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Acta Orthopaedica et Traumatologica Hellenica

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Acta Orthopaedica et Traumatologica Hellenica

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Instructions for Authors

1. Scope

"Acta Orthopaedica et Traumatologica Hellenica (AOTH)" is the official journal of the Hellenic Association of Orthopaedic Surgery and Traumatology, (HAOST) first published in 1948. The current edition of Acta Orthopaedica et Traumatologica Hellenica (AOTH) is published in English, online, without any article processing charges (APCs). It offers a compact forum of communication to orthopaedic surgeons and related science specialists. It publishes only peer reviewed articles. The peer review process is the established method for research validation in science whereby a work is critically assessed by expert referees demonstrating both the right level of knowledge in the field of the work, while being fully independent from it. Acta Orthopaedica et Traumatologica Hellenica (AOTH) follows a blind peer review process mediated and ensured by the Editor-in-Chief and the Editorial Board members. Aiming for clinically pertinent, scientifically correct, ethical, original and review quality research, only scientifically sound articles, deemed of high enough interest and originality that will receive favorable reports from our Editors/Reviewers Board will be accepted for publication.

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The journal accepts and publishes the following types of articles:

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Submissions should be done through the journal's website at https://eexot-journal.com. Manuscripts should be send to aothjournal@gmail.com. Submission should adhere to the journal's instructions with respect to the authorship, abstract, introduction (rationale of the paper), materials/methods, results, discussion, conclusions, references (format), illustrations and tables. Submissions not adhering to the journal's instructions will be send back to the authors for corrections that will delay the peer review process.

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Submission of a manuscript implies that the work described has not been published before; that it is not under consideration for publication anywhere else; that its publication has been approved by all co-authors, if any, as well as by the responsible authorities – tacitly or explicitly – at the institute where the work has been carried out. The Editors, the journal, and the Publisher will not be held legally responsible should there be any claims for compensation.

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Title page: It includes the title of the manuscript (concise, informative and capture of the message), the names of the authors, the affiliations of the authors, and the name, affiliation, address, e-mail address, and telephone number of the corresponding author.

Blinded manuscript: The manuscript should be blinded i.e. it should not include authors; names and affiliations.

Abstract and Keywords: An abstract and Keywords are required, as indicated above depending on the manuscripts types.

Text structure: the text of the Original Articles needs to be organized as follows: Introduction, Materials and Methods, Results and Discussion. Review Articles should include sections and subsections with appropriate headings depending on the topic; too many headings and subheadings should be avoided because they complicate reading. Case reports should include an Introduction, Case presentation, and Discussion. Pictorial Essays (Images papers) should include an Introduction and Discussion section only.

Abbreviations: Abbreviations should be used as minimum as possible, and should include only widely known and accepted abbreviations such as ORIF (open reduction and internal fixation), ICU (intensive care unit), etc. When used, they should be defined the first time they are used, followed by the acronym or abbreviation in parenthesis.

Acknowledgements, sponsorships and grants: Acknowledgements should be added at the end of the manuscript before the References section. It should read as follows: "The authors thank… or acknowledge….".

Measurement Units: All measurements should be mentioned in international units (SI). The full stop should be used as a decimal (i.e. 3.5 cm). Spaces should be added around the plus/minus symbol (i.e. 13.6 ± 1.2). There should not be any spaces around range indicators (i.e. 15-20) or equality/inequality symbols (i.e. r=0.37, p<0.005).

Figure and Tables: Figures and tables should be cited in the text consecutively in the order in which they appear. They should be cited in parentheses at the end of the respected sentence, and not be referred to in the text. They should be counted in Arabic numbers: i.e. (Figure 1) and (Table 1), and any Figure parts should be identified with lower case letters, i.e. (Figure 1a).

Figures need to be of high quality (minimum resolution of 1,200 dpi) in TIFF or JPEG format.

Patient anonymity should be ensured and patient identifying images such as intraoperative or clinical photographs should be avoided. All identifying data (name, identification numbers, initials) must be removed from text, images and tables.

Figures and Tables legends should be explanatory and appropriate (what the figures and tables show). The legends should be listed at the end of the text, after the References section. The Figures and Tables should not be embedded in the text, but they should be uploaded in separate respective files, named respectively, i.e. (Figure 1a).

Studies cited in the Tables should be cited according to the references list of the manuscript.

9. References

References section is not an afterthought but a continuum of the paper. They should be up to date and of acceptable quality. Their accuracy is the responsibility of the authors. They should be cited in the text in the order in which they appear. The numbering needs to be in Arabic numbers and formatted in superscript in the respective areas of the text, after the punctuation (i.e. .[1]).

All authors should be listed for all references of a manuscript.

When a book chapter is cited, the authors and title of the chapter, editors, book title, edition, city and country, publisher, year and specific chapter pages should be mentioned.

For Online Document, the following should be mentioned: authors (if any), title of page, name of institution or owner of Web site; URL; dates of publication, update, and access.

References examples:

Journal article:

Mavrogenis AF, Altsitzioglou P, Tsukamoto S, Errani C. Biopsy Techniques for Musculoskeletal Tumors: Basic Principles and Specialized Techniques. Curr Oncol. 2024;31(2):900-917. doi: 10.3390/curroncol31020067.

Sun J, Mavrogenis AF, Scarlat MM. The growth of scientific publications in 2020: a bibliometric analysis based on the number of publications, keywords, and citations in orthopaedic surgery. Int Orthop. 2021;45(8):1905-1910. doi: 10.1007/s00264-021-05171-6.

Kolovos S, Sioutis S, Polyzou M, Papakonstantinou ME, Karampikas V, Altsitzioglou P, Serenidis D, Koulalis D, Papagelopoulos PJ, Mavrogenis AF. The risk of DDH between breech and cephalic-delivered neonates using Graf ultrasonography. Eur J Orthop Surg Traumatol. 2024;34(2):1103-1109. doi: 10.1007/s00590-023-03770-0.

Book chapters:

Mavrogenis AF, Antoniadou T, Dimopoulos L, Filippiadis D, Kelekis A. Metastasis (Chapter 26). In: Textbook of Musculoskeletal Disorders. Vincenzo Denaro, Umile Giuseppe Longo (Eds). © Springer Nature. 2023. ISBN 978-3-031-20986-4.

Online document:

Copyright Registration Guidance: Works Containing Material Generated by Artificial Intelligence Available at: https://www.federalregister.gov/documents/2023/03/16/2023-05321/copyright-registration-guidance-works-containing-material-generated-by-artificial-intelligence. Published Feb 2023. Accessed on Jan 27, 2024.

10. Review and Proof reading of manuscripts

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Dear Colleagues,

Acta Orthopaedica et Traumatologica Hellenica (AOTH), the Official Journal of the Hellenic Association of Orthopaedic Surgery and Traumatology, is published since 1949 and is devoted to dissemination of news and information on all aspects of orthopaedic surgery.

Beginning from 2025, **all papers published in Acta Orthopaedica et Traumatologica Hellenica (AOTH) acquire a DOI (Digital Object Identifier); each published article acquires a specific DOI.** Scientific articles that acquire a DOI are identified as first-class articles immediately actionable on the network, therefore reachable to a great community of scientists all over the world.

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Sincere thanks,

Andreas F. Mavrogenis

Editor-in-Chief, Acta Orthopaedica et Traumatologica Hellenica (AOTH)

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For Authors

Writing for Acta Orthopaedica et Traumatologica Hellenica (AOTH)

Andreas F. Mavrogenis

Editor-in-Chief, Acta Orthopaedica et Traumatologica Hellenica (AOTH)

This article is addressed to the curious readers who may benefit of some simple rules on how to write a scientific paper. It offers advices and tips on medical writing for the junior authors and the less experienced in medical writing on how to prepare a quality submission. These tips apply to any author and any journal, and it is the Editor's personal view and experience in medical writing. Before starting the paper, search the related literature; choose quality papers that are electronically available; provide appropriate correct citations for any material previously published to avoid plagiarism. Before writing the paper, read the authors' instructions. These instructions will need to be met in any case.

Authorship

The number and the order of the authors' names should be fair by reflecting their contribution and the order of their contribution to the manuscript. Those who authored should be listed as authors of the manuscript. Those who have contributed to the work, but not enough to merit their inclusion in the authorship, should be acknowledged in the acknowledgment section. Authorship is not a way to thank a colleague for support, access to resources, or mentorship. Scientific misconduct (fraud) in authorship includes a gift or complimentary authorship, ghost authorship, and coercion authorship.

Title

It should be short and concise; it should capture the message. Titles raising or answering questions will far be more appealing than titles merely pointing to the topic. Do not use run-on (long and busy) titles.

Abstract

It should include all the important information from each section that is the background, questions/purposes, materials/methods, results, and conclusions. The readers should be able to understand the total paper by just reading the Abstract. Some read only the Abstract (e.g., because they do not have the time or access to the full text). Keywords are important for indexing and should be chosen carefully.

Introduction (approximately 500 words)

It is the most critical section. It should start with focus on the topic. General and irrelevant information should be avoided. The first paragraph should present the background. The second paragraph should present what is important on the topic. Appropriate citations (the related studies) should be added. These studies should be further discussed at the discussion section.

The section should end with a clear rationale. Questions to be asked when formulating the rationale are the following: (1) What is missing from the literature for this study to merit publication? (2) How does this study add to the related literature? (3) Does it confirm or reject previous reports? After the rationale, the purposes of the study (study questions or hypotheses) should be listed. The purposes may be primary (the most important) and secondary (the least important). Writing should be clear and concise.

Materials and Methods (approximately 1000–1500 words)

The section should start with the Materials in brevity and clarity. An example could read as follows: *"We present ….. patients admitted and treated at the authors' institution with …… from 2000 to 2024. There were … men and … women with a mean age of … years (range, ….. years)"*. These two sentences provide almost all basic demographic information of the materials of the study. Follow-up is materials and should be provided here; the same for loss to follow-up including the reasons for the loss. Clinical reports must state inclusion and exclusion criteria and whether the series is consecutive or selected; if selected, criteria for selection should be stated. These should inform the readers for any sources of bias.

When reporting clinical studies, the authors must state informed consent (where appropriate) and approval of the institutional review board or ethics committees of their institution. These should be added at the first paragraph of the Materials and Methods sections as follows: *"All patients gave written informed consent for their data to be included in this study. This study was approved by the Institutional Review Board (IRB)-Ethics Committee of the authors' institution"*. Alternatively, *"Informed consent was not necessary for review articles" or "IRB and Ethics Committee approval was not necessary at the authors' institution for retrospective studies"*.

The Methods should contain adequate detail for another investigator to replicate the study. The authors should clearly present what they did and how they did it in the study and analysis. The Methods should be validated with appropriate citations such as for a used score, method, classification, etc.

If authors use statistical analysis, a paragraph should appear at the end of Materials and Methods stating all statistical tests used. When multiple tests are used, the authors should state which tests are used for which sets of data. The level of statistical significance is 0.05 in most cases.

Results (approximately 500 words)

It should be the answers to the study questions in the same order as formulated in the rationale at the last paragraph of the Introduction section. it is easier and more informative to format the study answers (results) in paragraphs. Each paragraph should start with a key statement of the most important result, and then the description and statistical analysis should follow.

The authors should provide which group/method/ analysis is more significant compared to another and parenthetically state the p-value immediately after the comparative terms. Provide the actual p-values instead of p-values greater or lesser than 0.05. Parenthetic reference to all figures and tables enables easier interpretation of the data. Avoid too many numeral data in tables because it complicates and fatigues reading.

Discussion (approximately 1500-3000 words)

The Discussion should start with a restatement of the problem or question in brief for emphasis, followed by the study findings and a synthesis of the comparison and the author's new data to arrive at conclusions.

The second paragraph should be the limitations. I prefer the readers should be informed early for the limitations of the study. Failure to explore the limitations suggests the authors either do not know or choose to ignore them, potentially misleading the reader.

In the next paragraphs the authors should discuss their findings in comparison to the literature. They should synthesize their data with that in the literature. The text should be formatted in paragraphs respective to the study questions/ answers. Appropriate and quality studies should be used. Generally, many of these reports will include those cited at the Introduction section. A Table that summarizes the results of the most important published related studies would be useful here (refer to papers with similar tables for the format).

The ultimate paragraph of the section should be the conclusions. The conclusions should be based solely on data that come out of the paper. Conclusions irrelevant of the study findings should not be used. General and philosophical statements should be avoided. Statements such as "need for further research" or "need for future studies" should be avoided because they underpower the study.

References

Choose quality references, and read the most important papers in full text; approximately 25% of the references used in the references list of a paper are actually read by the authors when writing the paper. References should be accurate and up-to-date. Electronically available citations should be preferred; abstracts and submitted articles (pending publication), newsletters, proceedings, and meetings syllabus should not be used because many in these categories ultimately do not pass peer review because it is not possible to be traced and cited. Use citations from the journal to submit your paper; this will gain the Editor that you are aware of the journal; it will increase the visibility of the paper and the impact of the journal.

Figures and Tables

Figures and tables should complement not duplicate material in the text. They present information that would be difficult to describe in text form. Well-written papers contain one or two tables or figures for every study question/purpose posed in the Introduction. The legends should be explanatory and concise; what the figure/table show.

References

1. Brand RA. Writing for clinical orthopaedics and related research. Clin Orthop Relat Res. 2008;466(1):239-47. doi: 10.1007/s11999-007-0038-x.
2. Mavrogenis AF, Auffret Babak I, Caton JH. Writing for SICOT-J. SICOT J. 2021;7:E1. doi: 10.1051/sicotj/2021042.
3. Mavrogenis AF, Scarlat MM. Writing for "International Orthopaedics": authorship, fraud, and ethical concerns. Int Orthop. 2021 Oct;45(10):2461-2464. doi: 10.1007/s00264-021-05226-8.

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Editorial

Generation Z in orthopaedic surgery

Andreas F. Mavrogenis

A new generation evolves every 15 to 20 years. Each generation shows complexities and interactions between generations that are interesting and true (Table). Generation Z, also known as Gen Z, Zoomers, post-Millennials, Zers, iGeneration, Internet generation, Homeland generation, Founders, Pivotals, Generation nice, Screenagers, Share generation, Centennials, and Plurals, is the name given to the generation of young people born in the late 1990s up to the early 2000s. They are the successors to generation Y (Millennials) and precede generation Alpha (the children of Millennials).[1-4] Generation Z is the first generation to be born into the world of Internet, smart devices and apps. They spend more time on electronic devices, and on the Internet than any previous generation. Their smartphone is an extension of their hand, and their smartwatch does more than just tell time. Currently, generation Z are the people in orthopaedic residency and early practice.[1-4]

The first members of generation Z entered residency programs in 2020, and currently many are working in hospitals as residents or junior physicians.[1-4,8] Zoomers believe the practice of medicine should not be exhausting, but fulfilling. They dislike spending long periods of time listening to lectures, and they mirror their experiences in social media. Meetings and hospital duties should be minimal and absolutely scheduled in order to ensure a good quality of life, and accompanied by a defined period of daily work that should not be exceeded.[1,4] Working less and paid more will be the attitude in the practice of medicine.[1,4,8]

Figure. *Generation Z surgeon in practice.*

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Table. Summary of social generations and their characteristics.

Characteristics	**Lost generation**	**Greatest generation**	**Traditionalist generation**	**Baby boomers**	**Generation X**	**Generation Y (Millennials)**	**Generation Z**	**Generation A**
Birth dates	1880-1900	1900-1930	1930-1945	1945-1965	1965-1980	1980-1995	1995-2015	2015-2020s
Description	The young people who came of age around the time of World War I (the Generation of 1914; la Génération du feu; the [gun]fire generation)	The young people who came of age around the time of World War II (the G.I. generation; the WWII generation)	The silent generation (a small generation because of effect of the Great Depression and World War II)	The people born after the World War II during the mid-20th century baby boom (noticeable increase in the birth rate, The Boomers), during and after the Vietnam War, during the Vietnam War, the Civil Rights eras and the Watergate scandal.	The children and young people returning from school to an empty home and needing to use a key to let themselves in the house (The Latchkey Generation) because of free-range parenting (decrease fertility, increased divorce rates, increased maternal participation in the workforce, and decreased childcare options outside the home)	The oldest people of this generation became adults with the turn of the millennium (the Millennials), the first people to grow up with the internet (The Digital or the Global generation), the people who tend to return a call with a text message (The Texters), the people who experienced the slower economic growth and more recessions since entering the workforce than any other generation (the Unluckiest Generation). The majority are the children of Baby Boomers	The first people to have grown up with access to the internet and portable digital technology from a young age The majority are the children of younger Baby Boomers or Generation X	The first people to be born entirely in the 21st century and the third millennium (the Alpha generation) The majority are the children of Millennials
Historical notes	World War I, Industrial Revolution	World War II, Great Depression	World War II. Great Depression	Space exploration, nuclear threat	Vietnam War, end of Cold War, September 11 terrorist attacks	The turn of the millennium	Terrorism, social networking, smartphones, shared family responsibilities, gender equality, climate change	COVID-19 pandemic, climate change (will be significantly more affected by any other generation)
Technologies	Radio (soap operas, music, sport, educational broadcasts, news, political propaganda)	Rapid technological innovation (radio, telephone, automobile)	Industry Energy (radio, newspaper, television)	Plastics, television, magnetic tape, transistors, integrated circuits, and lasers	Mass media, increasing rise of the internet, computers and social media	Internet, computers, social media, mobile devices, and technology in general, developments in artificial intelligence and robotics	Information and communications technologies, social media networking	Information and communications technologies, social media networking, streaming services, parental internet use, decreasing interest in traditional television
Education	Laws restricting child labour. Compulsory education	The average educational attainment was less than 9 years (compared to 12 years for their children)	Compulsory education from the age of 5-14 years old Reading comics, playing board games, going to the cinema, and joining children's organizations such as the scouts	Modern mathematics (Bourbaki school), physics, college education, traditional classroom setting, focus on lectures and textbooks, often self-directed learners and valued face-to-face interactions with their teachers	Comprehensive school training, continued growth in college enrolments	More better educated people from developing nations, more people with high-school diplomas and Bachelor's degree, many jobs were suitable for remote work due to modern technology (backlash against immigration and globalization)	High enrolment in primary schools and colleges in both developed and developing countries, favour innovative educational and training solutions, pragmatic, tech-savvy, and flexible personalized education that is aligned with their career aspirations	Increasing use of technology in classrooms and other aspects of life, born into a world overflowing with knowledge provide a unique educational model and demands special opportunities and innovative approaches from teachers

Characteristics	**Lost generation**	**Greatest generation**	**Traditionalist generation**	**Baby boomers**	**Generation X**	**Generation Y (Millennials)**	**Generation Z**	**Generation A**
Birth dates	1880-1900	1900-1930	1930-1945	1945-1965	1965-1980	1980-1995	1995-2015	2015-2020s
Health and welfare	Sewer systems to remove human waste, legal standards for the quality of drinking water, gas lights and candles	Electricity, flourishing of literature, arts, music, and cinema	Economic conditions and living standards improved significantly, unemployment rested (2%) and consumer goods became common, abortion and homosexuality were illegal, reformed marriage laws allowed for increased divorces	Optimism, economic prosperity, a growing middle class, and tremendous improvements in the standards of living for the average citizen in the developed world (the average person could live like the upper class in the previous generation)	The first to come of age with MTV and music videos, largely responsible for the indie film movement Possibly higher risk of heart attacks because of high-blood pressure, diabetes, and chronic kidney disease	Social networking (Facebook and Twitter) The highest rates of overweight and obesity, strokes, heart attacks, drug addiction and overdoses, mental health issues, dental and oral health issues	Reliant to the internet to research their options and to place orders, relatively high income and high spending habits Health and mental health issues, screen time effects, sleep deprivation, cognitive abilities, myopia, food allergies, obesity, arthritis, stroke, anxiety, depression, early puberty, cyberbullying	Decreasing fertility rates because of rising standards of living, higher access to contraceptives, and more educational and economic opportunities Health and mental health issues, screen time effects, allergies, obesity and malnutrition
Attributes	Rejection of: materialism, youthful idealism, and the American Dream	Self-sacrifice, frugal consumers and prudent savers.	Self-sacrifice, traditional, conservative in experience and attitudes (the people who believes the old ways are best)	Altruism and intellectual stimulation, less self-centered, optimism, rule follow, lived to work	Unimpressed,high self centered, sceptical, reject rules	Hopeful, high self centered, re-write rules	More educated, well-behaved, sceptical, stressed and depressed compared to previous generations, heavily influenced by trends promoted by influencers on social media, need to be trendy	Digital natives and spending hours in front of screens, engagement with diverse artificial intelligence technologies, environmentally conscious
Authority	Aimless, disoriented, wandering, directionless spirit	Respectful, patriotic	Respectful, often serving as role models for other generations	Respectful, love/ hate, altruism	Individualists, entrepreneurial spirit	Informal, seek autonomy	Seek autonomy, give immediate feedback (texters)	Diverse
Leadership	Confusion and aimlessness in the early post-war years.	Hierarchy, committed and loyal	Hierarchy, professionalism, and dedication	Consensus, hierarchy, less self-centered	Competence-based	Team-based	Dislike micromanagement, more concerned than older generations with academic performance, job prospects, and delaying gratification	To be seen
Reward style	Focused on material wealth, unable to believe in abstract ideals	Job well done, modestly living, strong work ethics	Job well done, strong work ethics	Money, title, work to save for retirement	Freedom, values security and independence, achieving a work-life balance, work to live	Transparency in working, meaningful work, economic return values, work and enjoy	Transparency in working, meaningful and challenging work, values purpose, ethics and life at work balance, live and enjoy	To be seen

Generation Z surgeons spend less time reading books. Nonetheless, they are very educated, mostly because they have continuous digital access to an enormous amount of knowledge and information from the Internet. However, although they are skillful at finding information, often they do not analyze that information for validity and accuracy; if the information appears on the web it is assumed *de facto* accurate and true.[1-4]

Generation Z are less politically correct in their daily behavior, and they are very dedicated to their overall personal wellness.[3] They are less self-confident and less likely to ask questions due to insecurity and anxiety. They have an increased acceptance of sexual and gender fluidity and reject gender stereotypes.[1] Their addiction to digital life creates deficits in attention spans, vocabulary, and performance at university; 40% of generation Z people self-identify as digital device addicts, and another 40% report feeling bad about themselves as a result of social media.[1] Only 60% of generation Z are optimistic about their future compared to 89% of Millennials, and 28% are motivated by money compared to 42% of Millenials.[6] At least 75% of generation Z are not happy with email, they find it takes too much time and is too formal, and approximately 70% of generation Z and Millennials will prefer to reply with a text message than answer or return a telephone call (the generation of texters). The potential reasons for this are the anxiety associated with real-time conversations, potential awkwardness, not having the answers and the pressure to respond immediately. Most conversations take place on social media with images, memes and emoticons alongside texts.[7] A further complication to their educational development is their inability to concentrate. The attention span for Millennials was 10 minutes, but for generation Z it is 6 minutes and may be as short as 8 seconds when using a digital device.[1,9]

It is concerning that generation Z curriculum vitae are short, and they exhibit more difficulty in writing a medical paper than previous generational cohorts.[4,10-12] Most seem to be seeking the easy way; they misuse the Internet and Artificial Intelligence (AI) tools to write, translate, and correct medical papers. This is acceptable if performed correctly; however, AI should not replace a well-crafted human manuscript, and if used it should be acknowledged and disclosed.[10,11]

At AOTH, we have adapted our editorial policy to meet the preferences of young authors; we encourage them to write and submit their papers to be considered for publication at the journal, and we have reserved a special section in the journal for papers submitted by young scientists. We hope that AI will become more helpful than harmful in continuous medical education and academic writing.

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Original

Ankle syndesmotic injuries: short-term radiological outcomes and complications following tightrope fixation

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Abstract

Introduction: Ankle syndesmotic injuries are complex and require accurate reduction and stabilisation to restore normal ankle biomechanics. While traditional screw fixation is widely used, it carries risks such as screw loosening, breakage, and the need for secondary removal. The suture-button Tightrope system offers dynamic stabilisation and facilitates earlier mobilisation. This study aimed to evaluate radiographic stability and complications associated with the ankle Tightrope technique for ankle syndesmotic injuries at our institution.

Methods: We retrospectively reviewed 83 patients (mean age, 41.3 years) who underwent ankle Tightrope fixation for syndesmotic disruption between 2013 and 2023. Demographic data, injury characteristics, procedural details, radiographic parameters, and complications were systematically analysed.

Results: Tightrope fixation demonstrated a statistically significant improvement in syndesmotic parameters (MCS, TFO and TFCS), maintained throughout follow-up. Most patients achieved early weight-bearing within 6 weeks with a prolonged median follow-up of 20.4 weeks. The overall complication rate was 13.2%, with very low incidences of infection, device migration, button malposition, and syndesmotic diastasis. There were no cases of aseptic osteolysis, peri-implant fracture, or revision fixation.

Conclusions: Tightrope fixation provides a reliable, safe, and minimally invasive alternative to screw fixation for syndesmotic injuries, maintaining anatomical reduction with low complication rates. Its use facilitates early weight-bearing and accelerated rehabilitation, providing a reproducible and effective strategy for both isolated and fracture-associated syndesmotic disruptions.

Keywords

Ankle fractures; tightrope fixation; radiographic outcome; complications

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Introduction

Ankle fractures are a common orthopaedic injury in England and Wales, with an estimated annual incidence of at least 15 cases per 10,000 people.[1] About 13% of ankle fractures and 0.5% of ankle injuries without fracture are associated with distal tibiofibular syndesmotic injury, which, if left untreated, can result in ankle instability, chronic pain, and post-traumatic arthritis.[2,3] Accurate diagnosis, anatomical reduction, and stable fixation of the syndesmosis are essential to promote healing of the syndesmotic complex and to restore anatomy, biomechanics and normal function of the ankle. The optimal technique for syndesmotic stabilisation remains debated. Traditionally, rigid fixation with cortical screws has been standard; however, screw loosening, breakage, and the need for secondary removal are frequent issues. Also, Prolonged immobilisation and non-weight bearing or protected weight bearing can be associated with morbidity.

Furthermore, premature removal of screws before ligament healing increases the risk for ankle diastasis. The fibre-wire Tightrope system (Arthrex, Inc., USA) has emerged as a viable alternative to conventional screw fixation, offering biomechanical advantages and the potential for earlier postoperative mobilisation. However, Tightrope fixation is associated with its own complications.

This study aims to investigate the radiographic outcomes and complication rates associated with Tightrope fixation for syndesmotic injuries treated at our institution over a ten-year period.

Materials and methods

We retrospectively reviewed all cases (>16 years) of acute isolated ankle syndesmotic injury, either alone or in combination with an ankle fracture, treated with Arthrex ankle Tightrope at our institution between November 2013 and August 2023. A total of 91 patients were treated during this period. Exclusion criteria included inadequate medical records, insufficient imaging, clinical follow-up of less than 12 weeks, open fractures, uncontrolled diabetes, peripheral neuropathy, and pathological fractures. Details of excluded patients were as follows: 2 had inadequate medical records, 2 had inadequate imaging, 3 cases had follow-up less than 12 weeks, and one patient had an open fracture. Finally, 83 patients were eligible for inclusion in the current study.

Syndesmotic diastasis was defined by tibiofibular clear space (TFCS) >6 mm on anteroposterior or mortise radiograph, tibiofibular overlap (TFO) <6 mm on anteroposterior radiograph 10 mm proximal to the tibial plafond, or <1 mm on mortise radiograph, or medial clear space (MCS) greater than the superior joint space or >5 mm on anteroposterior radiograph.[4,5] Diagnosis of syndesmotic disruption was confirmed using preoperative plain radiographs and intraoperative fluoroscopic assessment, evaluating TFCS, TFO, and MCS parameters.

Surgical technique

All procedures were performed with the patient in the supine position under either general or regional anaesthesia, using a thigh tourniquet. Fracture fixation followed AO-ASIF principles. Fibular fractures were addressed first, typically using a one-third tubular plate or locking plate, with or without lag screws. In cases of high fibular fractures (>15 cm proximal to the tip of the lateral malleolus), syndesmotic fixation alone was performed. Medial malleolar fractures were stabilised using partially threaded cancellous screws or a tension band wire (TBW) construct. Assessment for syndesmotic injury was conducted intraoperatively utilising a combination of the hook test, stress dorsiflexion, and external rotation manoeuvres, with radiographic evaluation of medial clear space (MCS), tibiofibular overlap (TFO), and tibiofibular clear space (TFCS) under image intensification. When syndesmotic widening was identified, stabilisation was achieved using the Arthrex Tightrope fixation system, applied through the fibular plate in accordance with the manufacturer's recommended technique.[6] In most cases, Tightrope fixation was performed through two or three holes of a one-third tubular plate, particularly in isolated syndesmotic injuries or Maisonneuve-type fractures. The number of Tightropes used was determined at the discretion of the operating surgeon.

Post-operative management

Wound sutures were removed at two weeks post-operatively. All patients were immobilised in below-knee casts or protective boots and instructed to remain non-weight-bearing for six weeks. This was followed by a structured physiotherapy programme focusing on ankle range of motion, proprioceptive training, and gradual progression to full weight-bearing as tolerated, subject to satisfactory radiographic evaluation. Clinical assessments and weight-bearing radiographs were performed during follow-up visits in the fracture clinic.

Table 1. Demographics and patient summary results

Demographics	**Results** **Number/%/Mean/range/+/- SD** **(N=83)**
Age	Mean 41.33 (range 17-73 years)
Sex	
Men	48 (57.8%)
Women	35 (42.2%)
Side	
Right	38 (45.8%)
Left	45 (54.2%)
Smoker	30 (36.1%)
Diabetic	7 (8.4%)
ASA	
1	52 (62.7%)
2	28 (33.7%)
3	3 (3.6%)
BMI	30.35 (range 19-44.2)
Injury pattern	
Weber B fractures	17 (20.5%),
Weber C fractures	52 (62.7%)
Bimalleolar fractures	25 (30.1%)
Trimalleolar fractures	2 (2.4%)
Unimalleolar fractures	47 (56.6%)
Maisonneuve fractures	4 (4.8%)
Pure syndesmotic injury	5 (6%)
Injury surgery interval	4.16 days (range 1-25 days)

Radiographic Findings-(mm)	
Pre-op	
MCS	6.13+/-1.95
TFO	1.87+/-2.77
TFCS	7.87+/-1.71
Initial post Op-	
MCS	2.70+/-0.67
TFO	6.68+/-0.57
TFCS	4.71+/-0.66
Final follow up	
MCS	2.80+/-0.67
TFO	6.56+/-0.54
TFCS	4.86+/-0.67
No of Tightrope	
Single Tightrope	53 (63.9%)
Double Tightrope	30 (36.1%)
Distance from the tibial plafond	
Single tightrope	17.65 mm (range 7.1mm-32.3mm)
Double Tightrope	12.3 mm(range 7.1 mm-20.1mm) and 26.3 (range 15.7mm-38.6 mm).
Time to full weight bearing	6.01 weeks (range 5-8 weeks)
Post operative Immobilisation	
Cast	81 (97.6%)
Boot	2 (2.4%)
Formal Physiotherapy	54 (65.1%)
Ankle Exercise leaflets provided only	29 (34.9%)
Follow up	20.35 weeks (range 12-88 weeks).

Abbreviations: MCS – Medial clear space; TFO – Tibiofibular overlap; TFCS – Tibiofibular clear space.

Radiographic analysis included preoperative, initial postoperative, and final follow-up weight-bearing anteroposterior views, with measurements of medial clear space (MCS), tibiofibular overlap (TFO), and tibiofibular clear space (TFCS). The integrity of the Tightrope construct was assessed by comparing these parameters between the initial postoperative and final follow-up radiographs. A change in syndesmotic width exceeding 2 mm was considered the threshold for clinically significant widening.[7,8,9] All measurements were performed using digital radiographic software (PACS/Sectra).

Medical, operative, and radiographic records were systematically reviewed. Data collected included patient demographics, ASA classification, body mass index (BMI), smoking status, injury type, fracture pattern, associated comorbidities, time interval from injury to surgery, operative details, number of Tightropes used, distance of Tightrope placement from the ankle plafond, methods of fracture fixation, postoperative immobilisation protocol, weight-bearing status, physiotherapy involvement, duration of follow-up, and documented complications.

The recorded complications included infection, revision surgery, suture button removal, persistent unexplained pain, re-diastasis or syndesmotic widening, knot irritation, osteolysis, medial button malposition, and intraosseous migration of the lateral or medial button.

Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 31.0. A p-value <0.05 was considered statistically significant. Comparisons between groups were made using the two-sample independent *t*-test.

Results

A total of 83 patients were included in the study, comprising 48 males (57.8%) and 35 females (42.2%), with a mean age of 41.3 years (range: 17–73 years). The left ankle was affected in 45 cases (54.2%) and the right in 38 cases (45.8%). Thirty patients (36.1%) were regular smokers, and seven patients (8.4%) had diabetes. The majority were classified as ASA grade I or II (96.4%). Details of injury patterns are shown in Table 1. The most common fracture configurations were Weber C (52 patients, 62.7%) and unimalleolar fractures (47 patients, 56.6%). Pure syndesmotic injuries without associated fracture were observed in only five patients (6%). The mean body mass index (BMI) was 30.35 (range: 19–44.2). The average interval between injury and surgery was 4.16 days (range: 1–25 days). A single Tightrope device (Figure 1) was used in 53 cases (63.9%), while double Tightrope (Figure 2) fixation was employed in 30 cases (36.1%). In single Tightrope cases, the mean distance from the tibial plafond was 17.65 mm (range: 7.1–32.3 mm). For double Tightrope constructs, the mean distances were 12.3 mm (range: 7.1–20.1 mm) and 26.3 mm (range: 15.7–38.6 mm), respectively. The mean time to full weight-bearing was 6.01 weeks (range: 5–8 weeks). Postoperative immobilisation included below-knee casts in 81 patients and protective boots in 2 patients. Formal physiotherapy was undertaken by 54 patients (65.1%). The average follow-up duration was 20.35 weeks (range: 12–88 weeks). A comprehensive summary of demographics and clinical variables is provided in Table 1.

Radiographic measurements of medial clear space (MCS), tibiofibular overlap (TFO), and tibiofibular clear space (TFCS) were evaluated at three time points: preoperatively, initial postoperative period, and at final follow-up. The mean preoperative values were 6.13 ± 1.95 mm (MCS), 1.87 ± 2.77 mm (TFO), and 7.87 ± 1.71 mm (TFCS). Following Tightrope fixation, initial postoperative measurements showed significant improvement across all parameters: MCS decreased to 2.70 ± 0.67 mm, TFO increased to 6.68 ± 0.57 mm, and TFCS decreased to 4.71 ± 0.66 mm. These changes were statistically significant ($p < 0.001$ for all), confirming effective syndesmotic reduction. (Table 2) Also, at final follow-up, weight-bearing radiographs demonstrated sustained stability. The mean values were 2.80 ± 0.67 mm (MCS), 6.56 ± 0.54 mm (TFO), and 4.86 ± 0.67 mm (TFCS). Comparison between initial postoperative and final follow-up measurements revealed no statistically significant differences: MCS increased by 0.10 mm ($p = 0.33$), TFO decreased by

Table 2. Comparison of MCS, TFO and TFCS between preoperative and initial post-op (n = 83)				
	Preoperative (mm)	**Initial postoperative (mm)**	**Mean Difference (mm)**	***P*-value**
MCS	6.13 ± 1.95	2.70 ± 0.67	–3.43	<0.001
TFO	1.87 ± 2.77	6.68 ± 0.57	+4.81	<0.001
TFCS	7.87 ± 1.71	4.71 ± 0.66	–3.16	<0.001

Note: Values are expressed as mean ± standard deviation. *P*-values calculated using a paired *t*-test.

Table 3. Comparison of MCS, TFO and TFCS between initial post-op and final follow-up (n = 83)				
	Initial Post op (mm)	**Final Follow up (mm)**	**Mean Difference (mm)**	**P value**
MCS	2.70+/-0.67	2.80+/-0.67	0.10	0.33
TFO	6.68+/-0.57	6.56+/-0.54	0.12	0.165
TFCS	4.71+/-0.66	4.86+/-0.67	0.15	0.149

Table 4. Complications of ankle Tightrope fixation	
Complications	**No (%)**
Overall complication	**11 (13.2%)**
Knot/suture irritation	1 (1.2%)
Infection	
-Superficial	1 (1.2%)
-Deep/osteomyelitis	1 (1.2%)
Re diastasis/widening of syndesmosis	1 (1.2%)
Removal of suture button due to problem with button	2 (2.4%)
Medial intraosseous migration button	1 (1.2%)
Lateral intraosseous migration button	1 (1.2%)
Malposition of medial endobutton	2 (2.4%)
Unexplained chronic pain	1 (1.2%)

0.12 mm ($p = 0.165$), and TFCS increased by 0.15 mm ($p = 0.149$). All changes remained within the accepted threshold of ≤2 mm, indicating durable syndesmotic fixation throughout the follow-up period. (Table 3)

The overall complication rate directly attributable to Tightrope fixation was 13.2%. Knot irritation on the lateral aspect was reported in one patient (1.2%), and one patient (1.2%) developed a superficial infection at the knot site, which was successfully treated with oral antibiotics. One patient (1.2%) experienced a deep in-

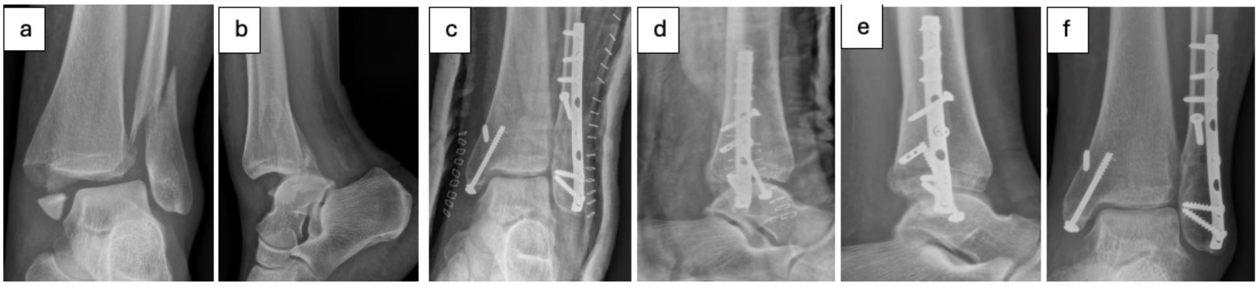

Figure 1: X-ray images of a patient with the tri-malleolar ankle fracture dislocation associated with syndesmosis injury fixed with a single Tightrope: Preoperative (a, b), Early Postoperative (c, d), and Final Follow-up (e, f).

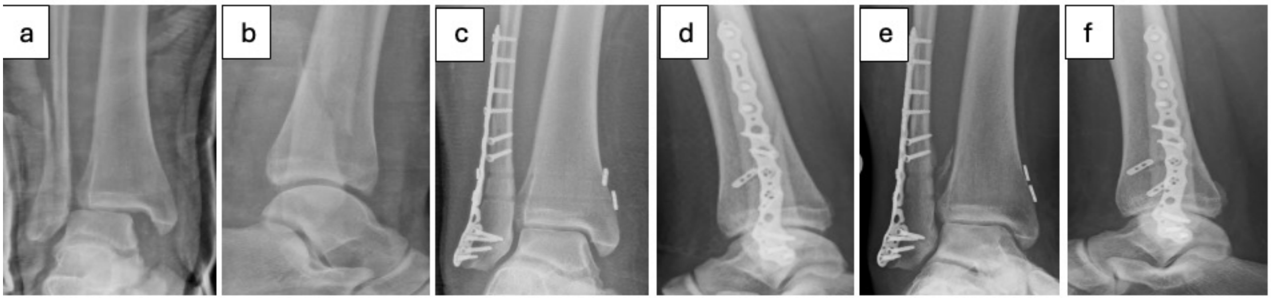

Figure 2: X-ray images of a patient with the bimalleolar ankle fractures associated with syndesmosis injury fixed with a Double Tightrope: Preoperative (a, b), Early Postoperative (c, d), and Final Follow-up (e, f).

fection that required surgical debridement and removal of both the Tightrope and the associated metalwork. Migration of the suture button was observed in two cases: one (1.2%) with intraosseous lateral migration in a patient where a Tightrope was applied without a fibular plate, and one (1.2%) with intraosseous medial migration. Malposition of the medial Endobutton occurred in two patients (2.4%). None of the patients with minimal intraosseous migration had any syndesmotic widening or diastasis. One patient (1.2%) reported persistent unexplained ankle pain, and another (1.2%) developed syndesmotic diastasis, which was managed conservatively as the patient declined revision surgery. Tightrope removal was performed in two patients (2.4%): one due to deep infection at 11 months and the other due to knot irritation at 12 months. In both cases, wound healing was uneventful post-removal, and no syndesmotic widening or residual pain was noted at final follow-up. A detailed summary of complications is presented in Table 4. There were no cases of aseptic osteolysis, peri-implant fracture, or revision fixation. Additionally, one patient underwent removal of all metalwork, including the Tightrope, due to a prominent fibular plate—this was not directly related to the Tightrope device. Three patients with Weber C fractures experienced chronic ankle pain attributed to underlying osteoarthritis rather than implant-related complications. Two patients reported moderate ankle stiffness during early follow-up, which resolved with physiotherapy.

Discussion

Ankle fractures associated with syndesmotic disruption are complex injuries that require accurate recognition, anatomical reduction, stable fixation, and progressive rehabilitation to optimise long-term outcomes and reduce the risk of post-traumatic degenerative arthritis. Despite their clinical importance, there is no established consensus on the optimal management of these injuries. Traditionally, metallic screw fixation has been the preferred method for syndesmotic stabilisation. However, the literature reflects considerable variability regarding screw type, size, number, positioning, cortical engagement, and protocols for removal, including timing and necessity.[2,3] Moreover, screw fixation is associated with several complications, including excessive rigid fixation, screw loosening (up to 20%), breakage (up to 28%), syndesmotic malreduction (reported as high as 52%), and the need for prolonged protected weight-bearing.[10–12]

Ankle Tightrope fixation devices have gained considerable popularity over the past 10–15 years. This low-profile system, implanted across the syndesmosis via a minimally invasive approach, offers dynamic stabilisation that accommodates physiological micromotion while maintaining accurate reduction. Compared to screw fixation, Tightrope devices provide effective resistance to diastasis, facilitate earlier weight-bearing, eliminate the need for routine implant removal, reduce malreduction rates, and are associated with an earlier return to work and improved functional outcomes.[10, 14–16]

Tightrope fixation demonstrated reliable radiographic and clinical outcomes in our cohort. Postoperative improvements in medial clear space (MCS), tibiofibular overlap (TFO), and tibiofibular clear space (TFCS) were statistically significant and sustained at final follow-up. Displacement between initial postoperative and final weight-bearing radiographs (MCS 0.10 mm, TFO 0.12 mm, TFCS 0.15 mm) remained well below thresholds for syndesmotic widening, indicating robust fixation and preserved reduction. These findings are consistent with current literature. Long-term data from Grassi et al. and Ræder et al. support the durability of suture button constructs and their association with reduced reoperation rates.[17,18] Migliorini et al. reported superior functional outcomes, fewer complications, and lower malreduction rates compared to screw fixation.[19] Fabião et al. confirmed sustained radiographic stability in isolated syndesmotic injuries.[20] Anand et al. observed a satisfactory reduction in 97% of Weber C fractures treated with Tightrope, further validating its radiographic reliability.[21]

The mean time to full weight-bearing in our cohort was 6.01 weeks, with 65.1% of patients receiving formal physiotherapy. Voight et al. reported return-to-sport timelines of less than eight weeks following Tightrope fixation combined with a structured rehabilitation programme.[22] The dynamic nature of suture button constructs allows early mobilisation without compromising stability, offering a distinct advantage over screw-based fixation, which often necessitates delayed weight-bearing and implant removal. Patel et al. further demonstrated that hybrid fixation incorporating suture buttons restores tibiofibular kinematics and supports safe early mobilisation.[23] Biomechanical evidence from Wixted et al. confirms the mechanical reliability of Tightrope fixation in resisting syndesmotic diastasis under physiological loads.[24]

Complications in our series were infrequent and manageable, with an overall rate of 13.2%. Suture button removal was required in only two cases (2.4%) due to infection and knot irritation; both resolved without persistent syndesmotic widening. Schepers et al. reported a 10% implant removal rate, primarily due to soft tissue irritation from prominent suture knots.[25] Degroot et al. noted a higher complication rate of 25%, necessitating removal in several cases.[16] Across the literature, the incidence of soft tissue irritation ranges from 5.6% to 21%.[3,14] This complication can be mitigated by surgical technique—specifically, trimming the fibre wire 1 cm beyond the knot and burying the end adjacent to the fibula. Notably, knot irritation is uncommon with the use of modern knotless Tightrope implants. In our series, complications related to infection were limited. One patient (1.2%) developed a superficial wound infection, successfully managed with oral antibiotics, while another (1.2%) experienced a deep infection requiring surgical debridement and suture button removal. Naqvi et al. reported a 6.1% infection rate among 49 patients, all necessitating implant removal.[14] Storey et al. documented a broader spectrum of complications, including 3% superficial wound infection, 3% osteomyelitis, and 2% aseptic osteolysis.[26] In their cohort, Tightrope removal was performed in 8% of cases for reasons including osteomyelitis, radiological track widening with pain, failed syndesmotic stabilisation, and unexplained discomfort. These findings highlight the importance of meticulous surgical technique and postoperative monitoring to minimise implant-related complications.

We reported a total of 2.4% incidence of intraosseous migration and 2.4% of a malposition of the medial button, but none of them had any diastasis of the syndesmosis**.** Storey et al. documented 3% intraosseous migration of the lateral endobutton, 1.9% diastasis, and 3% malpositioning of the medial Endobutton.[26] We had a 1.2 % incidence of diastasis and a 1.2% unexplained chronic pain. Device malpositioning and migration can both lead to diastasis of the syndesmosis.. In our cohort, there were no cases of aseptic osteolysis, peri-implant fracture, or revision fixation.

In our cohort, intraosseous migration and malpositioning of the medial endobutton were each observed in 2.4% of cases, with no associated widening of the syndesmosis. Storey et al. reported complication rates including 3% intraosseous migration of the lateral endobutton, 3% malpositioning of the medial endobutton, and 1.9% syndesmotic diastasis, with a notable proportion of patients requiring implant removal due to complications such as osteomyelitis and aseptic osteolysis.[26] These rates are comparable to those observed in the present study. In our series, diastasis was observed in only 1.2% of cases. Wixted et al. confirmed the biomechanical reliability of suture button constructs across varying configurations but emphasised that malposition may compromise fixation integrity and predispose to syndesmotic instability.[24] In contrast, Fabião et al. reported no cases of migration or diastasis in their cohort of isolated syndesmotic injuries treated with Tightrope, demonstrating sustained radiographic stability over mid-term follow-up.[20] We recommend a small medial incision to ensure accurate placement of the medial endobutton directly onto the tibial cortex. This technique prevents soft tissue interposition between the endobutton and cortex, thereby reducing the risk of malposition, construct loosening, and subsequent syndesmotic diastasis. To enhance lateral stability, we also advocate passing the Tightrope through the fibular plate. In cases such as isolated syndesmotic injuries or high fibular fractures, where a lateral plate may not otherwise be indicated, a two- or three-hole one-third tubular plate can be used to support the lateral Endobutton. This construct has proven effective in minimising lateral button migration and maintaining syndesmotic integrity throughout rehabilitation. In our series, there were no cases of aseptic osteolysis, peri-implant fracture, or revision fixation.

Collectively, these findings underscore the importance of meticulous implant positioning and reinforce the reproducibility and safety of Tightrope fixation when executed with precise surgical technique.

This study has several notable strengths. 1. It includes a robust cohort of 83 patients, providing a meaningful sample for evaluating outcomes following syndesmotic fixation. 2. Radiographic assessment was comprehensive, with serial measurements of medial clear space (MCS), tibiofibular overlap (TFO), and tibiofibular clear space (TFCS) obtained at preoperative, initial postoperative, and final follow-up intervals—offering objective evidence of reduction quality and maintenance. 3. The study reflects real-world orthopaedic practice, incorporating a range of injury patterns, ASA classifications, and rehabilitation protocols, thereby enhancing external validity. 4. Additionally, the moderate-term follow-up period allowed for the evaluation of both early and short-term outcomes.

However, our study has several limitations. 1.It was conducted at a single centre, which may introduce bias related to institutional surgical practices and variability in clinical documentation. 2. The non-randomised design limits statistical power for subgroup analysis and prevents causal inference. 3. Differences in surgical technique among operating surgeons could have influenced outcomes. 4. Some patients may have continued their care outside the institution, potentially leading to missed complications or reoperations. 5. The final follow-up did not include standardised assessments of ankle strength, range of motion, or validated functional outcome scores, making it difficult to evaluate the clinical impact of complications fully. 6. Additionally, heterogeneity in postoperative care—particularly in immobilisation methods and physiotherapy protocols—may have affected recovery. Nonetheless, the primary objective of this study was to assess radiographic outcomes and complications rather than functional outcomes.

Conclusions

Accurate anatomical reduction and stabilisation are essential for achieving optimal long-term outcomes in syndesmotic injuries. Ankle Tightrope fixation provides a minimally invasive, biomechanically stable alternative to traditional screw fixation. Careful surgical technique ensures safe, durable, and reproducible outcomes with minimal need for revision. Our experience demonstrates excellent radiographic outcomes and a low complication rate, allowing early weight-bearing and rehabilitation while preserving syndesmotic stability.

Conflict of Interest

The authors declared no conflicts of interest.

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Original

Risk factors for non-union in humeral shaft fractures: a retrospective analysis of intramedullary nailing outcomes

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Abstract

Background: Intramedullary nailing is the primary surgical treatment for many humeral shaft fractures. Non-union in these patients require new surgical treatments, with severe impact on the quality of life; identifying the risk factors associated with non-union is crucial to reduce this evolution. The goal of this retrospective cohort study is to analyze the aspects that can lead to non-union in humeral shaft fractures treated with intra-medullary nailing.

Methods: The authors retrospectively analyzed cases of humeral aseptic non-union treated with nail removal and Open Reduction Internal Fixation (ORIF) with a locking compression plate, in a single hospital between November 2013 and June 2024. From 33 identified cases, 20 patients met our inclusion criteria: age over 18 years, humeral shaft fractures (AO/OTA 12-A1 or 12-B2) involving the deltoid tuberosity treated with antegrade intramedullary nailing and failure of healing after 12 months. All the non-unions were not infected and vital normo or hypertrophic. The following exclusion criteria were applied: age under 18 years, pathological fractures, fractures treated non-surgically, or fractures treated with devices other than antegrade intramedullary nails.

Results: 20 patients (mean age 49 ± 10.6 years; 13 males, 7 females) underwent revision surgery with plate fixation after failed intramedullary nailing. Left-sided fractures accounted for 45% of cases. AO/OTA 12-A2

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was the most prevalent fracture pattern (55%), followed by 12-B2 (40%). Among the twenty patients, the fracture at the deltoid insertion was involved with a "V" fragment in thirteen cases of nonunion. The mean overall follow-up was 11 ± 3 months. Complete radiographical union was achieved in 19 patients (95%) with a mean time to bony union of 7.1 ± 3.5 months. No deep infections or osteomyelitis occurred.
Conclusions: The results of this study contraindicate IM nailing in humerus fractures AO types 12-A1, 12-A2, and 12-B2 with displacement of the "V" fragment. The non-union occurs due to the difficulty in reducing and fixing the "dynamic" gap caused by deltoid traction and the slow healing of that area. The solution for the vital non-union is to reduce the gap and use plate fixation, and this treatment is recommended, especially in an acute setting.

Keywords

Shaft humerus fractures; deltoid; non-union; intramedullary nailing; radiographs

Introduction

Humeral shaft fractures represent about 3% of all bone fractures and usually occur in young people following high-energy trauma or in the older population with low-energy torsional trauma.[1,2] Intramedullary (IM) nailing is a method of fixation considered in the management of humeral shaft fractures due to its capacity for minimally invasive stabilization, allowing early mobilization and providing biomechanical advantages. IM nailing is particularly indicated for segmental fractures, pathologic fractures, fractures in osteopenic bone, and those with long zones of comminution or compromised soft tissues. It also plays a therapeutic role in cases requiring early stabilization with minimal surgical trauma, such as in multi-trauma patients or pathological fractures due to tumors. The technique improves rotational control and axial loading of the fracture site, promoting union while allowing early mobilization.[3-5]

This paper aims to critically discuss the IM nailing of a shaft fracture pattern that involves the proximal area at the insertion of the deltoid.

Materials and Methods

We retrospectively analyzed all clinical cases of humeral aseptic vital nonunion of the humerus, following IM nailing. The non-union unions were treated by the same surgeon between November 2009 and June 2024. We reviewed the preoperative and postoperative X-rays. In total, we identified 33 clinical cases of humeral aseptic nonunion, of which 13 were excluded based on our criteria or were lost during the follow-up. We analyzed the following data: age, sex, fracture characteristics, type of nonunion (atrophic or hypertrophic), initial surgical treatment, last surgical treatment, presence of radial nerve palsy, duration of the palsy, and clinical and radiological follow-up at 1, 3, 6, and 12 months. We included patients who met the following inclusion criteria: age over 18 years, previous spiral, oblique, or third fragment humeral shaft fractures classified as AO/OTA 12-A1, 12-A2, or 12-B2 involving the deltoid tuberosity, treated with antegrade intramedullary nailing, and failure of fracture healing 6 months after surgery. Among the twenty patients, the fracture at the deltoid insertion with a "V" fragment was involved in fourteen cases of nonunion.

We excluded patients with the following features: age under 18 years, pathological fractures, fractures treated non-surgically, or fractures treated with devices other than antegrade intramedullary nails. All the patients underwent the same treatment: removal of the nail, revision of the non-united site; evaluation of the type of nonunion, and the need for biological or mechanical support. All the non-unions needed a reduction of the fragment and an increase in stability. The reduction was obtained by opening the site, using pointed clamps because the bone was fragile, and the fixation of a couple of lag screws, if possible, and then a plate. All patients began active and passive physiotherapy on the first postoperative day.

Surgical technique

The preoperative plan should consider the type of nail, the entry point, the type of locking screws, and the need for special removal instruments (such as for a broken nail). The condition of the axillary nerve and the cuff should also be examined.

The patient is positioned supine with the arm adducted on a radiolucent board, with the C-arm on the opposite side of the surgical team. The entire upper extremity is prepared and draped in a sterile manner, and a surgical timeout is conducted. The first step involves a lateral approach following the previous scar (Figure 1).

The first step is to identify the nail tip, insert the nail extractor, and locate and remove the distal locking screws. This step is important because removing the screws provides insight into the residual bone stock, especially in the proximal humerus, where the plate will be anchored.

The second step involves proximal dissection while protecting the axillary nerve (approximately 6 cm from the acromion tip), corresponding to the surgical humeral neck. Distally, the deep fascia is incised, and the biceps is retracted anteromedially to reveal the brachialis and brachioradialis muscles. The radial nerve is identified in the interval between these muscles, starting just proximal to where it penetrates the lateral intermuscular septum. The nerve is traced proximally by elevating the distal origin of the lateral head of the triceps. The triceps muscle is retracted from the posterior surface of the humerus. In the spiral groove area, the nerve lies between the lateral and medial heads of the triceps. This exposure reveals the humeral shaft and the non-union site. For vital non-union, the fragments are only minimally decompressed to define the correct reduction edges; for atrophic non-union, more aggressive debridement is recommended, keeping in mind that shortening may be acceptable.

In our cases, all sites were vital (Figure 2). The fracture can then be anatomically reduced and temporarily fixed with pointed clamps (Figure 3). If the fracture line exceeds 5 cm, 2.7 or 3.5 lag screws are used for compression. Compression can be achieved either with free lag screws or through lag screws placed by the plate. The plate should span the entire segment, extending distally to the previous screw holes, and be fixed with at least six cortices, preferably using locking systems (Figure 4).

The limb is then immobilized in a sling for one week for comfort. Postoperative rehabilitation begins the day after surgery, allowing the use of the limb for daily activities. However, any rotational movements are prohibited for 40 days.

Results

Among a cohort of 33 patients with non-union V deltoid fractures treated with open reduction and internal fixation (ORIF) with plate and screws, 20 patients with a mean age of 49 ± 10.6 years were included in the study after inclusion and exclusion criteria were applied. The overall mean follow-up was 11 ± 3 months. The flowchart of study population characteristics is available in Table 1.

Demographic and Injury Characteristics

The cohort comprised 13 male and 7 female patients, with left-sided fractures accounting for 45% of cases and right-sided fractures 55%. Low-energy trauma mechanisms, particularly falls from standing height, were the leading cause of injury in older patients (mean age > 65 years), whereas high-energy mechanisms such as road traffic accidents predominated in younger individuals (mean age < 40 years). According to the AO/OTA classification system, the distribution of fracture patterns was as follows: AO/OTA 12-A1 comprised 5% of cases, AO/OTA 12-A2 (the most common pattern) at 55%, and AO/OTA 12-B2 (wedge fractures) representing 40% of the cohort. Among the twenty patients, the fracture at the deltoid insertion with a "V" fragment was involved in thirteen cases of nonunion (Table 2).

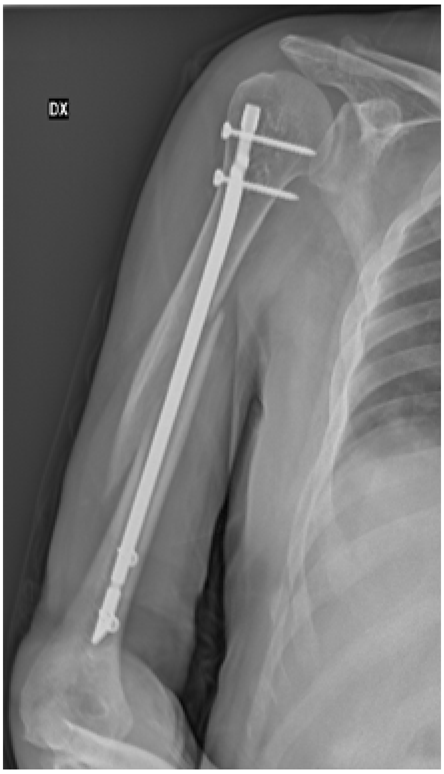

Figure 1. *Screws and nail are removed through the previous surgical incision*

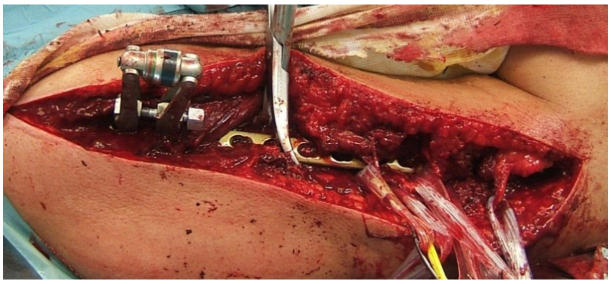

Figure 3. *No graft is needed. Just clamps or tie rod*

Surgical Management and Clinical Outcomes
All 20 patients were initially treated with antegrade intramedullary nailing at the first surgery. Subsequently, all cases underwent revision surgery consisting of nail removal followed by open reduction and internal fixation (ORIF) utilizing a locking compression plate (LCP) through a lateral approach. Mean time between initial failed intramedullary nailing and revision plate fixation was 14.5 ± 6.2 months. Radial nerve identification

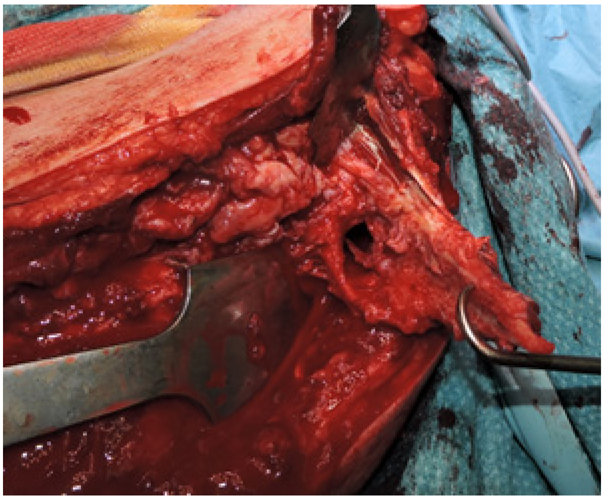

Figure 2. *Debridement of the site of the fracture and evaluation of the length of the V fragment in order to make the compression.*

and protection were accomplished in all cases during the lateral surgical approach.

Radiographical and Functional Union
Radiographical evidence of fracture healing was documented sequentially on plain radiographs and additional imaging studies performed at postoperative intervals. The mean time to radiographic bony union, defined as bridging callus visible on anteroposterior and lateral radiographs at the fracture site, was 7.1 ± 3.5 months. Complete radiographical union was achieved in 19 of 20 cases (95%), with one patient experiencing delayed union beyond 12 months without clinical symptoms like pain, swelling or stiffness; this single delayed union case demonstrated progressive callus formation and achieved consolidation by 14 months.

Complications
Radial nerve injury occurred in two patients (10%), presenting as transient neurapraxia secondary to iatrogenic injury. It recovered in about six months postoperatively. Hardware-related complications requiring elective implant removal in one case (5%), the patient had symptomatic soft-tissue impingement from distal screw placement, and removal was performed 18 months postoperatively. No deep surgical site infection or osteomyelitis was document-

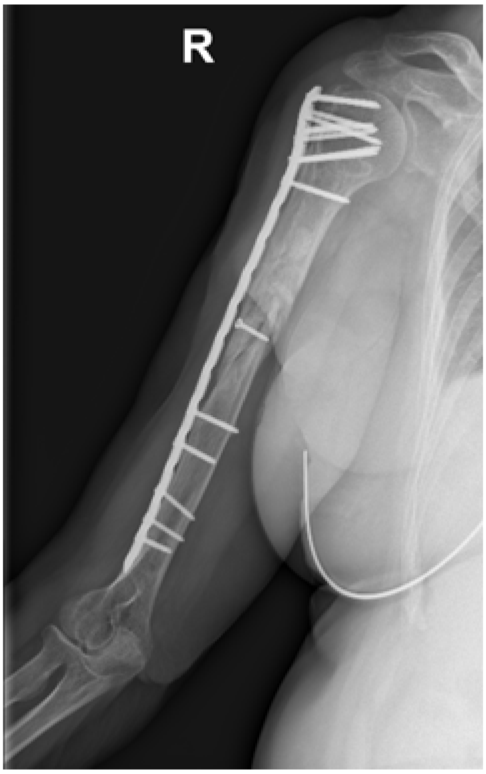

Figure 4. Radiographic control of the plate position

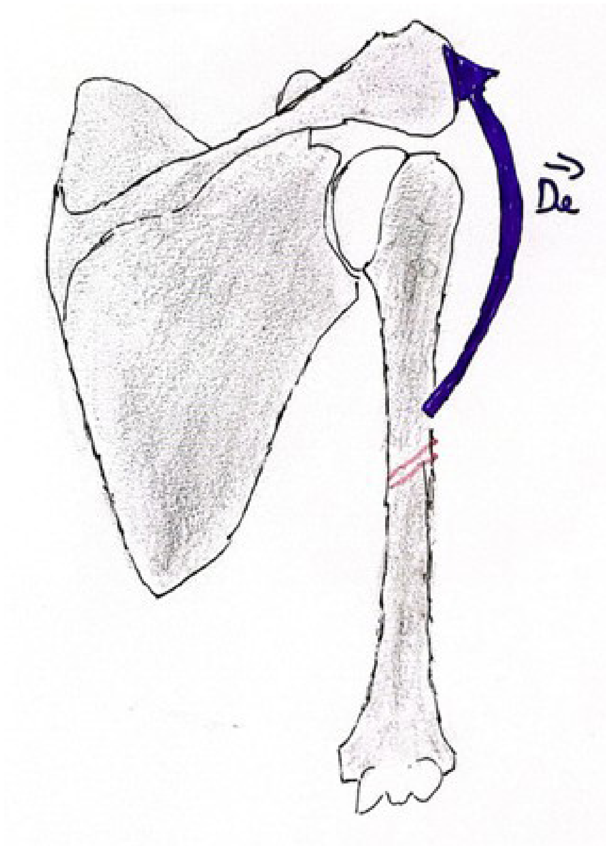

Figure 5. Biomechanism of the deltoid muscle

ed throughout the follow-up period. All patients achieved complete functional recovery and resumption of activities of daily living.

Discussion

The most important finding of this study is that humeral shaft fractures where the fracture line touches and displaces the insertion point of the deltoid muscle must be fixed with plates and screws, because closed reduction and IM nailing lead to nonunion.

The humeral shaft is predominantly composed of dense cortical bone surrounding a medullary canal, providing structural integrity and serving as a conduit for neurovascular elements. The shaft presents three surfaces (anterolateral, anteromedial, and posterior) and three borders (anterior, lateral, and medial), which serve as attachment sites for various muscles.[6,7] A key anatomical feature is the deltoid tuberosity, a V-shaped prominence located laterally on the midshaft, serving as the insertion point for the deltoid muscle in the area called deltoid insertion (DI).[8] The anterior, middle, and posterior deltoid muscle fibers enter the DI in a V-shaped tendinous confluence with a broad posterior band and a narrow separate anterior band, which accounted for the anterior one-fifth of the DI (0.44 cm).[8] Rispoli et al.[9] noted that after the deltoid insertion release, the interconnections between the deltoid tendon and its fascia were continuous with the brachialis muscle and intermuscular septum. The integrity of these interconnections may contribute to the preserved deltoid function despite the partial release of the deltoid in lateral plate fixation. Biomechanically, the humeral shaft is designed to withstand complex loading patterns, including axial compression, torsion, bending, and shear forces, which occur during various upper limb activities. Its tubular structure and cortical composition confer resistance to these stresses, facilitating effective force transmission between the shoulder and elbow joints (Figure 5). The deltoid muscle, particularly its insertion on the deltoid tuberosity, plays a pivotal role in shoulder

Table 1. Demographics (Data *are expressed as mean ± SD)*		
Patients (no)		**20**
Follow-up (months)	**Mean**	11 ± 3
Age at surgery	**Mean**	49 ± 10.7
Gender	**M**	13 (65%)
	F	7 (35%)
Side	**Right**	11 (55%)
	Left	9 (45%)

Table 2. *Fracture characteristics. *Data are expressed as mean ± SD*		
Patients (no)		**20**
Type of fracture	**12 A1**	1 (5%)
	12 A2	11 (55%)
	12 B1	8 (40%)
"V" fragment		13 (65%)
Fracture healing (radiographs)		7.1 ± 3.5 months*
Complications		3 (15%) (2 Radial neuroapraxia, 1 Hardware removal)

biomechanics. It significantly contributes to shoulder abduction and flexion strength, as its fibers exert forces that influence the mechanical environment of the humeral shaft.

To our knowledge, limited literature exists regarding the so-called "V deltoid fractures" area, where forces from the deltoid muscle create maximum stress and where a lack of reduction often results in nonunion. The surgical reference AO guide [10] recommends that for shaft fractures in this area, treatment should aim for stable osteosynthesis to allow early mobilization, prevent joint stiffness, and enhance functional recovery. For AO/OTA type A fractures, open reduction and internal fixation (ORIF) with compression plating remains the gold standard. ORIF enables anatomical reduction, direct visualization of the fracture, interfragmentary compression, and, if necessary, identification and protection of the radial nerve, which closely parallels the humeral shaft in the spiral groove.[11,12]

Minimally invasive plate osteosynthesis (MIPO) has become widely accepted as a less invasive alternative that preserves soft tissues and periosteal blood supply, promoting indirect bone healing through callus formation and potentially reducing nonunion risk. The classical anterior MIPO approach, as well as posterior, anterolateral, and anteromedial approaches, provide circumferential access to the humerus with smaller incisions and less soft tissue dissection.[13,14]

IM nailing has gained popularity due to improvements in implant design and technique, especially for multifragmentary fractures or in polytrauma patients. IM nailing offers rapid stabilization and minimal physiological impact, often associated with shorter union times and less blood loss compared to ORIF. However, concerns remain about shoulder impingement and the difficulty of accessing the radial nerve, which cannot be directly visualized during nailing.[15,16]

Table 3. Summary of the most important published studies comparing IM nailing and plate fixation for humeral shaft fractures and for humeral shaft nonunions.

Study	Study design	Population/ Fracture type	Treatment/ Comparison	Outcomes	Key conclusions
van Bergen et al.[5]	Systematic review (173 studies, 11,868 pts)	Adult OTA/AO 12 humeral shaft fractures treated nonoperatively or with IM nailing / plating	Nonoperative functional bracing vs IM nailing vs plate osteosynthesis (including MIPO)	Healing rate: 89% nonoperative, 94% IM nailing, 96% plating. Secondary radial nerve palsy: 1% nonoperative, 3% IM nailing, 6% plating. Implant failures and intraoperative complications more frequent with IM nailing.	Both IM nailing and plating achieve high union rates; plating (especially MIPO) shows slightly higher healing and better functional scores, at the cost of a higher rate of iatrogenic radial nerve palsy.
Hu et al.[33]	Systematic review and metaanalysis (14 studies, 903 pts)	Adult humeral shaft fractures	Intramedullary nail (IMN, 437 pts) vs locking compression plate (LCP, 466 pts)	IMN associated with shorter operative time and less intraoperative blood loss. Postoperative infection lower with IMN (RR 0.32). No significant differences in nonunion, delayed union, radial nerve injury or reoperation rates. ASES scores lower and shoulder/elbow motion limitation more frequent after IMN (RR 1.88).	IMN is biomechanically and surgically less invasive (shorter surgery, less blood loss, fewer infections), but early shoulder and elbow function tends to be better after LCP fixation, with similar union and nonunion rates between techniques.
Ouyang et al.[34]	Updated metaanalysis of 10 RCTs (439 pts)	Adult diaphyseal humeral fractures	Plate fixation vs intramedullary nailing	Plating significantly reduced postoperative shoulder impingement and restriction of shoulder motion compared with nailing. No significant differences in nonunion, delayed union, infection, radial nerve palsy, iatrogenic fracture comminution or implant failure between groups.	Both techniques achieve similar union and complication rates; plating appears to better preserve shoulder range of motion and reduce shoulderrelated complications compared with antegrade nailing.
Micic et al.[20]	Retrospective cohort (56 pts)	Humeral diaphyseal nonunion after conservative treatment	Dynamic compression plate (36 pts) vs intramedullary nail (20 pts) for nonunion	Union: 100% in the plate group vs 90% in the IM nail group. Mean time to union ≈ 4.2 months (plate) vs 4.5 months (nail) (NS). Complications: 13.8% plate (mostly transient radial nerve palsy) vs 10% IM nail (including distal humeral fracture during nail insertion). CMS and DASH slightly better with plating, not statistically significant.	Both plating and IM nailing provide high union rates for humeral shaft nonunion, with somewhat higher union and functional scores after plating. IM nailing offers shorter surgery, less blood loss and shorter hospital stay, which may benefit elderly or comorbid patients.

Patino et al.[35]	Retrospective comparative study (57 pts)	Acute humeral shaft fractures treated operatively	Plate fixation (27 pts) vs antegrade locked IM nailing (30 pts)	Healing: 100% in plate group vs 93.3% in nail group. Full shoulder ROM: 66.6% plate vs 40.0% nail ($p = 0.02$). Excellent RodríguezMerchán score: 66% plate vs 40% nail. Complications: 7.4% plate vs 20% nail (including 2 nonunions and subacromial impingement)	Plate fixation resulted in better shoulder ROM and functional scores and fewer complications than antegrade IM nailing, although both techniques achieved good overall clinical results and high union rates.
Hudson et al.[36]	Retrospective case series (14 pts)	Complex humeral shaft fractures (AO/OTA B2, B3, C2, C3), many obese and/or polytrauma patients	Percutaneous antegrade IM nailing using a minimally invasive technique	Primary union achieved in 93% (13/14) after index nailing; final union 100% after one secondary plating procedure. No pre or postoperative radial nerve palsy. Mean ASES 78.2, Constant 72.1, Penn Shoulder 82.7, SANE 81.9 at ≥1 year.	Percutaneous IM nailing is an effective option for complex, comminuted humeral shaft fractures in highrisk patients, providing high union rates and satisfactory shoulder function, with low risk of radial nerve injury and limited softtissue morbidity.

The literature considers IM nailing a viable option for humeral shaft fractures, yet most studies inadequately address the mechanical challenges posed by the V fragment or ignore its unique biomechanical environment.[17] Current nonunion research mainly focuses on technical factors such as nail diameter, locking screw configuration, and entry point, while overlooking the critical role of deltoid muscle forces in fracture stability.[18] Recent systematic reviews of humeral shaft nonunion show variable union rates with IM nailing, ranging from 4% to 23%.[19] However, these studies rarely stratify outcomes based on the deltoid tuberosity. Micic et al. reported a 10% nonunion rate with IM nailing, compared to 0% with plate fixation, but did not specifically analyze fractures involving the deltoid insertion area.[20]

The biomechanical reasoning behind this involves the unique force vectors generated by the deltoid insertion.[21] The deltoid exerts significant distraction forces perpendicular to the humeral shaft, tending to cause angulation and displacement at the V fragment. Unlike plate fixation, which provides direct compression and resists these forces through its position on the tension side of the bone, IM nails rely primarily on interlocking screws to control rotation and length.[22] This disadvantage becomes especially evident when the fracture line involves or passes through the deltoid tuberosity, as the nail cannot sufficiently counteract the muscle's distractive forces.[23] Furthermore, the current literature shows a concerning lack of standardized criteria for assessing the reduction quality of the V fragment during IM nailing procedures.[24]

While overall fracture alignment and rotation are routinely evaluated, specific parameters for restoring the deltoid ridge anatomy are rarely reported.[25,26] This gap may explain the variable union rates seen across different series and underscores the need for more precise anatomical considerations in treatment planning.[27,28]

Our findings indicate that the mechanical environment created by IM nailing is insufficient to maintain reduction stability when deltoid forces are unopposed by sufficient interfragmentary compression. Treating nonunion involving the V fragment after IM nailing suggests that this fragment should be anatomically reduced and securely fixed to prevent mechanical failure and nonunion.[29]

Our series shows that all nonunion cases occurred where the deltoid ridge was inadequately managed during initial IM nailing, supporting the idea that this region requires specific surgical attention beyond what is used for standard diaphyseal fractures.[30] The conversion from failed IM nailing to plate fixation without bone grafting achieved union in all cases.

In our series, no atrophic nonunions were observed, so bone grafting was not used. This demonstrates the superiority of compression plating in managing the complex forces generated by deltoid muscle contraction. This aligns with biomechanical principles showing that plate constructs better resist bending and distraction compared to intramedullary devices, especially when placed on the tension side of the bone (Table 3).[31,32]

Based on our results, we suggest that fractures involving the deltoid tuberosity should be regarded as a distinct subset of humeral shaft fractures requiring modified treatment strategies. The presence of the V fragment should be an indication for plate fixation rather than IM nailing, regardless of other fracture features. This is especially important because nonunion in this region can severely impair shoulder function and overall upper limb performance due to deltoid muscle dysfunction.

This study has limitations, including its retrospective design that may introduce bias without randomization, the small sample size that could limit the analysis of clinical and radiological outcomes, and the absence of a control group treated primarily with plate fixation for V fragment fractures that precludes definitive conclusions about the best primary treatment. Additionally, long-term functional outcomes and patient-reported measures were not thoroughly assessed, possibly underestimating the full clinical impact. Nonetheless, strict surgical selection criteria may have influenced these limitations. A key strength is the uniform evaluation of patients undergoing the same procedure by the same surgeon, with similar demographic features, sample size, and follow-up. To date, no study has simultaneously assessed clinical and radiological results following plate and screw fixation for nonunion after IM nailing. Future research should aim to develop standardized radiographic criteria to identify V fragment involvement preoperatively, establish biomechanical testing protocols to compare fixation methods in this specific area, and conduct prospective studies to validate our recommendations. Advances in implant design, including locking plates tailored for the deltoid ridge or specialized nails with better proximal locking, could also provide new solutions for these challenging fractures.

Conclusion

Due to the anatomical and biomechanical features of AO type 12-A1, 12-A2, and 12-B2 fractures involving the "V deltoid fractures" we found that this fragment could not be reduced and fixed in a closed way and intramedullary nailing should not be the surgical choice of fixation. At this anatomical level, the fracture displacement frequently creates a gap that cannot produce sufficient callus formation. Successful healing requires closer contact between the fragments. Additionally, the gap is dynamic because of continuous displacement forces exerted by the deltoid muscle. As a result, the relative stability provided by bridging constructs, such as intramedullary nails, plates, or external fixators, is inadequate to ensure reliable consolidation. Only anatomical reduction combined with absolute stability can guarantee consistent and successful healing in these cases. In these specific patterns, plate fixation with lag screws, when feasible, offers better outcomes by enabling anatomical reduction and providing absolute stability. These types of pseudarthrosis remain biologically active, so achieving an as close as possible anatomical reduction with clamps or lag screws promotes primary healing without the need for bone grafting. Moreover, placing the plate laterally effectively counteracts the deforming force from the deltoid muscle, which is the main cause of displacement in these fractures.

Conflict of Interest

The authors declared no conflicts of interest.

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AOTH

Case report

Surgical treatment of ischial tuberosity avulsion in teen athlets – a case report

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Abstract

Avulsion fractures of ischial tuberosity are traumatic lesions relatively rare that occur mainly, in the following sports: soccer, sprinting and gymnastics.
The authors report a clinical case of a 13-year-old boy with an avulsion fracture of the ischial tuberosity by indirect trauma during a soccer game, describing its surgical treatment with two sponjy cannulated screws and the respective clinical outcome.

Keywords

Ischial tuberosity; avulsion; trauma; surgery

Introduction

The ischial tuberosity constitutes the insertion of the harmstring muscles (long portion of femoris biceps, semitendinous, semimembranous) and the adutor magnus. The first group acts in knee flexion and hip extension.[2] The ossification timing of this apophysis during skeletal development is not well defined, but usually fuses until 25 years-old. Since these lesions occur more frequently in non-ossified apophysis, these are less common in adults.[3] Although they are rare, these avulsions constitute the most severe type of lesion of the harmstrings,[4] dividing is two categories: traumatic and non-traumatic.[3] When these lesions happen after a traumatic event, they manifest as: a sudden pain posterior to the hip or thigh with an abnormal gait or inability to walk, oedema or buttock ecchymosis, inability to seat, changes in the mobility of hip or knee with intense pain na extension, adduction and external rotation of the hip.[2] Apophysitis result in less complications and occur at a lower mean age, in comparison to the avulsions that may lead to chronic pain referred to the posterior aspect of the thigh.[3] The incidence of acute lesions seem to be higher between 15 and 17 years of age,[3]

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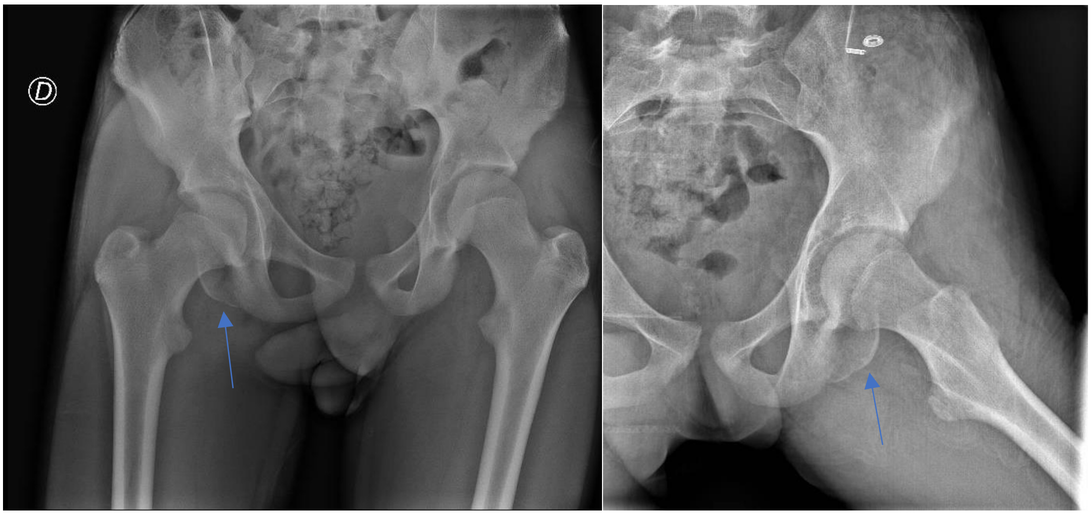

***Figure 1.** Antero-posterior and postero-anterior radiographs of the hip with identification of the avulsed fragment (blue arrow in both radiographs)*

***Figure 2.** (a, b) – Coronal view with the inverted comma sign (a) and sagital view og the right hip (b)*

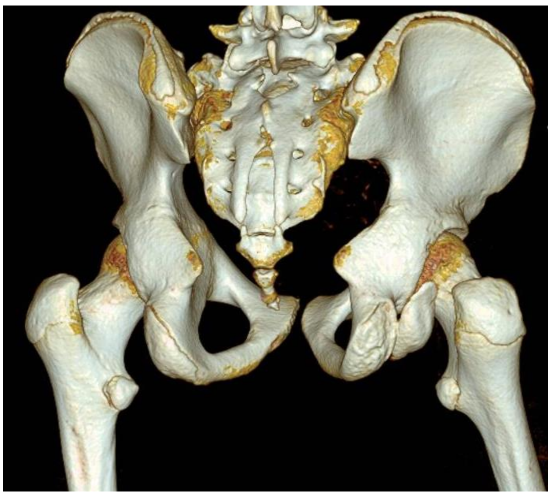

***Figure 3.** 3D reconstruction of the fragment showing a displacement of about 25 millimeters.*

since it is from that period that starts the ossification of the tuberosity, diminishing its elasticiy and strength (2 to 5 times weaker) in comparison to the normal tendon.[2]

The first description occurred in 1912 by Berry, with the emergence of various case reports, but there is no consensus about the treatment of these fractures.[2] The degree of dislocation of the fragment is usually a decisive factor. In fractures with a slight deviation, conservative treatment is frequently adequate, with indication to movement restriction in an early phase and rehabilitation in a later stage. Starting from 2 cm of deviation, especially in athlets and manual workers with need to a rapid return to previous activity, the most consensual treatment is surgical,[1] since the risk

Figure 4. Positioning of the patient and demarcation of the subgluteal crease and incision.

of non-union in complete avulsions might be the double of those seen in partial avulsions.[5]

Despite the conservative treatment has worked in some situations in the past, more recently have emerged analysis about its complications, such as fibrosis, harmstrings shortening, sciatic nerve compression, ischium pseudarthrosis with persistente gait pain.[6] Surgical options include fixation with cannulated screws, anchor sutures, plating or fragment excision,[5,7,8] comprising open or endoscopic techniques.[9]

Case report

A thirteen year-old boy, presented in the emergency room with hip pain after doing a split during a soccer game. After the hyperextension movement of his right hip he described a "pop" sound with a sudden localized pain with inability to walk.[4] He was diagnosed radiographically (Figure 1) with an avulsion fracture of the ischial tuberosity. For better characterisation and planning the patient underwent a computed tomography (CT) scan (Figure 2) with 3D reconstruction. (Figure 3)

The patient right after the Surgery noted a slight hypoestesia in the genital area, but recovered completely. The antero-lateral displacement of the fragment indicates an intense contraction of the harmstring and adutor tendons after the sudden flexion and abduction of the hip and extension of the knee.[1] During the procedure, the patient was positioned in prone position with support of the trunk, pubic symphysis, antero-superior iliac crests with the right knee in flexion in combination with the abduction and internal rotation of the hip. (Figure 4)

It was performed a posterior subgluteal approach, with na incision about 10 cm on the gluteal crease, followed by the subcutaneous dissection and identification of the inferior border of the gluteus maximus muscle.[5,10,11] Its fascia was seccioned and it was lifted away from the work window. Below the gluteus maximus it was possible to feel the avulsed fragment. The surgeon isolated the sciated nerve, protecting it carefully with slightly damp wads and moving it laterally to avoid its contact with the fragment and fibrosis. With hohmann retractors it was bordered the fragment and the fracture bed, allowing the reduction and temporary fixation with 1.4 mm kirschner wires. (Figure 5)

The definitive fixation was performed under direct control by fluroscopy with verification of the trajectory of the implants – Figure 6 – three 3.5 mm cannulated screws (Asnis III, Stryker). Hemostasis and closure were carried out, using vicryl 1-0 in fascia, vicryl 2-0 subcutaneous tissue and vicryl rapide 3-0 to the intradermal suture. The patient was imobilized with an hinged knee brace with extension limitation starting from 50º and free flexion. He was discharged with unloading orders for the operated side with the usage of crutches until 6 weeks, removing the brace and

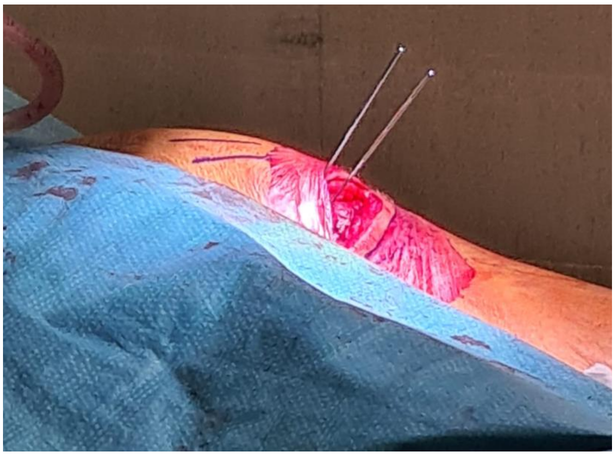

Figure 5. Positioning of the kirschner wires.

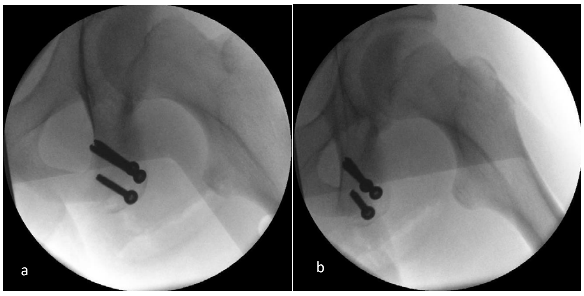

Figure 6. (a, b) – Postero-anterior (a) and alar oblique view radiographs of the right hip (b)

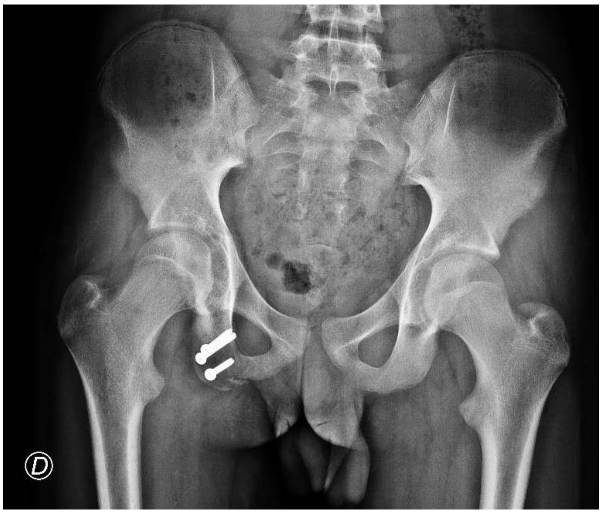

Figure 7. Antero-posterior radiograph of the pelvis 3 months after surgery

keeping the crutches for another extra month for protection, but physioteraphy to muscle strenghtening as tolerated. At 3 months he was clinically well with material in situ (Figure 7) but the surgeon mantained his indication of sports inhibition until 6 months after the intervention. The parents of the patient gave written informed consent for the patient's details to be included in this paper.

Diagnosis and Treatment

Early diagnosis of these lesions is important to secure the most appropriate and earlier treatment leading to a faster recovery. In chronical painful non-unions, surgery is the prefered option with good results.[1] The pelvic radiograph allows the diagnosis, but the fragment´s orientation, outline and dimensions are better defined by CT scan. Magnetic resonance reveals the hematoma volume and muscle contusion, such as the ultrasound in experiente hands, but there are not always necessary. Electromyography might have a place in chronical cases with sciatic nerve entrapment.[3] Some authors defend in one hand, the use of magnetic resonance in the occult avulsions, due to the signal intensity in the soft tissues and tuberosity caused by edema and subperiosteal fluid; and in the other hand, the use of ultrasound in the identification of nervous lesions.[2] Avulsion fractures of the ischial tuberosity may be confounded with piriformis syndrome, spinal disc disease, bursitis and bone tumours. Furthermore in some cases, when the treatment occurs after a long time, a pseudoarticular structure with the avulsed fragment may develop, resembling a tumour.[12]

Conclusion

We consider that an early diagnosis is of utmost importance, such as a detailed histoy and physical exam, with resource of the appropriate complementary diagnostic exams. The degree of suspection as to be high. There is no consensus in the treatment of these situations due to it slow incidence, but na individual plane based on patient´s expectations must be favoured. More and more has been accepted the decisive cut-off to surgery of displacements above 1.5-2 cm [6,13,14,15,16,17], or the persistence of pain after months of conservative treatment.[9]

Conflict of Interest

The authors declared no conflicts of interest.

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Case report

Complex multiligament knee reconstruction following high-impact trauma with primary repair and internal bracing: a case report

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Abstract

Open fracture-dislocations of the knee are high-impact injuries often associated with extensive ligamentous damage, presenting significant challenges in orthopaedic trauma care. The rarity of such injuries makes the pre-operative planning and post-operative rehabilitation especially challenging. Standardized treatment consists of either early - <3weeks, or late - >3weeks reconstruction with autografts. This case report discusses the surgical management of a complex knee trauma with early repair of all ligaments using modern fixation methods. Our case presents a 33-year-old male sustained a complex open fracture-dislocation of the left knee. The injury included a posterolateral tibial plateau fracture, comminuted patellar fracture, avulsion of the lateral femoral condyle, and complete ruptures of the ACL, PCL, MCL, and LCL. Initial emergency surgery involved wound debridement and external fixation. Subsequent surgeries addressed ligament repair, using modern fixation techniques, like Internal Brace. The patient achieved excellent recovery, returning to daily activities within 18 weeks without complications. This case underscores the potential benefits of primary ligament repair over traditional reconstruction in managing complex knee injuries. The successful outcome highlights the importance of early intervention, and modern fixation techniques in optimizing recovery.

Keywords

Multiligament knee reconstruction; primary ligament repair; internal bracing

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Introduction

Knee open fracture-dislocation is a high impact trauma that involves extensive ligamentous damage. These types of injuries present formidable challenges in orthopaedic trauma care as they often associate with neurovascular complications and future instability of the joint. The reconstruction of multiple torn ligaments, particularly in the context of open fractures and dislocations, requires careful pre-operative planning and fast surgical intervention in order to ensure optimal patient outcomes.[1] Traditional methods of ligament's reconstruction often rely on autografts or allografts; however, the repairment of torn ligaments has garnered attention for its potential benefits in promoting biological integration and reducing immunogenic complications. Due to the rarity of this type of trauma, there are no standardized protocols on how to treat these injuries and therefore the question regarding the type of graft and the approach (open or arthroscopic) is still open.[2] The acute character of the injury gives the possibility to repair the affected ligament with anchor and enhancing the fixation with the Internal brace system.

By documenting this case, we aim to illustrate the efficacy of repairing techniques in multi-ligament knee repair, discuss the surgical nuances, and review the postoperative outcomes. This contributes to the broader discourse on optimizing treatment protocols for complex orthopaedic injuries, highlighting the evolving practices in ligament repair and the promising role of ligament repair in achieving successful long-term results.

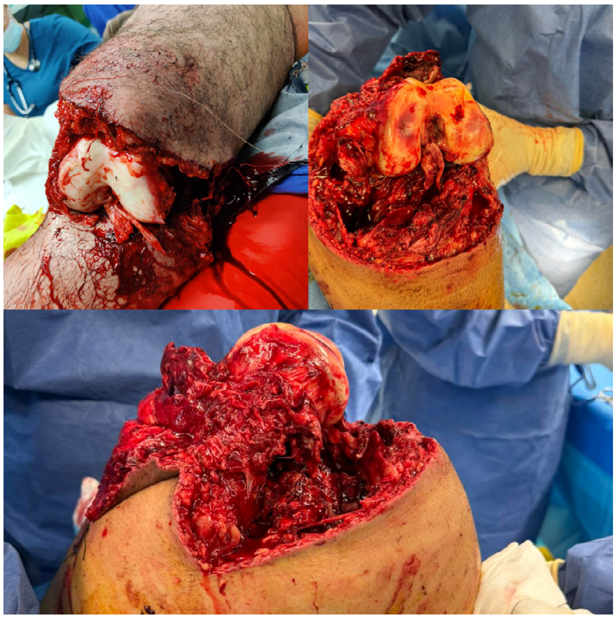

***Figure 1**. Patient's left limb upon arrival to the hospital. Open dislocation-fracture of left knee can be seen along with the PCL tendon and femoral condyles*

Case report

A 33-year-old male was brought to the emergency department via ambulance after a severe motorcycle accident. The patient was presented with a complex open fracture-dislocation of his left knee joint (Figure 1). The injury included a posterolateral tibial plateau fracture, a comminuted patellar fracture, an avulsion fracture of the lateral femoral condyle, and complete ruptures of the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament (LCL). The patient's medical history was unremarkable, with no chronic medical conditions, surgical interventions or known allergies. Upon arrival to the emergency department, the patient presented with a severely deformed left knee with visible open trauma, including bone fragments protruding through the wound. Despite the high energy of the injury and extensive soft tissue damage, the patient maintained intact neurovascular function in the affected limb.

A thorough diagnostic evaluation was conducted. A full body computed tomography (CT) scan revealed no evidence of intracranial hemorrhage, skull fractures, or cervical spine injuries. Bilateral first rib fractures were noted in the chest though there was no associated pneumothorax or hemothorax. Abdominal CT imaging showed no internal injuries. Focused imaging of the left lower extremity confirmed a complex fracture of the posterior column of the tibial plateau, a comminuted patella fracture, an avulsion fracture of the lateral femoral condyle, and complete tears of all major knee ligaments, including the ACL, PCL, MCL, and LCL. An additional X-ray of the

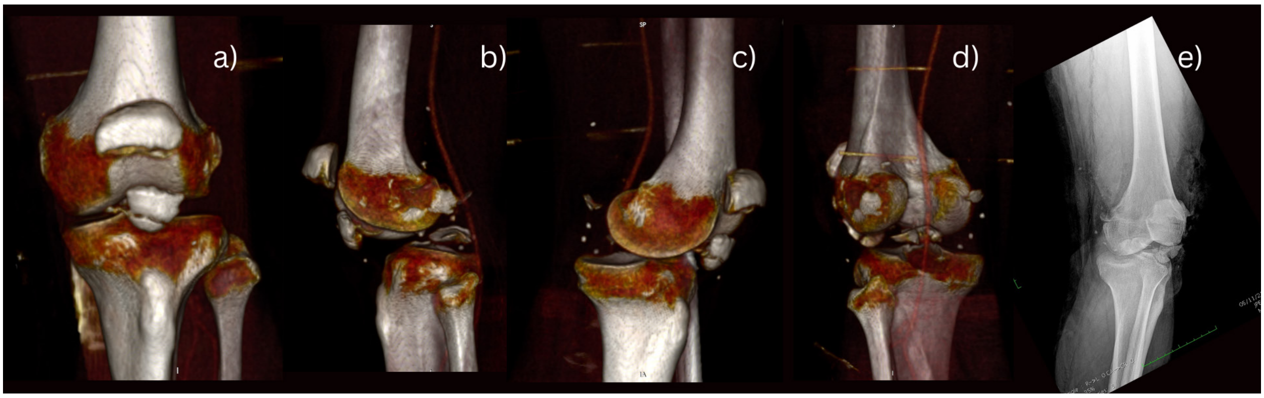

***Figure 2.** – a) AP view of CT of the patient's knee pre-operatively b) Lateral view of CT of the patient's knee pre-operatively c)Medial view of CT of the patient's knee pre-operatively d)Posterior view of CT of the patient's knee pre-operatively e) AP X-ray of the patient's left limb pre-operatively*

left limb further corroborated these findings (Figure 2) The case was classified as a KDV injury under Schenck's classification system, indicating a periarticular fracture-dislocation involving the femoral and tibial condyles with associated ligamentous disruption.[3,10] The prognosis indicated a complex and lengthy recovery process due to the severity of the trauma and the need for multiple surgical interventions.

The patient underwent a series of three surgeries as part of his comprehensive treatment plan. The first surgery was an emergency procedure performed immediately upon hospital arrival. It involved surgical cleaning and debridement of the wound, meticulous assessment of neurovascular integrity and application of external fixation to the left femur and tibia. This initial intervention aimed to stabilize the injury and prevent infection.

Three days post-injury, the patient underwent planned reconstructive surgery under general anesthesia. Positioned supine on a radiolucent flat table. After initial surgical cleaning, the external fixation was removed, and the existing wound was open again provided optimal exposure of the distal femur and proximal tibia. Initially a comminuted fracture of posterior column of tibial plateau was reduced and fixed using intraosseous sutures. The lateral meniscus was sutured next, restoring its integrity. (Figure 3)

For the PCL repair, a PCL guide was placed to the anteromedial side of tibia and centered in the tibial PCL footprint. A tunnel was drilled after the correct positioning of the guide. Then, the PCL was sutured, and the sutures were passed through the canal and fixed to the tibia using Smith & Nephew XTendobutton, attaching the PCL to its position.

For the ACL repair, an ACL guide was centered in the femoral ACL footprint ensuring the anatomical placement of the ligament. The tunnel was drilled from the footprint until the lateral wall of femoral condyle. ACL was sutured and the sutures were passed through the tunnel and fixed with the same technique as PCL.

For the MCL repair, a transverse tunnel from medial to lateral side of the tibial shaft was created. The ligament was sutured, and the sutures were passed through the tunnel and fixed with XTendobutton on the lateral side of tibial shaft attaching the MCL to its position. After, the MCL was enhanced proximally and distally with Internal Brace Swive Lock Anchor - Arthrex system.

For the LCL repair, a tunnel from posterolateral to anteromedial side of the tibial shaft was created. The ligament was sutured, and the sutures were passed through the tunnel and fixed and enhanced with the same technique as the MCL.

The lateral femoral condyle was reduced and fixed with two semi-threaded cannulated screws with washers. The comminuted patella fracture was reduced and fixed with intraosseous sutures and a tension band. After closing the wound, external fixation was reapplied to the femur and

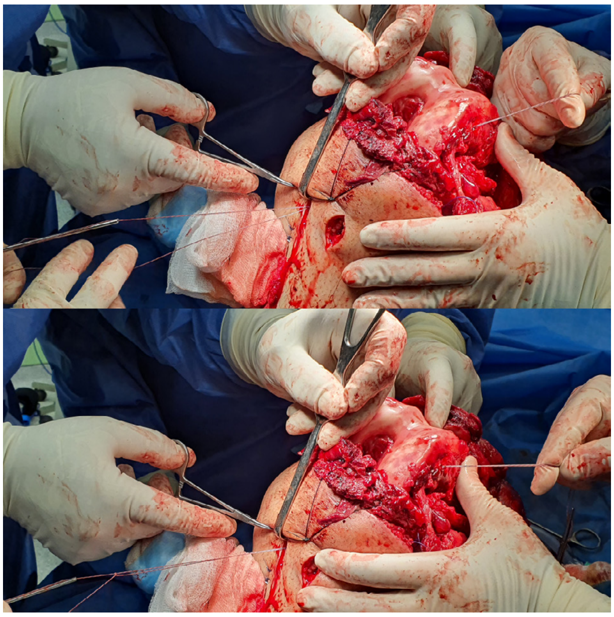

***Figure 3**. Intraoperative photo of the ligament's repair. The positioning of the patient is demonstrated along with the open approach to the knee joint*

***Figure 4**. a) Post-operative AP X-Ray of the patient's left knee joint b)Post-operative lateral X-Ray of the patient's left knee joint*

tibia, with the knee positioned in neutral position to ensure continued stabilization. Postoperative imaging confirmed an adequate anatomical reduction of the fractures. (Figure 4) This approach is consistent with the comprehensive treatment strategies for complex knee injuries detailed in the literature.

Pain management was provided with morphine 3mg PRN. The patient was closely monitored in the orthopaedic ward for 20 days post-operatively, with no signs of infection and stable vitals throughout. Due to the fragility of the trauma, physical therapy was not initiated. However, the patient was allowed to move in bed and flex and extend his ankle joint to avoid stiffness and muscle atrophy.

The third surgery was performed 20 days after the second and involved the removal of the external fixation and application of a functional knee brace. The patient was discharged the following day with instructions on partial weight-bearing using a functional knee brace locked at 0-90 degrees.

The patient attended bi-weekly outpatient visits initially, which were reduced to monthly after one month. Regular X-rays demonstrated proper fracture healing and joint stability. Four months postoperatively, an MRI (Figure 5) indicated that the reattached ligaments were not loose and remained securely attached to the bone, providing excellent stability and functionality. The patient reported no pain during movement or rest and had achieved an adequate range of motion with normal neurovascular signs. During follow-up visits, the stability of the knee joint was assessed with specific tests: ACL stability with Lachman test and Anterior drawer test, PCL with posterior drawer test, LCL with varus stress test, and MCL with valgus stress test. The patient adhered well to the prescribed rehabilitation protocol, including the use of the functional knee brace and partial weight-bearing instructions. No adverse or unanticipated events were reported. He returned to his daily activities, and to his job as a delivery man 6 months post injury.

At nine months post injury, the patient demonstrates full extension and 90 degrees of flexion in the left knee (Figure 5), with no pain during rest

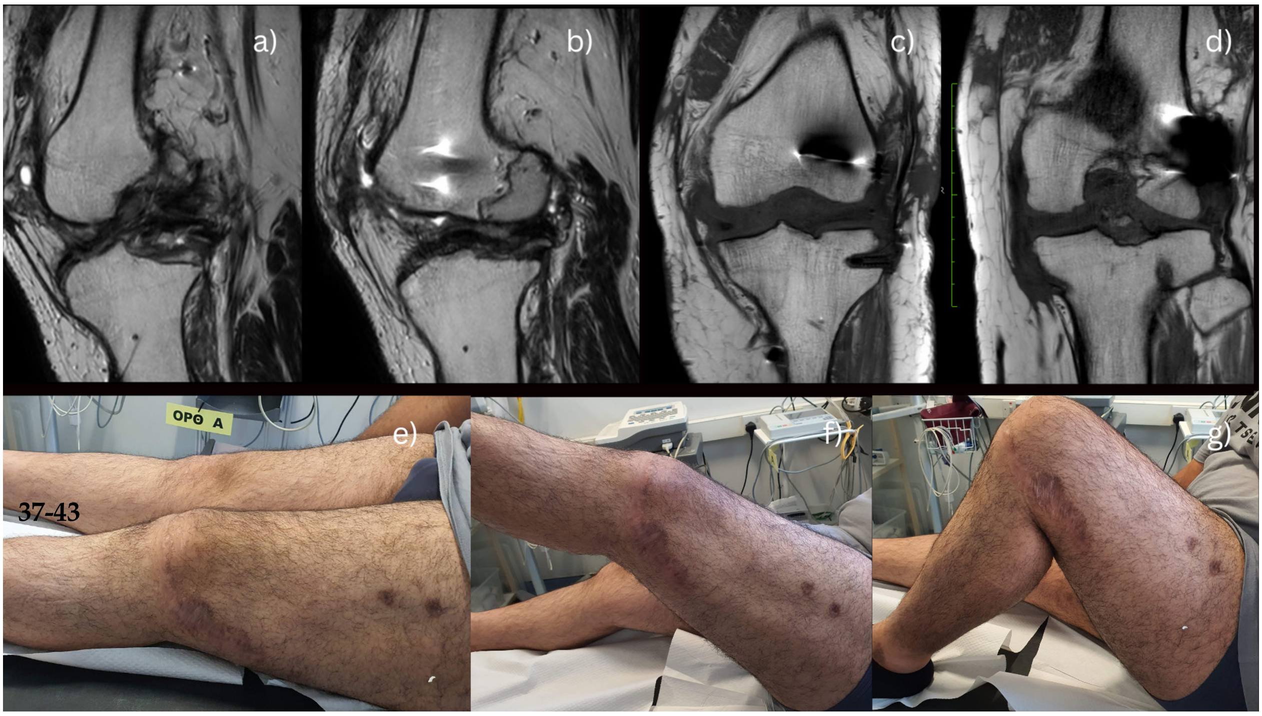

Figure 5*. a) Post-operative MRI of the left ACL b)Post-operative MRI of the left PCL c)Post-operative MRI of the left LCL d)Post-operative MRI of the left MCL e,f) 9 months post-operatively patient is able to fully extend his left knee g) 9 months post-operatively patient is able to achieve a 90 degree flexion in his left knee*

or movement. His knee joint remains stable, and the patient has no complaints. He has returned to work as a delivery man, performing all his daily activities without difficulty, and is able to fully bear weight on his left limb. His gait is completely normal [video], indicating a successful recovery. The patient's status shows excellent recovery, reflecting a full return to his daily activities and occupational responsibilities.

Discussion

The case report presented an effective management of a KD-V[3] multiligamentous knee injury using acute open single-stage repair with Internal Brace augmentation. This approach aligns with contemporary trends favoring early surgical intervention and repair of damaged ligaments to enhance outcomes and facilitate rapid return to pre-injury activity levels.[4] Our results add to the growing body of evidence supporting the feasibility and benefits of primary ligament repair in multi ligamentous knee injuries (MLIK).

Schenck's KD classification system, particularly the KD-V subtype, underscores the complexity of injuries involving both ligamentous and bony elements, which are typically associated with high-energy trauma.[3,10] The successful outcome of our patient, who returned to normal activities within 18 weeks post-surgery and resumed work within 6 months, highlights the effectiveness of primary ligament repair, even in such severe cases. The application of Schenck's classification in this context not only facilitated a structured approach to treatment but also supported decision-making in the management of complex periarticular injuries.

The high incidence of repairable ligaments underscores the potential of repair strategies over reconstruction. Specifically, the repair rates for the ACL, PCL, MCL and LCL are notably high, suggesting that many ligaments, even in complex injuries, can be effectively repaired rather than reconstructed[5]. This approach offers several advantages, including reduced surgical morbidity, preservation of native tissue and avoidance of complications associated with graft harvesting. The successful result in our patient demonstrates that primary ligament repair can restore function efficiently, allowing for a quicker recovery and return to daily activities.

However some factors such as age and BMI may influence the repairability of ligaments, that's why each case must be examined differently to achieve the best result possible for each patient.[6,8] These factors highlight the importance of patient selection in optimizing outcomes for ligament repair and suggest that specific patient demographics may benefit more from repair techniques.

The timing of surgical intervention is crucial for achieving optimal outcomes. Literature supports that early intervention within the period of three weeks tends to yield better outcomes due to superior tissue quality and the ability to distinguish ligaments separately.[7] However, the ideal timeframe remains debated, and further research is needed to determine the optimal window for repair to balance the benefits of early intervention with the risks of postoperative stiffness.

Finally, the application of modern techniques such as suture augmentation in ligament repair has shown promising results in enhancing stability and facilitating early rehabilitation.[9] Our patient's excellent recovery and absence of complications or reinjury attest to the potential of these techniques in managing complex knee injuries. Despite the limitations of our case report, including the fact that it is a sole case, the findings provide a strong basis for further research into the efficacy of primary ligament repair. Continued investigation into patient selection criteria, surgical techniques, and long-term outcomes will be essential to fully realize the benefits of primary repair in the treatment of Multiligamentous knee injuries.

Acknowledgment
Special thanks to the patient for the cooperation during his therapy.

Conflict of Interest
The authors declared no conflicts of interest.

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AOTH

Case report

Risk factors, presentation, and management of arthrofibrosis in post-arthroscopic knee surgery: a systematic review

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Abstract

Arthrofibrosis is a severe complication following arthroscopic knee surgery, particularly anterior cruciate ligament (ACL) reconstruction, leading to joint stiffness, pain, and functional limitations. Despite advancements in surgical and rehabilitation strategies, it remains a significant challenge in orthopedic practice. This systematic review examines the risk factors, clinical presentation, and management strategies for arthrofibrosis after arthroscopic knee surgery. A comprehensive literature search was conducted across PubMed, Embase, Scopus, Cochrane Library, and Web of Science following PRISMA guidelines. Studies addressing arthrofibrosis risk factors, diagnosis, and treatment outcomes were included. Relevant data were extracted and analyzed. Five studies met the inclusion criteria. Risk factors were categorized into surgical (graft malposition, prolonged tourniquet use, concomitant procedures), patient-related (prior surgery, systemic inflammation, genetic predisposition), and rehabilitation-associated (delayed mobilization, inadequate pain control). Clinically, arthrofibrosis presents as progressive stiffness, restricted range of motion, and quadriceps inhibition, often requiring imaging for confirmation. Management strategies range from early rehabilitation and pharmacological approaches to surgical interventions in refractory cases. Arthrofibrosis is a multifactorial condition requiring early recognition and targeted intervention. Preventive strategies focusing on optimized surgical techniques, patient selection, and rehabilitation protocols are essential. Further research is needed to develop novel antifibrotic therapies and improve functional outcomes.

Keywords

Arthrofibrosis; arthroscopic knee surgery; clinical presentation; management; risk factors

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Introduction

Arthrofibrosis is a well-recognized and debilitating complication following anterior cruciate ligament (ACL) reconstruction, characterized by excessive fibrotic tissue formation leading to restricted knee motion, persistent pain, and functional impairment. It represents one of the most challenging postoperative complications in orthopedic surgery, with a reported incidence ranging from 2% to 35%.[1] Despite advances in surgical techniques and rehabilitation protocols, arthrofibrosis remains a significant concern, often necessitating prolonged rehabilitation and, in severe cases, additional surgical interventions to restore joint mobility. The condition manifests in a spectrum of severity, from mild loss of terminal knee extension to severe joint contracture, profoundly affecting patients' quality of life and athletic performance.[2]

The reported global incidence of arthrofibrosis following arthroscopic knee surgery ranges between 2% and 35%. In high-volume orthopedic centers, the prevalence tends to be lower due to advancements in rehabilitation strategies and minimally invasive surgical techniques. However, arthrofibrosis remains a major concern among patients with delayed rehabilitation, improper graft placement, and those predisposed to excessive fibrotic responses.[3] In Indonesia, specific epidemiological data on arthrofibrosis following ACL reconstruction are limited. However, case reports and institutional studies indicate that the condition is present and clinically significant. A case report from Indonesia highlights the occurrence of arthrofibrosis as a debilitating complication post-ACL reconstruction, aligning with global incidence rates. Additionally, the rising number of ACL injuries in Indonesia, particularly among young athletes and physically active individuals, suggests a growing need to address postoperative complications, including arthrofibrosis.[4]

Numerous risk factors have been identified as contributing to the development of arthrofibrosis after ACL reconstruction, encompassing both surgical and patient-related variables. Intraoperative risk factors include aggressive synovial resection, improper tunnel placement leading to excessive graft tension, and prolonged tourniquet use, all of which can contribute to increased intra-articular inflammation and fibrosis.[5] The clinical presentation of arthrofibrosis is variable, with symptoms ranging from mild stiffness to profound motion loss. Early manifestations often include pain, swelling, and difficulty achieving full knee extension, which, if left untreated, may progress to more severe forms of fibrosis involving both the anterior and posterior compartments of the knee. In advanced cases, patients experience significant limitations in both extension and flexion, leading to impaired gait mechanics and functional disability.[6] The management of arthrofibrosis ranges from conservative approaches to surgical interventions. Early-stage arthrofibrosis is often managed through aggressive physiotherapy, pain control, and pharmacological interventions, including nonsteroidal anti-inflammatory drugs (NSAIDs) and corticosteroids, aimed at reducing inflammation and promoting joint mobility.[7] However, in cases where conservative measures fail, more invasive treatments such as manipulation under anesthesia (MUA), arthroscopic lysis of adhesions, and open surgical debridement may be necessary. Therefore, a systematic review of existing literature is essential to establish evidence-based guidelines for the prevention and treatment of arthrofibrosis after arthroscopic knee surgery.[8]

Despite the growing body of literature on arthrofibrosis after arthroscopic knee surgery, there remains a lack of high-quality evidence specifically addressing the risk factors, clinical presentation, and optimal management strategies for arthrofibrosis. Current studies provide conflicting results regarding the most effective surgical techniques, rehabilitation protocols, and pharmacologic treatments, making it difficult for clinicians to implement standardized best practices.[9] This systematic review aims to bridge this gap by synthesizing available evidence to provide a comprehensive analysis of arthrofibrosis after arthroscopic knee surgery

Method

This systematic review will be conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological rigor, transparency, and reproducibility. The study protocol will be registered in PROSPERO, an international prospective register for systematic reviews, to enhance transparency and reduce the risk of duplication. The methodology will include clearly defined eligibility criteria, a comprehensive literature search, systematic study selection, rigorous data extraction, and a thorough quality assessment process. Additionally, quantitative synthesis will be conducted when possible to generate pooled estimates regarding risk factors, clinical presentation, and management strategies for arthrofibrosis after ACL reconstruction.

Eligibility Criteria

A set of inclusion and exclusion criteria will be established to guide the selection of relevant studies. The inclusion criteria will encompass studies that investigate arthrofibrosis as a complication following ACL reconstruction, particularly those that assess its risk factors, clinical presentation, or management. Eligible studies will include randomized controlled trials (RCTs), cohort studies, case-control studies, and case series studies. Only peer-reviewed journal articles published in English will be considered. Studies will be excluded if they focus on arthrofibrosis unrelated to ACL reconstruction, as well as case reports, conference abstracts, editorials, expert opinions, and narrative reviews. Pediatric studies will be excluded due to potential variations in outcomes related to open growth plates. Non-English publications will also be excluded due to feasibility constraints in translation and interpretation. Additionally, studies with insufficient data or poor methodological quality will not be considered for inclusion.

Information Sources and Search Strategy

A comprehensive literature search will be conducted across multiple electronic databases, including PubMed, Embase, Scopus, Cochrane Library, and Web of Science. The search strategy will incorporate Medical Subject Headings (MeSH) terms, keywords, and Boolean operators to maximize sensitivity and specificity. Keywords such as "arthrofibrosis," "arthroscopy," "ACL reconstruction," "knee stiffness," "risk factors," "surgical outcomes," and "management" will be used in various combinations to identify relevant studies. The search strategy will be tailored for each database, ensuring that appropriate indexing terms are utilized. A MeSH term includes such as: (("Arthrofibrosis"[MeSH] OR "Knee Stiffness") AND ("Anterior Cruciate Ligament Reconstruction"[MeSH] OR "ACL Reconstruction" OR "Arthroscopy" OR Arthroscop*)) AND ("Risk Factors" OR "Surgical Outcomes" OR "Management" OR "Rehabilitation"). The reference lists of included studies and relevant systematic reviews will be manually screened to identify additional articles that meet the inclusion criteria. Grey literature, including unpublished studies and conference proceedings, will not be considered due to concerns regarding quality control and reproducibility.

Study Selection Process

All retrieved studies will be imported into EndNote or Rayyan for duplicate removal and systematic screening. The study selection process will occur in three distinct phases. First, two independent reviewers will conduct a title and abstract screening to identify potentially relevant studies. Articles that clearly do not meet the eligibility criteria will be excluded at this stage. Second, the remaining articles will undergo a full-text review, where two independent reviewers will assess their relevance based on the inclusion and exclusion criteria. Any discrepancies in study selection will be resolved through discussion, and a third reviewer will be consulted if consensus cannot be reached. Finally, studies that meet all inclusion criteria will be included in the systematic review. The PRISMA flow diagram will be used to document the number of studies identified, screened, included, and excluded at each stage of the selection process. (Figure 1)

Data Extraction

A standardized data extraction form will be developed to ensure consistency in data collection. Two independent reviewers will extract key study information, including author, publication year, study design, sample size, and patient demographics such as age, sex, body mass index (BMI), and comorbidities. Surgical details will also be recorded, includ-

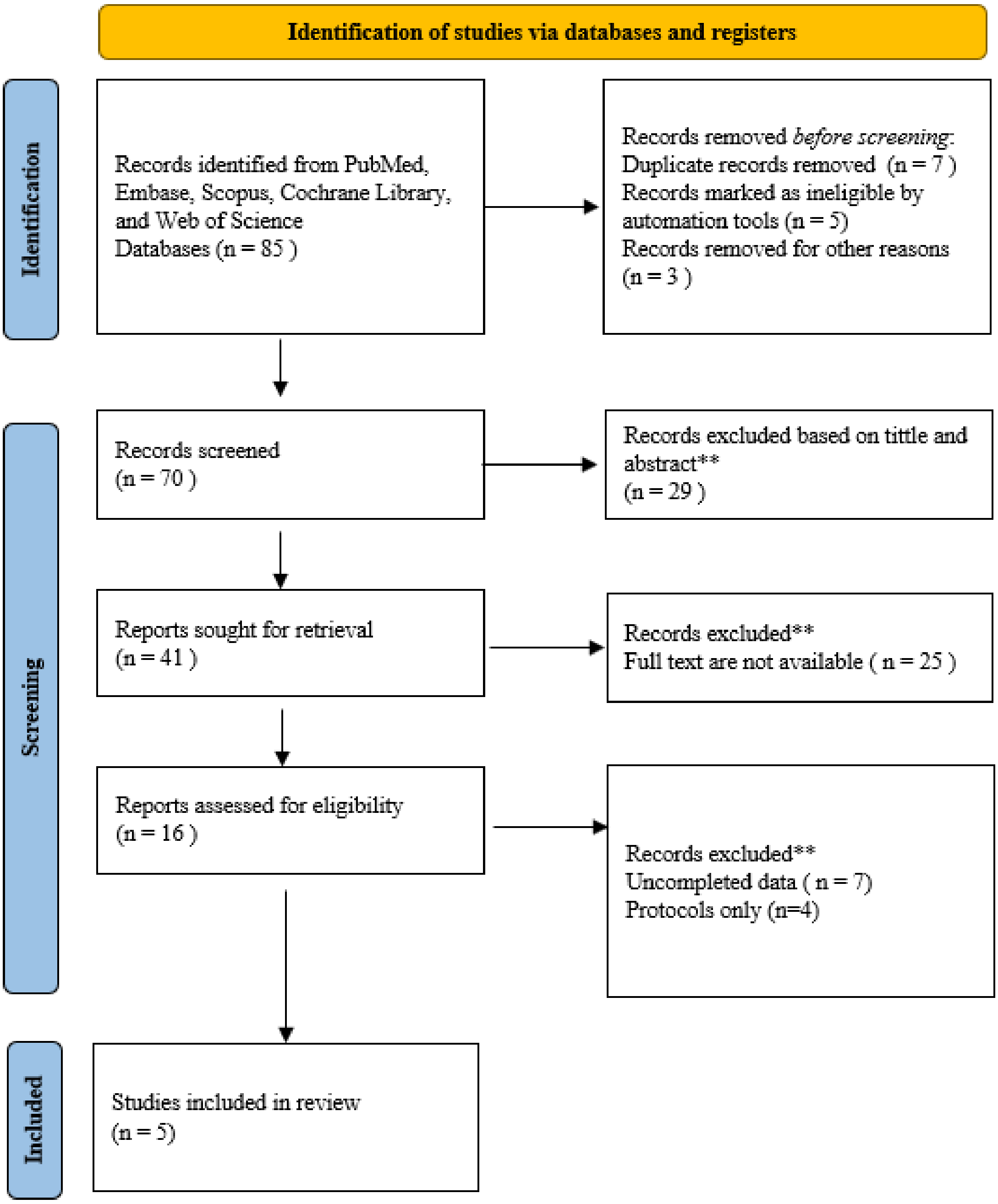

Figure 1. *PRISMA Flow Chart*

ing the type of ACL reconstruction performed, graft selection, tunnel placement, and surgical technique. Identified risk factors for arthrofibrosis will be categorized into patient-related, intraoperative, and postoperative variables. Data on clinical presentation will include symptom onset, severity of stiffness, and diagnostic methods used. The effectiveness of different management strategies, both conservative and surgical, will be assessed, along with reported clinical outcomes such as range of motion (ROM), functional scores (IKDC, Lysholm), patient satisfaction, and recurrence rates.

Quality Assessment
Each study will be independently assessed by two reviewers to determine the risk of bias in domains such as selection bias, performance bias, detection bias, attrition bias, and reporting bias. Any disagreements will be resolved through discussion, and a third reviewer will be consulted if necessary. Studies with a high risk of bias will be discussed in the limitations section and may be excluded from meta-analysis if their inclusion is deemed to significantly affect the validity of pooled estimates.

Result
The PRISMA flowchart provides a structured overview of the study selection process in this systematic review on arthrofibrosis following post-arthroscopic knee surgery. It ensures transparency and rigor by detailing how studies were identified, screened, and included. A total of 85 records were initially retrieved from databases. Before screening, 15 records were removed, where seven were duplicates, five were excluded by automation tools, and three were removed for other reasons. This step helps eliminate redundancy and irrelevant studies. Sixteen studies were assessed in detail for relevance and completeness. However, 11 studies were excluded, seven due to incomplete data and four because they were protocols without actual results. Ultimately, five studies met all eligibility criteria and were included in the final review. These studies form the basis of the systematic analysis of arthrofibrosis risk factors, presentation, and management.

All included studies utilize either a retrospective cohort design or case series, focusing on analyzing past clinical cases rather than conducting prospective trials. (Table 1) This approach provides insights into long-term treatment outcomes but may introduce limitations related to data completeness and potential bias. The sample sizes vary significantly across studies, ranging from small cohorts of 32 participants to larger groups exceeding 200 patients. Gender distribution is inconsistent, with some studies reporting a predominance of male participants, such as Rushdi et al. (93% male), while others do not provide gender details. The mean age of participants also varies, reflecting the diverse populations analyzed in different studies.

Regarding clinical characteristics, all studies focus on arthrofibrosis as a complication of knee surgery, with some specifying patellofemoral arthrofibrosis as a distinct condition. The primary interventions examined include arthroscopic lysis of adhesions, capsular release, and surgical management, all aimed at improving the range of motion (ROM) and reducing symptoms. Follow-up durations differ across studies, spanning from 6 months to over 10 years, which influences the assessment of long-term treatment effectiveness. Outcomes across studies consistently demonstrate that arthroscopic interventions lead to significant improvements in ROM, reduced pain levels, and better functional scores, such as the International Knee Documentation Committee (IKDC) score and Lysholm score. Additionally, some studies identify potential risk factors for arthrofibrosis, including early ACL reconstruction (within one month of injury) and female gender. Despite variations in study populations and methodologies, the overall findings suggest that timely intervention and proper rehabilitation can lead to positive outcomes in patients with arthrofibrosis following knee surgery.

Discussions
Arthrofibrosis is a pathological condition characterized by excessive fibroproliferative response and intra-articular scarring following knee surgery, particularly after anterior cruciate ligament (ACL) reconstruction. It is one of the most significant complications associated with arthroscopic knee procedures, leading to restricted joint mobility, persistent pain, and functional limitations. The condition results from an aberrant wound healing process, where excessive collagen deposition and fibrosis lead to adhesions within the intra-articular and periarticular structures, ultimately restricting the normal biomechanics of the knee joint.[15] Despite advances in surgical techniques and postoperative rehabilitation strategies, arthrofibrosis remains a major challenge in orthopedic surgery, often necessitating prolonged physical therapy and, in severe

Table 1. Characteristics of Study

No	Author (Year)	Year	Country	Design Study	Sample Size (n)	Gender	Age (mean)	Lysholm score (Points / 100)	Diagnosis	Etiology	Type of Intervention	Follow-up (mean)	Conclusions
1	Calloway et al.[10]	2018	USA	Case Series	32	7 females	32.8 years (range, 19-58 years)	NR	Refractory patellofemoral arthrofibrosis	NR	arthroscopic release for refractory PFA after ACL reconstruction	43.6 months (range, 16-98 months).	The IKDC score significantly improved from 49.6 to 69.4 (P < .00001), with 50% of patients reaching a meaningful clinical improvement. WOMAC scores also increased from 74 to 85.3 (P < .00001), with 47% achieving clinical improvement. Most patients (97%) felt the procedure was beneficial, and 78% said they would undergo it again.
2	Dauty et al.[11]	2023	Australia	Cohort retrospective	Arthrofibrosis group (n=92), control group (n=842)	NR	28.0 ± 8.0	83 ± 9	Arthrofibrosis	Pre-existing joint condition	NR	NR	Female gender, early ACL reconstruction (<1 month), BPTB procedure, meniscal repair, and BMI ≥ 25 were not confirmed as risk factors. The only identified risk factor was a history of competitive sports (OR: 3.56, 95% CI: 2.20–5.75, p = 0.0001). Meanwhile, age under 18 (OR: 0.40, p = 0.015) and inpatient rehabilitation (OR: 0.28, p = 0.0001) were protective factors.
3	Fabricant et al.[12]	2018	USA	Cohort retrospective	90	31% male	14.4 ± 3.5 years	NR	Arthrofibrosis	NR	lysis of adhesions and manipulation	42± 56 months.	Patients who had preoperative dynamic splinting (51%) initially had better flexion (99° vs. 77°, P=0.001), but there was no significant difference at the final follow-up (121° vs. 128°, P=0.08).

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No	**Author (Year)**	**Year**	**Country**	**Design Study**	**Sample Size (n)**	**Gender**	**Age (mean)**	**Lysholm score (Points / 100)**	**Diagnosis**	**Etiology**	**Type of Intervention**	**Follow-up (mean)**	**Conclusions**
													Treatment failure was not affected by the time between the initial procedure and LOA/MUA. The percentage of patients who regained full ROM was similar between those who had dynamic splinting and those who did not (65% vs. 59%, P=0.70).
4	Lamba, et al.[13]	2023	USA	Cohort retrospective	40	46.2% male	27.2 years (range, 11.0-63.8 years)	NR	Arthrofibrosis	Delayed rehabilitation	lysis of adhesions, capsular release with or without manipulation under anesthesia, and excision of cyclops lesions.	10.0 years (range, 2.9-20.7 years)	Before surgery, the average knee flexion was 102° (range: 40°–150°) and extension was 8° (range: 0°–25°). After arthroscopic treatment, flexion improved to 131° (range: 110°–150°), and extension averaged 0° (range: –10° to 5°). The overall range of motion (ROM) significantly increased from 94° (range: 40°–140°) preoperatively to 131° (range: 107°–152°) at the final follow-up (P < .001). Pain levels also improved, with the visual analog scale (VAS) score decreasing from 3.0 before surgery to 1.2 afterward (P = .001).

Table 1. Characteristics of Study

No	Author (Year)	Year	Country	Design Study	Sample Size (n)	Gender	Age (mean)	Lysholm score (Points / 100)	Diagnosis	Etiology	Type of Intervention	Follow-up (mean)	Conclusions
5	Rushdi, et al.[14]	2019	Malaysia	Case Series	200	93% male	26 years old	NR	Arthrofibrosis	NR	Surgical intervention	6 months	The incidence of arthrofibrosis following ACL reconstruction in our centers is approximately 5%. However, this rate can be minimized through appropriate preventive strategies, including comprehensive preoperative assessment, careful patient selection, ensuring full restoration of range of motion (ROM) before surgery, and optimizing the timing of the procedure.

cases, surgical intervention to restore joint motion. This systematic review provides a comprehensive synthesis of current evidence on the risk factors, clinical presentation, and management strategies for arthrofibrosis following ACL reconstruction, a significant complication that adversely affects postoperative recovery and functional outcomes. The findings highlight the multifactorial etiology of arthrofibrosis, involving an interplay between biological, biomechanical, and rehabilitation-related factors. This condition remains a major concern in orthopedic surgery, as it can prolong rehabilitation, increase the likelihood of revision procedures, and impair long-term knee function. Understanding the underlying mechanisms, risk factors, and available management strategies is critical for optimizing treatment outcomes and preventing excessive joint fibrosis.

Arthrofibrosis is a multifactorial condition that arises from an excessive fibrotic response following arthroscopic knee surgery, particularly anterior cruciate ligament (ACL) reconstruction. (Table 2) The pathogenesis involves a complex interplay between surgical, patient-related, and postoperative rehabilitation factors that contribute to aberrant tissue healing and scar formation. Identifying these risk factors is critical for early prevention, timely intervention, and improved patient outcomes. Several intraoperative factors have been implicated in the development of arthrofibrosis, primarily due to their role in triggering an exaggerated inflammatory response and excessive scar tissue formation.

One of the most significant contributors is improper graft placement, particularly anteriorization or excessive tensioning of the ACL graft, which can lead to biomechanical alterations and increased strain on the joint capsule. Studies have demonstrated that malpositioned grafts may cause impingement within the intercondylar notch, promoting inflammation and fibrosis.[16] Furthermore, excessive synovial resection and aggressive intraoperative soft tissue manipulation can disrupt normal joint homeostasis, increasing the likelihood of inflammatory-mediated fibrotic changes.[17]

Prolonged tourniquet use during arthroscopic procedures is another surgical factor associated with a heightened risk of arthrofibrosis. Prolonged ischemia-reperfusion injury leads to increased cytokine release, oxidative stress, and endothelial damage, all of which contribute to an amplified inflammatory cascade that predisposes patients to fibrotic adhesion formation.[18] Additionally, the use of allografts versus autografts has been debated in the context of arthrofibrosis risk. While allografts reduce donor site morbidity, some studies suggest that autografts, particularly bone-patellar tendon-bone (BPTB) grafts, may be associated with a higher incidence of postoperative stiffness due to increased local inflammation at the harvest site.[19] The type of concomitant procedures performed during ACL reconstruction also influences the likelihood of arthrofibrosis. For example, patients undergoing additional meniscal repairs, microfracture surgery, or cartilage restoration procedures have an elevated risk of stiffness due to the combined inflammatory burden and the necessity for postoperative motion restrictions.[20] Similarly, lateral extra-articular tenodesis (LET) or anterolateral ligament reconstruction (ALLR), often performed adjunctively in cases of high-grade rotational instability, may increase joint fibrosis if not carefully managed during rehabilitation.

Certain patient-specific variables predispose individuals to a heightened fibrotic response following knee surgery. One of the most well-established risk factors is a history of prior knee surgery. Patients with previous surgical interventions, particularly open procedures or multiple revisions, exhibit an increased risk of developing intra-articular adhesions due to pre-existing scar tissue and altered synovial fluid composition.[21] Additionally, a history of joint infections, such as septic arthritis, further exacerbates the risk of arthrofibrosis by inducing chronic synovial inflammation and fibrosis. Systemic inflammatory conditions, including diabetes mellitus, rheumatoid arthritis, and other autoimmune disorders, have also been linked to an increased predisposition to excessive scar formation. Hyperglycemia, for instance, is known to impair collagen remodeling and promote fibroblast proliferation, contributing to the pathogenesis of arthrofibrosis.[22] Similarly, patients with hypercoagulable states, such as those with a genetic predisposition to deep vein thrombosis (DVT), may experience heightened fibrin deposition within the joint, further exacerbating the risk of adhesions.

Genetic predisposition plays a crucial role in determining an individual's likelihood of developing arthrofibrosis. Variations in genes associated with inflammatory cytokine regulation, such as tumor necrosis factor-alpha (TNF-α), transforming growth factor-beta (TGF-β), and matrix metalloproteinases (MMPs), have been implicated in abnormal wound healing responses.[23] These genetic factors may explain why certain patients exhibit an exaggerated fibrotic response despite optimal surgical and rehabilitation protocols. Age and sex are additional demographic variables that may influence arthrofibrosis risk. Younger patients, particularly those under 20 years of age, may have a more robust healing response, predisposing them to excessive scar tissue formation. Conversely, older individuals with pre-existing osteoarthritis may develop joint stiffness due to underlying degenerative changes. Sex-based differences have also been reported, with some studies suggesting that female patients may be at a slightly higher risk due to hormonal influences on collagen synthesis and soft tissue remodeling.[4]

The postoperative rehabilitation phase plays a pivotal role in determining the risk of arthrofibrosis. One of the most critical factors is delayed mobilization and prolonged immobilization following surgery. Early joint motion is essential for preventing intra-articular adhesions, maintaining synovial flu-

Table 2. Risk Factors and Management Strategies for Arthrofibrosis After Arthroscopic Knee Surgery			
	Category	**Key Factors / Strategies**	**Clinical Interpretation**
Risk Factors	Surgical-related	Graft malposition, excessive graft tension, aggressive synovectomy, prolonged tourniquet use, concomitant procedures	Technical errors and excessive intraoperative tissue trauma amplify inflammatory response, increasing the risk of fibrotic adhesion formation
	Graft-related	BPTB autograft, larger graft diameter, harvest-site morbidity	Certain graft characteristics may provoke greater local inflammation, potentially predisposing to postoperative stiffness
	Patient-related	Prior knee surgery, systemic inflammatory disease, genetic predisposition, female sex, young age	Host biological response plays a critical role in fibrotic tendency, independent of surgical technique
	Rehabilitation-related	Delayed mobilization, prolonged immobilization, inadequate pain control, poor protocol adherence	Failure to restore early knee extension and controlled ROM is a major modifiable risk factor for arthrofibrosis
Management	Conservative	Early physiotherapy, controlled ROM exercises, CPM, NSAIDs, corticosteroids	Early-stage arthrofibrosis may be reversed by suppressing inflammation and promoting collagen remodeling through guided motion
	Minimally invasive	Manipulation under anesthesia, arthroscopic lysis of adhesions	Early arthroscopic intervention is associated with superior restoration of ROM compared with delayed procedures
	Surgical (advanced)	Open capsular release, revision procedures	Reserved for refractory cases with established fibrosis and severe functional limitation
	Emerging therapies	Antifibrotic agents, PRP, MSCs, gene-targeted therapies	Novel biologic approaches aim to modulate fibrotic pathways but currently lack robust clinical evidence

id circulation, and promoting collagen remodeling. Patients who fail to achieve full extension within the first six weeks postoperatively are at an increased risk of developing long-term stiffness.[24] Inadequate pain control is another major contributor to arthrofibrosis. Persistent pain leads to reflexive quadriceps inhibition, reduced joint mobility, and subsequent scar tissue formation. Multimodal analgesia, including regional nerve blocks, nonsteroidal anti-inflammatory drugs (NSAIDs), and cryotherapy, is essential for mitigating this risk.[25] However, over-reliance on opioid medications without an emphasis on early mobilization may paradoxically contribute to stiffness due to prolonged inactivity.

Rehabilitation intensity and protocol adherence significantly impact arthrofibrosis development. Overly aggressive rehabilitation, including excessive forced stretching or premature high-impact loading, may exacerbate inflammation and contribute to fibrotic tissue deposition. Conversely, an overly conservative approach that does not prioritize early weight-bearing and range-of-motion exercises can lead to avoidable stiffness.[26] Striking the right balance between protecting the healing graft and promoting functional recovery is paramount in preventing arthrofibrosis. Additionally, postoperative complications such as hemarthrosis and persistent joint effusion can further increase the risk of fibrosis. Uncontrolled intra-articular bleeding leads to fibrin deposition, which serves as a scaffold for fibrotic adhesions. Therefore, proper surgical hemostasis, the judicious use of anticoagulation therapy, and close monitoring for postoperative swelling are crucial in reducing the incidence of arthrofibrosis.[27]

Arthrofibrosis is a significant and potentially debilitating complication following arthroscopic knee surgery, particularly anterior cruciate ligament (ACL) reconstruction. It is characterized by excessive fibrotic tissue formation within the joint, leading to restricted motion, persistent pain, and functional impairment. The condition varies in severity, ranging from mild stiffness and discomfort to profound joint contracture, severely affecting mobility and quality of life. The clinical presentation of arthrofibrosis is influenced by multiple factors, including the extent of intra-articular fibrosis, the involvement of periarticular structures, and the presence of underlying patient-specific risk factors such as a history of previous surgery, systemic inflammatory conditions, and genetic predisposition.[28]

In the early postoperative phase, patients with arthrofibrosis may present with disproportionate and persistent knee pain, localized swelling, and an inability to achieve full range of motion despite adherence to rehabilitation protocols. While some degree of transient stiffness is common following knee surgery, arthrofibrosis is characterized by a progressive and sustained limitation in movement that does not resolve with conservative management.[13] One of the earliest signs is difficulty in achieving full extension, often accompanied by increased resistance during passive stretching and pain upon forced extension. Patients may also report an unusual sensation of tightness within the joint, which is exacerbated during weight-bearing activities. Quadriceps inhibition and muscle atrophy may develop due to reduced knee mobility and pain-associated disuse, further compounding the functional impairment.[29]

As the condition progresses, the fibrotic process extends to the joint capsule, synovial tissues, and periarticular structures, leading to worsening motion deficits. A hallmark clinical feature of arthrofibrosis is the loss of terminal knee extension, commonly referred to as an “extension deficit,” which alters normal gait mechanics and predisposes the patient to patellofemoral maltracking, increased joint stress, and secondary cartilage degeneration. In more advanced cases, flexion deficits also develop, resulting in global joint stiffness and profound disability. Patients may experience increasing pain with activities of daily living, particularly during stair climbing, prolonged sitting, or attempts at deep squatting. The loss of both extension and flexion significantly impairs functional mobility and is often associated with a sensation of joint instability, further limiting physical activity.[12]

The clinical classification of arthrofibrosis is based on the severity and anatomical distribution of fibrotic adhesions within the knee. Localized arthrofibrosis, such as the well-documented Cyclops lesion, involves the formation of a fibroproliferative nodule anterior to the ACL graft, mechanically obstructing terminal extension and causing painful impingement. This condition, often detected during follow-up evaluations, typically requires surgical debridement to restore full extension. Diffuse intra-articular arthrofibrosis, on the other hand, involves extensive fibrosis within the joint capsule, leading to progressive loss of both extension and flexion. In more severe cases, extracapsular arthrofibrosis extends beyond the intra-articular structures, affecting the quadriceps muscle, patellar tendon, and posterior knee structures, further exacerbating functional deficits. The most severe form, global arthrofibrosis, is characterized by widespread fibrosis throughout the knee joint, resulting in severe motion loss, chronic pain, and significant long-term disability, often requiring aggressive surgical intervention.[24]

Diagnosis of arthrofibrosis is primarily clinical, with a thorough history and physical examination being the cornerstone of assessment. Key diagnostic criteria include a persistent limitation in passive and active knee motion, particularly in extension, despite appropriate rehabilitation efforts. The passive and active range of motion (ROM) assessment is crucial in determining the severity of restriction, with extension loss of more than 5° often considered significant. The patellar mobility test is useful in evaluating patellar tracking abnormalities and the presence of fibrotic adhesions restricting patellar movement. Additionally, the quadriceps activation test may reveal persistent quadriceps inhibition and muscle atrophy, further indicating the presence of arthrofibrosis-related dysfunction.[30]

While clinical evaluation remains the gold standard for diagnosing arthrofibrosis, imaging modalities play a complementary role in assessing the extent of fibrotic changes and ruling out other postoperative complications. Magnetic resonance imaging (MRI) is the most utilized imaging technique, capable of detecting intra-articular adhesions, capsular thickening, and synovial fibrosis. MRI is particularly valuable in identifying Cyclops lesions and evaluating the presence of associated joint effusion, which may suggest ongoing inflammation.[31] Dynamic fluoroscopy can be used to assess impingement during knee motion, providing additional insight into the mechanical restrictions caused by fibrotic tissue. In cases where diagnostic uncertainty remains, arthroscopic evaluation serves as the definitive diagnostic tool, allowing direct visualization of intra-articular fibrosis and adhesions while offering the opportunity for therapeutic intervention if necessary.

The management of arthrofibrosis following arthroscopic knee surgery remains a significant challenge in orthopedic practice, requiring a multifaceted approach tailored to the severity of the condition and the individual patient's response to treatment. Arthrofibrosis is a progressive condition characterized by excessive fibroproliferation, intra-articular adhesions, and capsular contracture, leading to pain, stiffness, and functional impairment.[32] The primary goal of management is to restore knee range of motion (ROM), alleviate symptoms, and prevent further fibrosis while minimizing the risk of recurrence. Given the heterogeneous nature of arthrofibrosis, treatment strategies range from conservative rehabilitation-based approaches to invasive surgical interventions, with emerging therapies focusing on the modulation of inflammatory and fibrotic pathways to improve long-term outcomes.[10]

The cornerstone of arthrofibrosis management is early detection and aggressive rehabilitation to prevent the progression of fibrosis. Conservative treatment remains the first-line approach, particularly in cases of mild to moderate arthrofibrosis, where early intervention can yield significant improvements in ROM and functional recovery. A structured physiotherapy regimen emphasizing controlled ROM exercises, stretching, and strengthening is essential to counteract the effects of fibrosis and restore joint mechanics. Evidence suggests that early postoperative mobilization, initiated within the first few days following arthroscopic surgery, significantly reduces the risk of developing arthrofibrosis by preventing intra-articular adhesions and promoting synovial fluid circulation. Physical therapy modalities such as passive stretching, continuous passive motion (CPM) devices, and aquatic therapy have been utilized to enhance ROM and minimize joint stiffness. CPM therapy has been shown to reduce postoperative stiffness by promoting mechanical elongation of collagen fibers and inhibiting fibroblast proliferation. Studies indicate that patients who undergo early CPM therapy demonstrate improved knee extension and decreased rates of arthrofibrosis compared to those who undergo delayed mobilization.[33] Additionally, eccentric quadriceps strengthening and neuromuscular re-education programs play a crucial role in restoring knee function and preventing muscle atrophy, which is commonly observed in patients with prolonged immobilization due to arthrofibrosis.

Pharmacologic interventions, including nonsteroidal anti-inflammatory drugs (NSAIDs) and corticosteroids, have been employed as adjunct therapies to mitigate inflammation and reduce fibrotic tissue formation. NSAIDs, such as celecoxib, have demonstrated efficacy in controlling postoperative inflammation and minimizing fibroblast activation, thus reducing the progression of arthrofibrosis. Intra-articular corticosteroid injections, particularly triamcinolone, have been used to modulate the inflammatory response in early-stage arthrofibrosis, with some studies reporting transient improvements in ROM and pain relief. However, long-term use of corticosteroids poses the risk of chondrotoxicity and should be used judiciously in select patients.[11]

When conservative measures fail to yield satisfactory improvements in ROM, more invasive interventions may be warranted. One of the earliest procedural interventions for arthrofibrosis is manipulation under anesthesia (MUA), in which the knee is forcibly flexed and extended to break intra-articular adhesions and restore mobility.[33] MUA is most effective when performed within the first 12 weeks postoperatively, as early-stage adhesions are more pliable and responsive to mechanical stretching.[34] However, aggressive manipulation carries the risk of iatrogenic injury, including ligamentous strain, chondral damage, and even femoral fractures in osteoporotic patients.

For patients who fail to respond to MUA or present with established fibrotic changes, arthroscopic lysis of adhesions is a preferred minimally invasive alternative. Arthroscopic debridement allows direct visualization and excision of fibrotic tissue, cyclops lesions, and infrapatellar contractures contributing to motion restriction.[22] Studies have shown that early arthroscopic intervention, particularly within six months post-surgery, leads to superior outcomes compared to delayed procedures, as long-standing fibrosis is more resistant to mechanical release.[10] Postoperative rehabilitation following arthroscopic debridement is critical to sustaining gains in ROM, with intensive physiotherapy and bracing protocols recommended to prevent recurrent fibrosis.

In severe and refractory cases of arthrofibrosis, open surgical intervention may be necessary to restore functional mobility. Open capsular release involves extensive excision of fibrotic tissue, including anterior and posterior capsular contractures, to re-establish knee extension and flexion.[22] This procedure is often reserved for patients with chronic arthrofibrosis unresponsive to previous interventions, where severe joint contracture significantly impairs daily activities and quality of life. Clinical outcomes following open capsular release are variable, with reports indicating that while many patients achieve functional improvements, a subset remains at risk for recurrent fibrosis, particularly in the presence of ongoing inflammation or genetic predisposition to excessive scar formation.[13]

Total knee arthroplasty (TKA) is considered a last resort for patients with end-stage arthrofibrosis, particularly in cases where joint degeneration and chondral damage are extensive. While TKA can alleviate pain and restore some degree of function, postoperative stiffness remains a concern, necessitating strict adherence to rehabilitation protocols to optimize outcomes.[33] Recent advancements in surgical techniques, including patient-specific implants and robotic-assisted TKA, have shown promise in improving precision and reducing the risk of postoperative fibrosis, although long-term studies are needed to validate these approaches.[21]

With growing insights into the molecular mechanisms underlying arthrofibrosis, emerging therapies are being explored to target the fibrotic cascade at a cellular level. Antifibrotic agents, such as losartan and pirfenidone, have demonstrated potential in modulating TGF-β signaling and reducing fibroblast proliferation in preclinical studies.[35] Additionally, biologic therapies, including platelet-rich plasma (PRP) and mesenchymal stem cell (MSC) injections, have been investigated for their regenerative properties in mitigating fibrosis and promoting tissue remodeling. While early findings are promising, large-scale clinical trials are needed to establish the efficacy and safety of these novel interventions. Gene therapy is another exciting avenue, with research focusing on gene silencing techniques to suppress key fibrotic mediators and prevent excessive scar formation. CRISPR-based approaches targeting fibrotic genes such as connective tissue growth factor (CTGF) and periostin are being explored as potential therapeutic strategies to prevent arthrofibrosis at the molecular level.[36] Although still in experimental stages, these advancements offer hope for more effective and personalized management of arthrofibrosis in the future.

This systematic review provides a comprehensive analysis of arthrofibrosis following arthroscopic knee surgery, focusing on its risk factors, clinical presentation, and management strategies. By synthesizing current evidence, it offers valuable insights into the pathophysiology and treatment approaches, aiding clinicians in optimizing patient outcomes. The review follows PRISMA guidelines, ensuring methodological rigor, transparency, and reproducibility. Additionally, by including recent epidemiological data and emerging therapeutic approaches, this study highlights key advancements and areas for future research. Despite its strengths, this review has several limitations. The variability in definitions, diagnostic criteria, and outcome measures across studies introduces heterogeneity, making direct comparisons challenging. Some included studies may have selection biases, and the quality of evidence may be limited due to small sample sizes or retrospective designs. Additionally, the lack of high-quality randomized controlled trials on novel antifibrotic treatments limits definitive conclusions on emerging therapies. Future research should focus on standardized methodologies and long-term outcomes to strengthen the evidence base for arthrofibrosis management.

Conclusion

Arthrofibrosis after arthroscopic knee surgery remains a significant challenge, leading to pain, stiffness, and functional limitations. Despite advancements in surgical techniques and rehabilitation, it continues to affect patient outcomes, emphasizing the need for early diagnosis and effective management. A multimodal treatment approach is essential, beginning with conservative strategies such as early mobilization and physiotherapy. When non-surgical methods fail, interventions like manipulation under anesthesia or arthroscopic adhesiolysis may be required. In severe cases, open surgical release or total knee arthroplasty may be necessary, though the risk of recurrence remains a concern. Future research should focus on refining risk assessment, optimizing rehabilitation protocols, and exploring novel antifibrotic therapies. Standardizing diagnostic criteria and treatment guidelines will be crucial in improving outcomes. By integrating early intervention and personalized treatment strategies, clinicians can better prevent and manage arthrofibrosis, ultimately enhancing patient recovery and long-term knee function.

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Conflict of Interest

The authors declared no conflicts of interest.

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