibial diaphysis in view are preferred, utilizing the medial tibial plateau as a reference for PTS measurement. The tibial axis can be determined by placing two circles along the tibial diaphysis at 5 and 15 cm below the tibial plateau. [10] Currently, there is a lack of standardized guidelines for comparing PTS measurements across various imaging modalities, underscoring the importance of careful interpretation by surgeons and readers.[32]

Biomechanical Rationale

PTS-reducing osteotomies

The PTS significantly impacts ACL characteristics by means of its influence on ATT. A high PTS (≥12°) is an established risk factor for ACL injuries and subsequent reconstruction failure [28,33–35]. Increased PTS leads to larger ATT, placing excessive strain at the ACL, thereby increasing the risk of injury or graft failure.[33,36,37] PTS-reducing osteotomies aim at stabilizing the knee by reducing the PTS, hence decreasing the forces acting on the ACL, thereby improving ordinary knee biomechanics.[34,38]

PTS-increasing osteotomies

The dynamic effects of PCL deficiency also significantly impact the knee's long-term biomechanics, particularly in the patellofemoral and medial compartments. Posterior subluxation of the medial tibial plateau with knee flexion subjects the posterior horn of the medial meniscus to excessive forces, increasing contact pressures in the medial compartment by approximately 30%.[39–41] Additionally, the coupled anterior-posterior and rotational instability seen in PCL deficiency subjects the patellofemoral joint, especially the lateral patellar facet and inferior pole of the patella, to abnormally high contact pressures. These biomechanical consequences likely contribute to the accelerated osteoarthritic changes observed in these patients, further emphasizing the potential of medial opening wedge HTO to alter the progression of PCL-deficient knee conditions.[8,42] Besides ATT of 1.9±2.5 mm has been observed when axial compressive forces are applied.[8] In another study, increasing the axial compressive load from 134 to 200 N in a medial opening wedge HTO resulted in further ATT, corroborating the association between decreased PTS and increased risk of PCL reconstruction failure.[9,31]

Clinical Rationale

PTS-reducing osteotomies

Clinically, PTS-decreasing osteotomies are indicated for patients with ACL deficiency, particularly those with recurrent ACL injuries or failed ACL reconstructions associated with increased PTS.[33–35,43,44] Reducing the PTS to a neutral angle, usually between 4° and 6°, has been proven to enhance knee stability and reduce the risk of further ACL injuries.[13,45,46] Moreover, this technique may benefit patients suffering from meniscal injuries, patellofemoral instability, and early-onset osteoarthritis, all of which may be exacerbated by increased PTS.[10,33,37,47]

PTS-increasing osteotomies

Clinically, anti-recurvatum (PTS-Increasing) osteotomies are indicated for patients with pathological genu recurvatum deformities exceeding 15° and presenting with symptoms such as knee instability, anterior knee pain, and functional impairment. These deformities, often associated with either osseous alterations, soft tissue stretching, or a combination of both, can severely compromise joint stability, quadriceps function, and patellofemoral mechanics.[48,49] Correcting the deformity through an anterior opening wedge osteotomy has shown promising results, with studies reporting up to an 83% success rate in improving function and reducing pain, particularly when performed proximal to the tibial tuberosity.[50,51] This technique addresses hyperextension by increasing the PTS and improving knee biomechanics, making it a viable option for patients with debilitating recurvatum deformities or those experiencing anterior impingement symptoms due to hyperextension.[50–52]

Indications and Patient Selection

PTS-reducing osteotomies

PTS reducing osteotomies are primarily indicated in patients with an increased PTS, typically ≥12° on lateral radiographs.[35,50,53] Excessive PTS places greater mechanical stress on the ACL, particularly when ATT exceeds 10 mm.[13] Therefore, PTS-reducing osteotomies are most commonly considered in patients with recurrent anterior instability, especially in cases of failed or revision ACL reconstruction.[28,43] In addition, chronic meniscal injuries, particularly those involving the posterior horn of the medial meniscus, may coexist with increased PTS and contribute to abnormal knee biomechanics, further supporting the indication for PTS reducing osteotomy in appropriately selected patients. PTS should not be interpreted using a strict threshold value alone, as the risk of ACL failure increases progressively with increasing PTS and must be evaluated together with multiple patient-specific risk factors.[46]

PTS -increasing osteotomies

PTS -increasing osteotomies are generally indicated in patients with decreased PTS, typically <5° on lateral radiographs.[3] Reduced PTS may contribute to posterior knee instability and increased posterior tibial translation, particularly when posterior tibial translation exceeds 10 mm.[54] These procedures are therefore commonly considered in patients with symptomatic posterior instability, including those with previous PCL reconstruction failure. Posterior meniscal injuries associated with instability may also coexist with reduced PTS and further compromise knee biomechanics.

Patients with severe osteoarthritis, significant coronal plane deformities, or marked hyperextension deformities greater than 10° may not be suitable candidates for isolated PTS-modifying osteotomy and may require combined corrective procedures.[33]

Surgical Approaches

PTS-reducing osteotomies

Anterior closing wedge osteotomy

There are three primary techniques for handling the tibial tubercle during the procedure:

1. **Supra-tubercle Technique**: This approach potentially enhances healing due to the extensive surface area of cancellous bone available in the proximal tibia.[6] However, it poses challenges because of the thinness of the osteotomized segment, which increases the risk of inadvertent damage to the patellar tendon.[23]

2. **Infra-tubercle Technique**: This method is advantageous in maintaining the natural tension of the extensor mechanism, as it avoids direct manipulation. Hypothetically, it was assumed to carry a higher risk of nonunion, attributed to the distraction forces exerted by the patellar tendon on the proximal fragment and the relatively reduced vascular supply compared to the more proximal metaphyseal bone.[34,55] However, outcome studies have demonstrated rapid union following infratuberosity osteotomy.[56] A critical consideration lies in preoperative planning: prior work indicates that individualized planning is necessary for accurate osteotomy execution, rather than relying on the conventional "1 mm per degree" rule when performing a closing-wedge technique.[35]

3. **Tibial Tubercle Osteotomy (TTO) Technique: (Fig. 2):** This option is technically less demanding and permits adjustment of the tibial tubercle as needed for optimal alignment. However, it can limit early postoperative range of motion, potentially leading to knee stiffness, particularly when performed alongside ACL reconstruction.

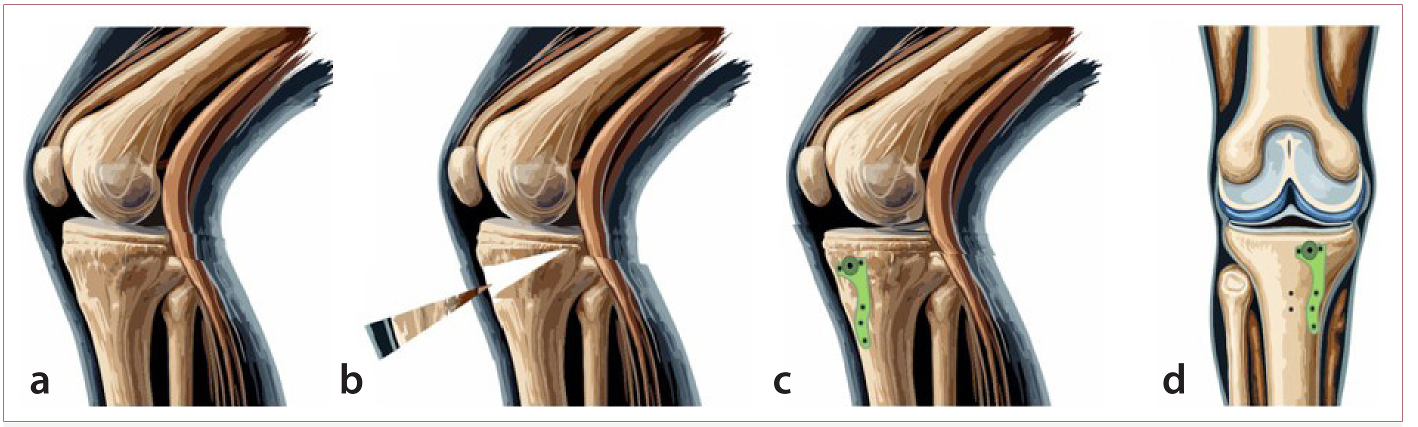

Figure 2. Surgical steps of anterior closing wedge proximal tibial osteotomy for posterior tibial slope reduction. **(a)** Lateral view of the proximal tibia demonstrating the planned osteotomy site. **(b)** Tibial tubercle osteotomy and resection of the anterior bony wedge. **(c)** Lateral view after completion of the anterior closing wedge osteotomy, showing reduction of the posterior tibial slope and stabilization with plate-and-screw fixation. **(d)** Anteroposterior view of the final construct demonstrating fixation of the osteotomy site.

Ultimately, each technique can achieve the desired correction, with the choice often depending on the surgeon's preference and the specific clinical scenario.[23]

Posterior opening wedge osteotomy

The posterior opening-wedge osteotomy (POWO) technique is designed to correct an excessive PTS, which can contribute to failed ACL reconstructions. This method involves exposing the posterior surface of the proximal tibia and inserting two K-wires anteroposteriorly as osteotomy guides, along with a mediolaterally inserted wire as a hinge blocker. The osteotomy is initiated posteriorly, advancing anteriorly with a single-bladed saw to open the osteotomy plane posteriorly with a gap spreader (Fig. 3). After the correction angle is achieved, fibular bone fragments are grafted into the opening to maintain stability, and a locking plate is applied for secure fixation. This technique is beneficial due to its minimally invasive approach, precise correction control, and ability to allow early rehabilitation, making it a preferred option for complex revision cases involving increased tibial PTS.[57]

PTS -Increasing Osteotomies

Anterior opening wedge osteotomy

There are two primary techniques for handling the tibial tubercle during the procedure described in the literature. However, because PTS-increasing procedures are rare, only limited case reports are available.

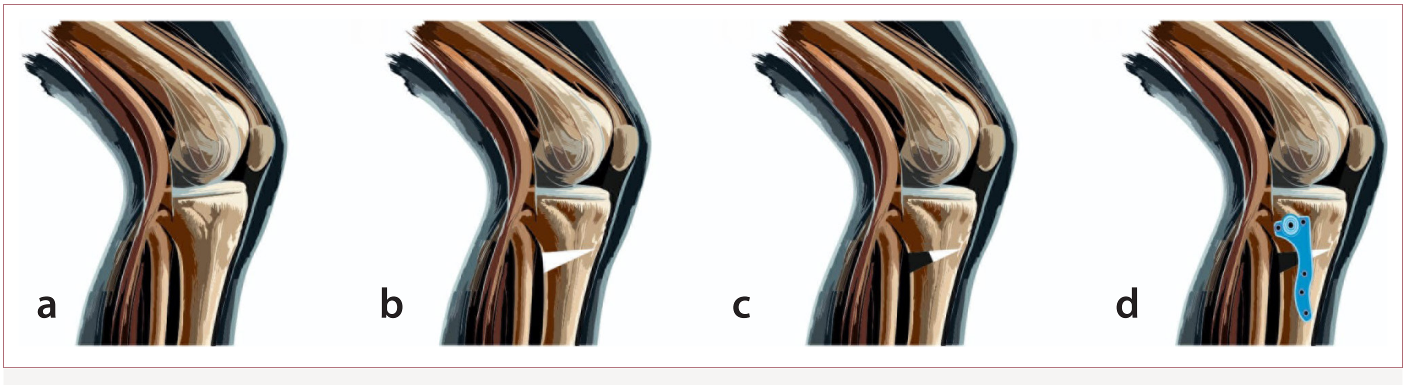

Figure 3. Surgical steps of posterior opening wedge proximal tibial osteotomy for posterior tibial slope increase. **(a)** The osteotomy is created beneath the first and second guide pins, progressing from posterior to anterior while preserving the anterior cortical hinge. **(b)** The osteotomy plane is gradually opened posteriorly using a gap spacer or laminar spreader. **(c)** Autologous fibular bone graft fragments are inserted into the osteotomy gap to maintain the correction. **(d)** Final stabilization is achieved with a locking plate and screws.

1. **Supra-tubercle Technique**: A plate and large Richards staple are used for fixation. This approach was reported in a patient with a 13-degree anterior tibial slope and failed PCL reconstruction.[20]

2. **Tibial Tubercle Osteotomy (TTO) Technique:** (**Fig. 4**) Another technique includes a tibial tubercle osteotomy (TTO) followed by an opening wedge high tibial osteotomy (HTO). This sequence helps avoid changes in patellar height during the correction.[58]

Postoperative Rehabilitation Protocols

Postoperative rehabilitation is crucial after both PTS-decreasing and PTS-increasing osteotomies. The following protocol represents a general rehabilitation framework commonly used after PTS-modifying osteotomies. In clinical practice, rehabilitation strategies may vary depending on the type of osteotomy performed, the fixation method used, the degree of correction, and the presence of concomitant ligament reconstruction procedures.[5,57,59]

Phase 1: Immediate Postoperative (0–3 weeks)

- Non-weight bearing with crutches
- Knee immobilization in full extension
- Early quadriceps activation and patellar mobilization

Phase 2: Early Rehabilitation (Weeks 4–6)

- Transition to partial weight bearing
- Gradual increase in range of motion, focusing on achieving full extension and flexion beyond 90°

Phase 3: Intermediate Rehabilitation (Weeks 7–12)

- Full weight bearing
- Strengthening exercises for quadriceps and hamstrings
- Balance and proprioceptive training

Phase 4: Advanced Rehabilitation (Weeks 12–24)

- Return to sport specific exercises and higher intensity activities
- Clearance for sports and high impact activities based on strength and neuromuscular control
- Pivoting and non-contact sports at 9 months, and pivoting and contact sports at 1 year postoperatively

Difficulties and Management

PTS modifying osteotomies are generally successful procedures; however, several complications may occur depending on the surgical technique, degree of correction, and fixation stability.

Anterior closing wedge osteotomy (ACW)

ACW procedures may be associated with loss of correction if fixation stability is insufficient or if premature weight bearing occurs during the early postoperative period.

Hinge fractures may also occur during large angular corrections when the cortical hinge is not adequately preserved. In addition, alterations in patellofemoral biomechanics may develop if patellar height changes occur following PTS reduction.[5,34,45,59–63]

Anterior opening wedge osteotomy (AOW)

AOW techniques may carry a risk of delayed union or nonunion due to the opening wedge gap and the need for stable fixation. Inadequate fixation stability or insufficient biological

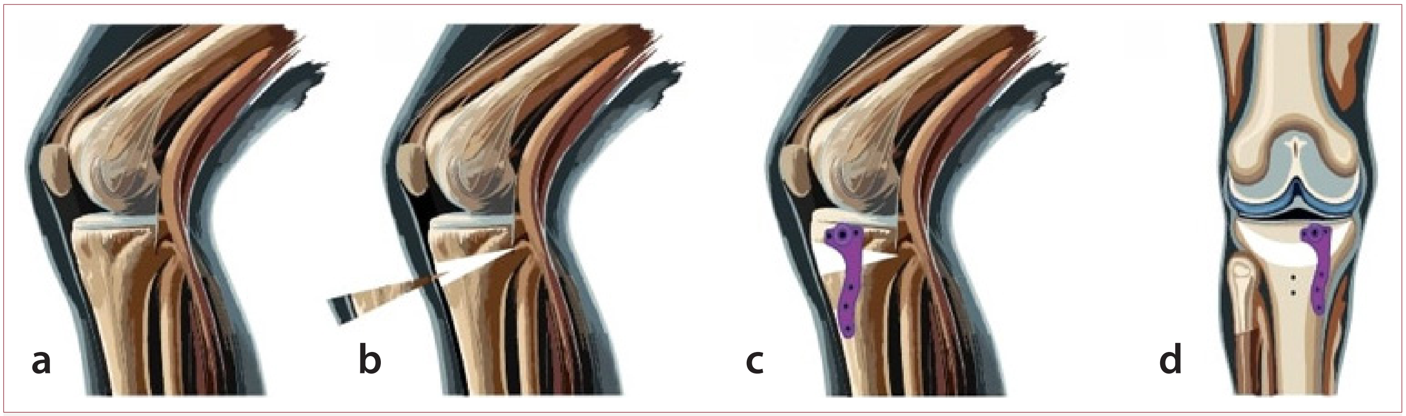

Figure 4. Schematic representation of anterior opening wedge proximal tibial osteotomy. **(a)** The intended osteotomy site is identified on the lateral aspect of the proximal tibia. **(b)** Tibial tubercle osteotomy is performed, and the osteotomy is opened anteriorly to achieve the planned correction. **(c)** Lateral view of the completed osteotomy with maintenance of the anterior opening wedge and stabilization using plate-and-screw fixation. **(d)** Anteroposterior view demonstrating the final fixation construct.

healing potential may contribute to delayed consolidation at the osteotomy site.[59]

Posterior opening wedge osteotomy (POWO)

POWO techniques require careful posterior exposure and may therefore carry a potential risk of neurovascular injury due to the close proximity of the popliteal neurovascular structures. In addition, PTS -reducing osteotomies may be associated with complications such as hinge fractures, infection, implant irritation or removal, and malcorrection.[64] Infection and hardware irritation are additional complications that may occur following PTS modifying osteotomies. Although the incidence of infection is generally lower compared with that associated with external fixation techniques, such as Ilizarov methods, implant-related irritation may occur and may require hardware removal.[58,59,61]

Clinical Results

Clinically, PTS -decreasing osteotomies are indicated for patients with ACL deficiencies, particularly those with recurrent ACL injuries or failed ACL reconstructions associated with increased posterior PTS.[33,34,43] Reducing the PTS to a more physiological range, typically between 4° and 6°, has been shown to improve knee stability and decrease the risk of further ACL injury or graft failure.[13,45] This approach may also benefit patients with associated meniscal pathology, patellofemoral instability, or early degenerative changes exacerbated by excessive PTS.[10,32,33] From a surgical decision-making perspective, PTS -reducing osteotomy may be considered in both primary and revision ACL reconstruction settings. In primary ACL reconstruction, PTS correction may be considered in carefully selected patients with markedly increased PTS and excessive ATT, particularly when additional risk factors such as chronic posterior horn meniscal injury are present.[65] Recent concepts such as the Avalanche classification emphasize that the indication for PTS -reducing osteotomy should be based on a multifactorial risk assessment rather than a single PTS threshold. [51] However, PTS -reducing osteotomy is more commonly performed in the revision ACL reconstruction setting, where excessive PTS has been identified as an important risk factor for graft failure and recurrent instability.[50,64] Correction of sagittal tibial alignment in these patients may reduce graft strain and improve the biomechanical environment for ligament reconstruction.

Both single-stage and staged surgical strategies have been described. In selected cases, PTS -reducing osteotomy can be performed simultaneously with revision ACL reconstruction, particularly when adequate tunnel positioning and fixation can be achieved during the same procedure.[65] Conversely, staged procedures may be preferred in complex revision situations, such as tunnel malposition, tunnel widening, or compromised bone stock, in which osteotomy is performed first to restore tibial alignment before definitive ligament reconstruction.[64]

Clinical studies have demonstrated that PTS -modifying osteotomies can lead to meaningful improvements in knee stability and functional outcomes. In patients undergoing PTS -reducing osteotomies, reductions in ATT and improvements in clinical scores such as the Lysholm score, Tegner activity scale, and IKDC score have been consistently reported.[5,44,62,63,66]

CONCLUSION

PTS modifying osteotomies represent essential surgical interventions for managing knee instability caused by abnormal PTS angles. These procedures whether aimed at increasing or decreasing the PTS address specific biomechanical and clinical challenges including ATT in ACL deficient knees and posterior instability in PCL deficient or genu recurvatum conditions. Precise measurements of PTS using standardized imaging techniques careful patient selection and tailored surgical planning are critical for optimizing outcomes. Biomechanical evidence underscores the profound impact of PTS on knee joint forces and ligament stability, making PTS modification a powerful tool for restoring normal knee biomechanics. Short- and mid-term results demonstrate significant improvements in instability, functional scores, knee stability, and patient satisfaction, highlighting the efficacy of these procedures. However, complications such as hinge fractures patellofemoral issues and loss of correction emphasize the need for meticulous surgical technique and robust postoperative rehabilitation protocols.

DECLARATIONS

EEthics Committee Approval: This is a review, and therefore, ethics committee approval was not required in accordance with institutional policies.

Informed Consent: Informed consent was not deemed necessary for this study.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that they have no relevant or material financial interests that relate to the research described in this paper.

Funding Disclosure: No funding was received for this study.

Data Availability Statement: Data are available from the corresponding author upon reasonable request.

Use of AI for Writing Assistance: The authors declared that they did not use any generative artificial intelligence for the writing of this manuscript, nor for the creation of images, graphics, tables, or their corresponding captions.

Author Contributions: Concept – OFS, MYA, MEK; Design – OFS, MYA, MEK; Supervision – OFS, MYA, MEK; Data collection and/or processing – MT; Analysis and/or interpretation – OFS, MYA, MEK; Literature search – OFS, MYA, MEK; Writing – OFS, MYA, MEK; Critical review – OFS, MYA, MEK; References and fundings – OFS, MYA, MEK; Materials – NA. All authors have read and agreed to the published version of the manuscript.

Peer-review: Externally peer-reviewed.

ABBREVIATIONS

ACL: Anterior Cruciate Ligament

ACW: Anterior Closing Wedge Osteotomy

AOW: Anterior Opening Wedge Osteotomy

AP: Anteroposterior

ATT: Anterior Tibial Translation

CT: Computed Tomography

HTO: High Tibial Osteotomy

IKDC: International Knee Documentation Committee

MRI: Magnetic Resonance Imaging

PCL: Posterior Cruciate Ligament

POWO: Posterior Opening Wedge Osteotomy

PTS: Posterior Tibial Slope

TTO: Tibial Tubercle Osteotomy

REFERENCES

1. Pradhan P, Kaushal SG, Kocher MS, Kiapour AM. Development of Anatomic Risk Factors for ACL Injuries: A Comparison Between ACL-Injured Knees and Matched Controls. Am J Sports Med 2023;51:2267–74. [Crossref]
2. Winkler PW, Wagala NN, Carrozzi S, Nazzal EM, Fox MA, Hughes JD, et al. Low posterior tibial slope is associated with increased risk of PCL graft failure. Knee Surg Sports Traumatol Arthrosc 2022;30:3277–86. [Crossref]
3. Novaretti JV, Sheean AJ, Lian J, De Groot J, Musahl V. The Role of Osteotomy for the Treatment of PCL Injuries. Curr Rev Musculoskelet Med 2018, 11:298–306.
4. Heard WM, Chahal J, Bach BR: Recognizing and Managing Complications in ACL Reconstruction. Sports Med Arthrosc 2013;21:106–12. [Crossref]
5. Akoto R, Alm L, Drenck TC, Frings J, Krause M, Frosch K-H. Slope-Correction Osteotomy with Lateral Extra-articular Tenodesis and Revision Anterior Cruciate Ligament Reconstruction Is Highly Effective in Treating High-Grade Anterior Knee Laxity. Am J Sports Med 2020;48:3478–85. [Crossref]
6. Dejour D, Saffarini M, Demey G, Baverel L. Tibial slope correction combined with second revision ACL produces good knee stability and prevents graft rupture. Knee Surg Sports Traumatol Arthrosc 2015;23:2846–52. [Crossref]
7. Bernhardson AS, Aman ZS, Dornan GJ, Kemler BR, Storaci HW, Brady AW, et al. Tibial Slope and Its Effect on Force in Anterior Cruciate Ligament Grafts: Anterior Cruciate Ligament Force Increases Linearly as Posterior Tibial Slope Increases. Am J Sports Med 2019;47:296–302. [Crossref]
8. Giffin JR, Vogrin TM, Zantop T, Woo SL, Harner CD. Effects of Increasing Tibial Slope on the Biomechanics of the Knee. Am J Sports Med 2004;32:376–82. [Crossref]
9. Giffin JR, Stabile KJ, Zantop T, Vogrin TM, Woo SL-Y, Harner CD: Importance of Tibial Slope for Stability of the Posterior Cruciate Ligament—Deficient Knee. Am J Sports Med 2007;35:1443–9. [Crossref]
10. Hashemi J, Chandrashekar N, Gill B, Beynnon BD, Slauterbeck JR, Schutt RC Jr, et al. The Geometry of the Tibial Plateau and Its Influence on the Biomechanics of the Tibiofemoral Joint. J Bone Joint Surg Am 2008;90:2724–34. [Crossref]
11. Sevim ÖF, Ergün S, Şahin Ediz S, Eceviz E, Karahan M. Comparison of Side-to-Side Difference in Posterior Tibial Slope in Knees With Acute Versus Chronic Anterior Cruciate Ligament Deficiency. Orthop J Sport Med 2024;12:23259671241247524. [Crossref]
12. DePhillipo NN, Kennedy MI, Dekker TJ, Aman ZS, Grantham WJ, LaPrade RF. Anterior Closing Wedge Proximal Tibial Osteotomy for Slope Correction in Failed ACL Reconstructions. Arthrosc Tech 2019;8: e451–e457. [Crossref]
13. Dan MJ, Cance N, Pineda T, Demey G, Dejour DH. Four to 6° Is the Target Posterior Tibial Slope After Tibial Deflection Osteotomy According to the Knee Static Anterior Tibial Translation. Arthroscopy 2024;40:846–54. [Crossref]
14. Dean RS, DePhillipo NN, Chahla J, Larson CM, LaPrade RF. Posterior Tibial Slope Measurements Using the Anatomic Axis Are Significantly Increased Compared With Those That Use the Mechanical Axis. Arthroscopy 2021;37:243–9. [Crossref]
15. Akamatsu Y, Sotozawa M, Kobayashi H, Kusayama Y, Kumagai K, Saito T. Usefulness of long tibial axis to measure medial tibial slope for opening wedge high tibial osteotomy. Knee Surgery, Sport Traumatol Arthrosc 2016;24:3661–7. [Crossref]
16. Weinberg DS, Williamson DFK, Gebhart JJ, Knapik DM, Voos JE. Differences in Medial and Lateral Posterior Tibial Slope: An Osteological Review of 1090 Tibiae Comparing Age, Sex, and Race. Am J Sports Med 2017;45:106–13. [Crossref]

17. Faschingbauer M, Sgroi M, Juchems M, Reichel H, Kappe T. Can the tibial slope be measured on lateral knee radiographs? Knee Surg Sports Traumatol Arthrosc 2014;22:3163–7. [Crossref]
18. Beel W, Schuster P, Michalski S, Mayer P, Schlumberger M, Hielscher L, et al. High prevalence of increased posterior tibial slope in ACL revision surgery demands a patient-specific approach. Knee Surg Sports Traumatol Arthrosc 2023;31:2974–82. [Crossref]
19. Dejour H, Bonnin M. Tibial translation after anterior cruciate ligament rupture. Two radiological tests compared. J Bone Joint Surg Br 1994;76:745–9. [Crossref]
20. Yoon KH, Lee JH, Kim SG, Park JY, Lee HS, Kim SJ, Kim YS. Effect of Posterior Tibial Slopes on Graft Survival Rates at 10 Years After Primary Single-Bundle Posterior Cruciate Ligament Reconstruction. Am J Sports Med 2023;51:1194–201. [Crossref]
21. Condello V, Beaufilis P, Becker R, Ahmad SS, Bonomo M, Dejour D , et al. Management of anterior cruciate ligament revision in adults: the 2022 ESSKA consensus: part II—surgical strategy. Knee Surg Sports Traumatol Arthrosc 2023; 31:4652–61. [Crossref]
22. Hees T, Zielke J, Petersen W: Effect of anterior tibial bowing on measurement of posterior tibial slope on conventional X-rays. Arch Orthop Trauma Surg 2022; 143:2959–64. [Crossref]
23. Alaia MJ, Kaplan DJ, Mannino BJ, Strauss EJ. Tibial Sagittal Slope in Anterior Cruciate Ligament Injury and Treatment. J Am Acad Orthop Surg. 2021;29: e1045–56. [Crossref]
24. Chen Y, Ding J, Dai S, Yang J, Wang M, Tian T, et al. Radiographic measurement of the posterior tibial slope in normal Chinese adults: a retrospective cohort study. BMC Musculoskelet Disord 2022;23:386. [Crossref]
25. Hinterwimmer S, Beitzel K, Paul J, Kirchhoff C, Sauerschnig M, von Eisenhart-Rothe R, et al. Control of Posterior Tibial Slope and Patellar Height in Open-Wedge Valgus High Tibial Osteotomy. Am J Sports Med 2011;39:851–6. [Crossref]
26. Utzschneider S, Goettinger M, Weber P, Horng A, Glaser C, Jansson V, et al. Development and validation of a new method for the radiologic measurement of the tibial slope. Knee Surgery, Sport Traumatol Arthrosc 2011;19:1643–8. [Crossref]
27. Yoo JH, Chang CB, Shin KS, Seong SC, Kim TK. Anatomical References to Assess the Posterior Tibial Slope in Total Knee Arthroplasty: A Comparison of 5 Anatomical Axes. J Arthroplasty 2008;23:586–92. [Crossref]
28. Winkler PW, Wagala NN, Hughes JD, Lesniak BP, Musahl V. A high tibial slope, allograft use, and poor patient-reported outcome scores are associated with multiple ACL graft failures. Knee Surgery, Sport Traumatol Arthrosc 2022;30:139–48. [Crossref]
29. Bixby EC, Tedesco LJ, Confino JE, Mueller JD, Redler LH: Effects of Malpositioning of the Knee on Radiographic Measurements: The Influence of Adduction, Abduction, and Malrotation on Measured Tibial Slope. Orthop J Sport Med 2023;11:23259671231164670. [Crossref]
30. Jahn R, Cooper JD, Juhan T, Kang HP, Bolia IK, Gamradt SC, et al. Reliability of Plain Radiographs Versus Magnetic Resonance Imaging to Measure Tibial Slope in Sports Medicine Patients: Can They Be Used Interchangeably? Orthop J Sport Med 2021;9:23259671211033882. [Crossref]
31. Gwinner C, Weiler A, Roider M, Schaefer FM, Jung TM: Tibial Slope Strongly Influences Knee Stability After Posterior Cruciate Ligament Reconstruction: A Prospective 5- to 15-Year Follow-up. Am J Sports Med 2017;45:355–61. [Crossref]
32. Dejour D, La Barbera G, Pasqualotto S, Valoroso M, Nover L, Reynolds R, et al. Sagittal Plane Corrections around the Knee. J Knee Surg 2017;30:736–45. [Crossref]
33. Samuelsen BT, Aman ZS, Kennedy MI, Dornan GJ, Storaci HW, Brady AW, et al. Posterior Medial Meniscus Root Tears Potentiate the Effect of Increased Tibial Slope on Anterior Cruciate Ligament Graft Forces. Am J Sports Med 2020;48:334–40. [Crossref]
34. Hees T, Petersen W. Anterior Closing-Wedge Osteotomy for Posterior Slope Correction. Arthrosc Tech 2018;7: e1079-e1087. [Crossref]
35. Kayaalp ME, Yilmaz H, Inoue J, Grandberg C, Hughes JD, Musahl V. Infratuberosity osteotomies require greater wedge resection and result in increased cortical mismatch compared to supratuberosity: A morphometric study supporting individualized planning in posterior tibial slope correction. Knee Surg Sports Traumatol Arthrosc 2025. Epub ahead of print. [Crossref]
36. Vieider RP, Bilodeau RE, Kayaalp ME, Hauer TM, Dias K, Cong T, et al. Failed anterior cruciate ligament reconstructions have both increased posterior tibial slope and increased posterior tibial plateau offset. J Exp Orthop 2026;13:e70620. [Crossref]
37. Lee SJ, Kim JH, Choi W. Factors related to the early outcome of medial open wedge high tibial osteotomy: coronal limb alignment affects more than cartilage degeneration state. Arch Orthop Trauma Surg 2021;141:1339–48. [Crossref]
38. Agneskirchner JD, Hurschler C, Stukenborg-Colsman C, Imhoff AB, Lobenhoffer P: Effect of high tibial flexion osteotomy on cartilage pressure and joint kinematics: a biomechanical study in human cadaveric knees. Arch Orthop Trauma Surg 2004; 124:575–84. [Crossref]

39. Ahmed AM, Burke DL: In-Vitro of Measurement of Static Pressure Distribution in Synovial Joints—Part I: Tibial Surface of the Knee. J Biomech Eng 1983;105:216–25.

40. LaPrade RF, Wentorf F: Diagnosis and Treatment of Posterolateral Knee Injuries. Clin Orthop Relat Res 2002;402:110–21. [Crossref]

41. Lephart SM, Pincivero DM, Rozzi SL. Proprioception of the Ankle and Knee. Sport Med 1998;25:149–55. [Crossref]

42. Strobel MJ, Weiler A, Schulz MS, Russe K, Eichhorn HJ. Arthroscopic evaluation of articular cartilage lesions in posterior cruciate ligament—Deficient knees. Arthrosc J Arthrosc Relat Surg 2003;19:262–8. [Crossref]

43. Rozinthe A, van Rooij F, Demey G, Saffarini M, Dejour D. Tibial slope correction combined with second revision ACLR grants good clinical outcomes and prevents graft rupture at 7–15-year follow-up. Knee Surgery, Sport Traumatol Arthrosc 2022; 30:2336–41. [Crossref]

44. Kayaalp ME, Inoue J, Nukuto K, Giusto JD, Ahrendt G, Hughes JD, et al. Posterior tibial slope increases over time in patients undergoing revision ACL reconstruction: A long-term radiographic follow-up study. Knee Surg Sports Traumatol Arthrosc 2025. Epub ahead of print. [Crossref]

45. Tigani D, Ferrari D, Trentani P, Barbanti-Brodano G, Trentani F. Patellar height after high tibial osteotomy. Int Orthop 2001;24:331–4. [Crossref]

46. Schuster P, Mayer P, Leiprecht J, Schüttler K-F, Richter J, Efe T. Individualized indication for slope changing osteotomy in ACL insufficiency: the Avalanche Concept. Arch Orthop Trauma Surg 2025;146:14. [Crossref]

47. Ollivier M, Mabrouk A, Parratte S, Kley K, Hirschmann MT. Beyond the posterior tibial slope: Rethinking anterior cruciate ligament (ACL) re-rupture risk through integrated scoring. Knee Surg Sports Traumatol Arthrosc 2026;34:804–14. [Crossref]

48. Dejour D, Bonin N, Locatelli E: Tibial antirecurvatum osteotomies. Oper Tech Sports Med 2000;8:67–70. [Crossref]

49. Lecuire F, Lerat JL, Bousquet G, Dejour H, Trillat A.The treatment of genu recurvatum (author's transl)]. Rev Chir Orthop Reparatrice Appar Mot 1980; 66:95–103. [Article in French]

50. Sonnery-Cottet B, Mogos S, Thaunat M, Archbold P, Fayard JM, Freychet B, et al. Proximal Tibial Anterior Closing Wedge Osteotomy in Repeat Revision of Anterior Cruciate Ligament Reconstruction. Am J Sports Med 2014;42:1873–80. [Crossref]

51. Kim TW, Lee S, Yoon J-R, Han H-S, Lee MC. Proximal tibial anterior open-wedge oblique osteotomy: A novel technique to correct genu recurvatum. Knee 2017; 24:345–53. [Crossref]

52. Moroni A, Pezzuto V, Pompili M, Zinghi G. Proximal osteotomy of the tibia for the treatment of genu recurvatum in adults. J Bone Joint Surg Am 1992;74:577–86. [Crossref]

53. Vivacqua T, Thomassen S, Winkler PW, Lucidi GA, Rousseau-Saine A, Firth AD, et al. Closing-Wedge Posterior Tibial Slope–Reducing Osteotomy in Complex Revision ACL Reconstruction. Orthop J Sport Med 2023;11:23259671221144786. [Crossref]

54. Clancy WG, Shelbourne KD, Zoellner GB, Keene JS, Reider B, Rosenberg TD. Treatment of knee joint instability secondary to rupture of the posterior cruciate ligament. Report of a new procedure. J Bone Jt Surg 1983;65:310–22. [Crossref]

55. Dickschas J, Strobel MJ, Weiler A, Lobenhoffer P, Simon M. Tibial Slope Correction as an Infratuberosity Closing-Wedge Extension Osteotomy in ACL-Deficient Knees. Z Orthop Unfall 2020;158:532–3. [Article in English, German] [Crossref]

56. Schuster P, Mayer P, Schubert I, Leiprecht J, Micicoi G, Reuter B, et al. Infratuberositary slope-decreasing anterior closed wedge proximal tibial osteotomy is safe and shows rapid bone healing. Knee Surgery, Sport Traumatol Arthrosc 2025, 33:1033–43. [Crossref]

57. Tensho K, Kumaki D, Yoshida K, Shimodaira H, Horiuchi H, Takahashi J. Posterior Opening-Wedge Osteotomy for Posterior Tibial Slope Correction of Failed Anterior Cruciate Ligament Reconstruction. Arthrosc Tech 2023;12: e2303–11. [Crossref]

58. Kanakamedala AC, Gipsman A, Lowe DT, Strauss EJ, Alaia MJ. Combined Anterior Opening-Wedge High Tibial Osteotomy and Tibial Tubercle Osteotomy with Posterior Cruciate Ligament Reconstruction. Arthrosc Tech 2022;11:e601–8. [Crossref]

59. Lott A, James MG, Kaarre J, Höger S, Kayaalp ME, Ollivier M, et al. Around-the-knee osteotomies part II: Surgical indications, techniques and outcomes – State of the art. J ISAKOS 2024, 9:658–71. [Crossref]

60. Bito H, Takeuchi R, Kumagai K, Aratake M, Saito I, Hayashi R, et al. Opening wedge high tibial osteotomy affects both the lateral patellar tilt and patellar height. Knee Surg Sports Traumatol Arthrosc 2010;18:955–60. [Crossref]

61. Peng H, Ou A, Huang X, et al.: Osteotomy Around the Knee: The Surgical Treatment of Osteoarthritis. Orthop Surg. 2021, 13:1465–73. [Crossref]

62. Bosco F, Giustra F, Giai Via R, et al.: Could anterior closed-wedge high tibial osteotomy be a viable option in patients

with high posterior tibial slope who undergo anterior cruciate ligament reconstruction? A systematic review and meta-analysis. Eur J Orthop Surg Traumatol 2022, 33:2201–14. [Crossref]

63. Tollefson LV, Rasmussen MT, Guerin G, LaPrade CM, LaPrade RF. Slope-Reducing Proximal Tibial Osteotomy Improves Outcomes in Anterior Cruciate Ligament Reconstruction Patients With Elevated Posterior Tibial Slope, Especially Revisions and Posterior Tibial Slope ≥12. Arthroscopy 2025;41:3184–95. [Crossref]

64. Kayaalp ME, Winkler P, Zsidai B, Lucidi GA, Runer A, Lott A, et al. Slope Osteotomies in the Setting of Anterior Cruciate Ligament Deficiency. J Bone Joint Surg Am 2024;106:1615–28. [Crossref]

65. Song G, Ni Q, Zheng T, Zhang Z, Feng H, Zhang H. Slope-Reducing Tibial Osteotomy Combined With Primary Anterior Cruciate Ligament Reconstruction Produces Improved Knee Stability in Patients With Steep Posterior Tibial Slope, Excessive Anterior Tibial Subluxation in Extension, and Chronic Meniscal Poster. Am J Sports Med 2020;48:3486–94. [Crossref]

66. Rodriguez AN, Schreier F, Carlson GB, LaPrade RF. Proximal Tibial Opening Wedge Osteotomy for the Treatment of Posterior Knee Instability and Genu Recurvatum Secondary to Increased Anterior Tibial Slope. Arthrosc Tech 2021;10: e2717–1. [Crossref]