



NICOLAUS COPERNICUS
UNIVERSITY
IN TORUŃ



Quality in Sport. eISSN 2450-3118.

Journal Home Page

<https://apcz.umk.pl/QS/index>

BIAŁOWAŚ, Tymoteusz, KAROLAK, Dominika, KUŚMIEROWSKA, Natalia Sara, KUŚ, Monika, SŁOMKOWSKI, Grzegorz, CHOLEWIŃSKI, Kacper, VALIPUR KOLTI, Daria, POLAK, Milena, NOWAK, Magdalena Natalia and WIŚNIEWSKI, Konrad. Therapeutic Strategies for the Management of Knee Pain – A Review of Current Therapies and Perspectives. Quality in Sport. 2026;53:70104. eISSN 2450-3118. <https://doi.org/10.12775/QS.2026.53.70104>

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).

Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych). © The Authors 2026.

This article is published with open access under the License Open Journal Systems of Nicolaus Copernicus University in Toruń, Poland. Open Access: This article is distributed under the terms of the Creative Commons Attribution Noncommercial License, which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited. This is an open access article licensed under the terms of the Creative Commons Attribution Non-commercial Share Alike License (<http://creativecommons.org/licenses/by-nc-sa/4.0/>), which permits unrestricted, non-commercial use, distribution, and reproduction in any medium, provided the work is properly cited.

The authors declare that there is no conflict of interest regarding the publication of this paper.

Received: 22.03.2026. Revised: 30.03.2026. Accepted: 30.03.2026. Published: 05.04.2026.

Therapeutic Strategies for the Management of Knee Pain – A Review of Current Therapies and Perspectives

Tymoteusz Białowaś, ORCID <https://orcid.org/0009-0001-0889-2635>

e-mail: tymbial@gmail.com

Medical University of Warsaw

ul. Żwirki i Wigury 61, 02-091 Warsaw

Dominika Karolak, ORCID <https://orcid.org/0009-0007-1131-9171>

e-mail: karolakd16@gmail.com

Medical University of Warsaw

ul. Żwirki i Wigury 61, 02-091 Warsaw

Natalia Sara Kuśmierowska, ORCID <https://orcid.org/0009-0006-7572-0282>

e-mail: sara.kusmierowska@gmail.com

Medical University of Warsaw

ul. Żwirki i Wigury 61, 02-091 Warsaw

Monika Kuś, ORCID <https://orcid.org/0009-0009-6445-5593>

e-mail: Monika2kus@gmail.com

Medical University of Warsaw

ul. Żwirki i Wigury 61, 02-091 Warsaw

Grzegorz Słomkowski, ORCID <https://orcid.org/0009-0003-3742-8377>

e-mail: gw.slomkowski@poczta.onet.pl

Medical University of Warsaw

ul. Żwirki i Wigury 61, 02-091 Warsaw

Kacper Cholewiński, ORCID: <https://orcid.org/0009-0004-7185-5310>

e-mail: kacper.cholewinski@wp.pl

Medical University of Warsaw

ul. Żwirki i Wigury 61, 02-091 Warsaw

Daria Valipur Kolti, ORCID <https://orcid.org/0009-0005-9900-4419>

e-mail: dariaa1446@wp.pl

University Clinical Centre, Medical University of Warsaw

ul. Żwirki i Wigury 61, 02-091 Warsaw

Milena Polak, ORCID <https://orcid.org/0009-0007-6148-5354>

e-mail: milenapolak09@gmail.com

Medical University of Warsaw

ul. Żwirki i Wigury 61, 02-091 Warsaw

Magdalena Natalia Nowak, ORCID <https://orcid.org/0009-0002-1010-3364>

e-mail: magda.nowak2001@gmail.com

Cardinal Stefan Wyszyński University in Warsaw

ul. Kazimierza Wóycickiego 1/3, 01-938 Warsaw

Konrad Wiśniewski, ORCID <https://orcid.org/0009-0007-1076-6471>

e-mail: Konrad.840299@gmail.com

Cardinal Stefan Wyszyński University in Warsaw

ul. Kazimierza Wóycickiego 1/3, 01-938 Warsaw

Corresponding Author

Tymoteusz Białowąs, e-mail: tymbial@gmail.com

Abstract

Background. Knee pain can significantly impact patients' quality of life. Pain emerging with age is most commonly associated with osteoarthritis of the knee.

Aim. Current clinical management comprises three lines of treatment.

Results. The first and second lines focus on conservative and pharmacological management, while the third involves surgical intervention.

Conclusions. This paper discusses both current therapeutic standards and innovative treatment methods.

Material and methods. A targeted review of relevant literature was carried out using the PubMed database, using the following search terms: “Pain”, “Osteoarthritis”, “Knee”. And Pedagogy and Psychology of Sport (PaPoS) and Journal of Education, Health and Sport (JoEHaS) and Quality in Sport (QiS)

Keywords: Osteoarthritis, Knee, Pain

Introduction: Diagnostics In light of current medical knowledge, there is currently no single, validated diagnostic method or objective test that would allow for an unequivocal diagnosis of early-stage knee osteoarthritis. In the absence of universally accepted criteria, the clinical diagnosis established through expert consensus is considered the "gold standard." In the analyzed study, this process was based on an evaluation performed by a panel of 36 physicians (both general practitioners and specialists) who verified patients' medical records after a 5–10 year observation period to determine the occurrence of clinically significant disease. This approach served to develop predictive models which, utilizing baseline data from the first visit (history, physical examination, radiography, and hsCRP levels), aimed to predict the diagnosis over a 10-year perspective. However, results indicate that early diagnosis may rely primarily on simple in-office assessment (history and physical examination)[1].

Epidemiology and Symptoms: It is estimated that knee pain may affect as many as 654 million people globally. The majority of pain complaints begin in patients after the age of 45 on the basis of osteoarthritis, whereas in individuals under 40 years of age, the most common cause is Patellofemoral Pain Syndrome (PFPS) [2].

Aside from knee pain, patients frequently report other specific complaints. Morning stiffness is characterized by short-term stiffness after rest, typically lasting less than 30 minutes, caused by fluid accumulation and synovial edema during immobility [3]. Swelling or joint effusion, resulting from synovitis and fluid accumulation, often exacerbates after prolonged walking or standing [4]. Over time, patients experience a limited range of motion due to osteophytes and contractures [5]. Physical examination often reveals crepitus, a characteristic sound during movement resulting from uneven cartilage surfaces and osteophytes [6]. Furthermore, articular gelling—the tendency of joint surfaces to "stick" following a period of rest—causes significant stiffness [7]. In advanced OA, permanent changes in limb alignment occur, such as varus or valgus deformities. This malalignment increases the load on the medial or lateral compartment of the joint, accelerating disease progression [8].

Comorbidities are frequent in patients with OA. Common co-occurring conditions include low back pain, foot pain, and elbow pain [9], as well as cardiovascular, gastrointestinal, respiratory, and endocrine diseases. The average number of comorbidities is approximately 3.2 per patient, comprising both musculoskeletal and non-musculoskeletal conditions [10].

Pathophysiology:The general pathophysiology of knee osteoarthritis (OA) involves cartilage, subchondral bone, synovium, ligaments, and adipose tissue. The process begins with an imbalance between the synthesis and degradation of the cartilage matrix, leading to the loss of type II collagen and proteoglycans under the influence of MMP and ADAMTS enzymes. Micro-trauma and mechanical overload initiate local inflammation, in which cytokines (IL-1 β , TNF- α , IL-6) play a key role. Simultaneously, subchondral bone remodeling, osteophyte formation, and neovascularization with accompanying innervation occur, intensifying pain. Experts have long observed a significant inconsistency between radiographic findings and the patient's subjective pain experience[11].This process is also influenced by metabolic, genetic, and epigenetic factors, as well as oxidative stress, which collectively drive a vicious cycle of degeneration and inflammation within the joint [12].

Main Risk Factors:Several risk factors contribute to the development of the disease. Obesity (BMI >30) is considered the strongest risk factor. A statistically significant positive correlation was identified between the grade of articular cartilage degeneration and both patient age ($p < 0.0001$) and Body Mass Index (BMI) ($p = 0.0098$)[13].Other significant factors include previous knee injuries, such as trauma, meniscus, or ligament damage. Gender and age also play a role, with females being more susceptible and risk increasing particularly after 50 years of age. Physical and occupational activities that require heavy mechanical loading of the knees—such as high-impact sports like soccer, weightlifting, or long-distance running—are associated with higher risk, especially with coexisting prior injuries. High Bone Mineral Density (BMD), depression, and poor mental health are also implicated. Other factors, such as hysterectomy and hypertension, show weaker or conflicting evidence regarding their association with OA[14].

First Line of Treatment: Conservative Management

Patient Education, lifestyle modification, self-management, exercise, and weight loss are priority aspects of therapy. Adherence to these recommendations can minimize the need for surgical intervention. Psychological support and reassuring the patient that "osteoarthritis is not an inevitable part of aging" and that symptoms can vary significantly between individuals are crucial. This approach prepares the patient for potential disease progression and encourages active participation in therapy, allowing for maximum treatment efficacy .

Physical Exercise: Physical activity is one of the best-documented components of non-pharmacological treatment. It is recommended to perform 150 minutes of aerobic exercise per week or 2 days per week of strength training, which improves pain symptoms and patient functioning. A key aspect is collaboration with a physical therapist who will tailor the program to the patient's individual needs. Building a patient-therapist relationship also positively influences the overall effectiveness of therapy [15].

Weight Reduction: It is estimated that by 2030, over 55% of the global population will be classified as overweight or obese. This is one of the main risk factors for knee pain and OA, resulting from inflammation and metabolic changes. It is stated that weight loss of even 5–10% significantly improves functioning and reduces pain[16]. However, diet alone is not a sufficient form of therapy; the greatest efficacy is observed when combined with exercise [15]. Regarding adjunct therapies, there is currently a lack of sufficient scientific evidence confirming high efficacy for treatments such as heat/cold therapy, laser therapy, ultrasound, electrostimulation, manual therapy, taping, or acupuncture [15].

Second Line of Treatment: Pharmacology

Acetaminophen (Paracetamol) and NSAIDs. Acetaminophen is one of the analgesics most frequently used by patients as a first-choice drug; however, numerous meta-analyses demonstrate its very weak effect in knee osteoarthritis. It may be useful only as a short-term rescue medication when other agents are contraindicated. While it generally has a good safety profile, higher doses may cause hepatotoxicity, risk of hypertension, and worsening of renal function [17].

Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) act on a key element of the "inflammatory theory" of OA by inhibiting the synthesis of prostaglandins—mediators which directly stimulate chondrocytes to produce metalloproteinases that destroy the cartilage matrix[16] [18]. The most effective oral NSAIDs include Diclofenac (150 mg/d), Etoricoxib (60–90 mg/d), and Rofecoxib (25–50 mg/d), all showing >99% probability of achieving clinically significant pain reduction. Regarding topical NSAIDs, the strongest evidence concerns topical diclofenac, where doses of 70–81 mg/d and 140–160 mg/d show 92% and 96% probability of clinical improvement, respectively. Topical NSAIDs are considered the safest form of pharmacological treatment in knee OA [19].

However, the adverse effects of oral NSAIDs are significant. Risks include gastrointestinal ulcers and upper GI damage, which can be reduced by PPIs. All NSAIDs are associated with

an increased risk of myocardial infarction and heart failure due to sodium and water retention. Increased risk of hemorrhagic stroke appears limited to diclofenac and meloxicam. Furthermore, all NSAIDs have the potential to cause acute kidney injury (AKI) by reducing renal blood flow, with the risk being highest within the first 30 days of therapy [20].

Opioids Opioids have shown only small benefits in pain reduction and improvement of physical function compared to placebo, with no benefit to patients' quality of life. Surprisingly, strong opioids (morphine, hydromorphone, oxycodone) demonstrated worse efficacy than weak/intermediate opioids (tramadol, codeine). Their use was associated with a high risk of adverse events such as nausea, constipation, and drowsiness, leading patients to discontinue treatment nearly 4 times more often than in the placebo group [21].

New and Other Pharmacological Therapies TNF Inhibitors (e.g., adalimumab, etanercept) effectively reduced inflammatory parameters but showed no evidence of pain reduction in knee OA [22]. Hydroxychloroquine (HCQ) and Interleukin-1 (IL-1) Inhibitors proved ineffective despite theoretical foundations [22]. Methotrexate was distinguished in studies as the only disease-modifying drug, being the most effective among analyzed drugs for pain reduction and improvement in joint stiffness [22].

Regarding intra-articular injections, a 2025 systematic review compared corticosteroids, hyaluronic acid (HA), and platelet-rich plasma (PRP). Corticosteroids provide rapid short-term pain relief but lack sustained efficacy. PRP demonstrates superior long-term pain reduction and functional improvement compared to corticosteroids. The study identified the combination of PRP and Hyaluronic Acid as the most effective modality for long-term management, significantly outperforming single-agent therapies. These findings suggest that regenerative injections should be considered a key therapeutic option prior to surgical intervention[16] [23].

Third Line of Treatment: Surgical or manual intervention

When conservative and pharmacological treatment fails, surgical treatment is applied. Total Knee Arthroplasty (TKA) remains the "gold standard" for treating advanced osteoarthritis. This procedure is highly effective, providing pain relief and improved quality of life in over 90% of patients [24]. Regarding technical aspects, cemented fixation is the current standard, while cementless fixation is preferred in younger patients, though long-term survival is similar. Mobile bearings have not shown significant differences in revision rates compared to fixed bearings. Newer "Medial Pivot" designs mimic natural knee kinematics, with preliminary

studies suggesting better functionality [21]. Modern technologies like Robotic-Assisted TKA ensure greater precision but have not yet shown significantly better long-term clinical outcomes compared to traditional methods [24].

Genicular Artery Embolization (GAE) stands out as a modern and innovative therapy for knee osteoarthritis. Comprehensive systematic reviews confirm its long-term efficacy, demonstrating significant and durable pain reduction at 1, 3, 6, and 12 months post-procedure. The aggregated data supports GAE as a safe, minimally invasive intervention [25], [26]. Additionally, meta-analyses demonstrate that radiofrequency (RF) treatment is a safe and effective method for managing knee osteoarthritis, confirming statistically significant pain reduction compared to conservative management. Recent evidence indicates that RF treatment, particularly when targeting the genicular nerves, also leads to significant improvements in knee function and patient satisfaction [27], [28].

Conclusions: Management of knee pain due to osteoarthritis requires a comprehensive, multimodal strategy. Conservative measures, particularly exercise and weight reduction, constitute the first line of defense, followed by judicious use of NSAIDs. While Total Knee Arthroplasty is the definitive solution for advanced stages, recent innovations such as Genicular Artery Embolization and Radiofrequency ablation are bridging the gap between conservative care and surgery. Future therapeutic standards will likely increasingly rely on these minimally invasive interventions combined with personalized lifestyle modifications.

Discussion: The management of knee osteoarthritis (OA) is shifting from reactive surgery toward a proactive, multimodal strategy designed to bridge the "treatment gap" between conservative care and joint replacement.

Diagnostic and Therapeutic Paradigms - Diagnosis remains a primary clinical challenge. In the absence of validated early biomarkers, history and physical examination remain the "gold standard," often proving more predictive of long-term outcomes than early imaging. While weight loss and exercise are foundational, the pharmacological landscape is evolving. The limited efficacy of acetaminophen and the systemic risks associated with NSAIDs—particularly in patients with comorbidities—underscore the need for safer alternatives. In this context, the combination of Platelet-Rich Plasma (PRP) and Hyaluronic Acid (HA) emerges as a superior regenerative bridge, offering sustained relief compared to traditional corticosteroids.

Innovation and Surgical Integration - While Total Knee Arthroplasty (TKA) remains the gold standard for end-stage disease, this review highlights the importance of minimally invasive

"gap-fillers." Genicular Artery Embolization (GAE) and Radiofrequency (RF) ablation represent a significant evolution, targeting the neurovascular drivers of pain. These interventions allow for a "layered" approach to therapy, potentially delaying the need for surgery while maintaining high functional quality of life. Future standards of care must focus on this personalized integration of lifestyle, regenerative medicine, and interventional innovation.

Disclosure:

Author's contribution

Conceptualization: Tymoteusz Białowąs

Methodology: Tymoteusz Białowąs, Dominika Karolak, Natalia Sara Kuśmierowska, Monika Kuś, Grzegorz Słomkowski, Kacper Cholewiński, Daria Valipur Kolti, Milena Polak, Magdalena Natalia Nowak, Konrad Wiśniewski

Formal analysis: Tymoteusz Białowąs, Dominika Karolak, Natalia Sara Kuśmierowska

Investigation: Tymoteusz Białowąs, Kacper Cholewiński, Grzegorz Słomkowski, Daria Valipur Kolti, Milena Polak

Writing-rough preparation: Tymoteusz Białowąs, Dominika Karolak, Konrad Wiśniewski

Writing-review and editing: Tymoteusz Białowąs, Magdalena Natalia Nowak

Supervision: Tymoteusz Białowąs

Receiving funding – not applicable

All authors have read and agreed with the published version of the manuscript.

Funding Statement

The article did not receive any funding.

Institutional Review and Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflict of Interest Statement

Authors declare no conflicts of interest.

References

- [1] J. Runhaar, M. Kloppenburg, M. Boers, J. W. J. Bijlsma, and S. M. A. Bierma-Zeinstra, "Towards developing diagnostic criteria for early knee osteoarthritis: data from the CHECK study," *Rheumatology (Oxford)*, vol. 60, no. 5, pp. 2448–2455, May 2021, doi: 10.1093/RHEUMATOLOGY/KEAA643.
- [2] V. Duong, W. M. Oo, C. Ding, A. G. Culvenor, and D. J. Hunter, "Evaluation and Treatment of Knee Pain: A Review," *JAMA*, vol. 330, no. 16, pp. 1568–1580, Oct. 2023, doi: 10.1001/JAMA.2023.19675.
- [3] W. Zhang *et al.*, "EULAR evidence-based recommendations for the diagnosis of knee osteoarthritis," *Ann. Rheum. Dis.*, vol. 69, no. 3, pp. 483–489, Mar. 2010, doi: 10.1136/ard.2009.113100.
- [4] X. Wang *et al.*, "Associations Between Knee Effusion-synovitis and Joint Structural Changes in Patients with Knee Osteoarthritis," *J. Rheumatol.*, vol. 44, no. 11, pp. 1644–1651, Nov. 2017, doi: 10.3899/JRHEUM.161596.
- [5] D. J. Hunter and S. Bierma-Zeinstra, "Osteoarthritis," *The Lancet*, vol. 393, no. 10182, pp. 1745–1759, Apr. 2019, doi: 10.1016/S0140-6736(19)30417-9.
- [6] J. L. Couch *et al.*, "Noisy knees - knee crepitus prevalence and association with structural pathology: a systematic review and meta-analysis," *Br. J. Sports Med.*, vol. 59, no. 2, pp. 126–132, Jan. 2025, doi: 10.1136/BJSPORTS-2024-108866.
- [7] B. A. Hills and K. Thomas, "Joint stiffness and 'articular gelling': inhibition of the fusion of articular surfaces by surfactant," *Br. J. Rheumatol.*, vol. 37, no. 5, pp. 532–538, 1998, doi: 10.1093/RHEUMATOLOGY/37.5.532.

- [8] L. Sharma, J. Song, D. T. Felson, S. Cahue, E. Shamiyeh, and D. D. Dunlop, “The role of knee alignment in disease progression and functional decline in knee osteoarthritis,” *JAMA*, vol. 286, no. 2, pp. 188–195, Jul. 2001, doi: 10.1001/JAMA.286.2.188.
- [9] P. Suri, D. C. Morgenroth, C. K. Kwok, J. F. Bean, L. Kalichman, and D. J. Hunter, “Low back pain and other musculoskeletal pain comorbidities in individuals with symptomatic osteoarthritis of the knee: data from the osteoarthritis initiative,” *Arthritis Care Res. (Hoboken)*, vol. 62, no. 12, pp. 1715–1723, 2010, doi: 10.1002/ACR.20324.
- [10] “Co-morbidities of patients with knee osteoarthritis - PubMed.” Accessed: Nov. 20, 2025. [Online]. Available: <https://pubmed.ncbi.nlm.nih.gov/19494370/>
- [11] O. Buhairov and O. Tarabrin, “Modern view of mechanisms of chronic pain syndrome in patients with knee joint damage,” *Journal of Education, Health and Sport*, vol. 53, pp. 242–255, Feb. 2024, doi: 10.12775/JEHS.2024.53.020.
- [12] D. Primorac *et al.*, “Knee Osteoarthritis: A Review of Pathogenesis and State-Of-The-Art Non-Operative Therapeutic Considerations,” *Genes (Basel)*, vol. 11, no. 8, pp. 1–35, Aug. 2020, doi: 10.3390/GENES11080854.
- [13] B. Olesiak, A. Przedborska, and J. W. Raczkowski, “Degeneration grade of a femoropatellar joint and functional status of a knee joint,” *Pedagogy and Psychology of Sport*, vol. 5, no. 2, pp. 44–55, Feb. 2019, doi: 10.12775/paps.2015.05.02.003.
- [14] M. Blagojevic, C. Jinks, A. Jeffery, and K. P. Jordan, “Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis,” *Osteoarthritis Cartilage*, vol. 18, no. 1, pp. 24–33, Jan. 2010, doi: 10.1016/j.joca.2009.08.010.
- [15] L. O. Dantas, T. de F. Salvini, and T. E. McAlindon, “Knee osteoarthritis: key treatments and implications for physical therapy,” *Braz. J. Phys. Ther.*, vol. 25, no. 2, pp. 135–146, Mar. 2021, doi: 10.1016/j.bjpt.2020.08.004.
- [16] O. Tudaj *et al.*, “Treatment Methods for Knee Osteoarthritis - A Literature Review,” *Quality in Sport*, vol. 42, p. 60948, Jun. 2025, doi: 10.12775/qs.2025.42.60948.
- [17] D. Primorac *et al.*, “Comprehensive Review of Knee Osteoarthritis Pharmacological Treatment and the Latest Professional Societies’ Guidelines,” *Pharmaceuticals (Basel)*, vol. 14, no. 3, Mar. 2021, doi: 10.3390/PH14030205.
- [18] F. Berenbaum, “Osteoarthritis as an inflammatory disease (osteoarthritis is not osteoarthrosis!),” *Osteoarthritis Cartilage*, vol. 21, no. 1, pp. 16–21, Jan. 2013, doi: 10.1016/j.joca.2012.11.012.
- [19] B. R. Da Costa *et al.*, “Effectiveness and safety of non-steroidal anti-inflammatory drugs and opioid treatment for knee and hip osteoarthritis: network meta-analysis,” *BMJ*, vol. 375, Oct. 2021, doi: 10.1136/BMJ.N2321.
- [20] C. Cooper *et al.*, “Safety of Oral Non-Selective Non-Steroidal Anti-Inflammatory Drugs in Osteoarthritis: What Does the Literature Say?,” *Drugs Aging*, vol. 36, no. Suppl 1, pp. 15–24, Apr. 2019, doi: 10.1007/S40266-019-00660-1.
- [21] M. C. Osani, L. S. Lohmander, and R. R. Bannuru, “Is There Any Role for Opioids in the Management of Knee and Hip Osteoarthritis? A Systematic Review and Meta-Analysis,” *Arthritis Care Res. (Hoboken)*, vol. 73, no. 10, pp. 1413–1424, Oct. 2021, doi: 10.1002/ACR.24363.
- [22] S. Mathieu, A. Tournadre, M. Soubrier, and J. Sellam, “Effect of disease-modifying anti-rheumatic drugs in osteoarthritis: A meta-analysis,” *Joint Bone Spine*, vol. 89, no. 6, Nov. 2022, doi: 10.1016/J.JBSPIN.2022.105444.
- [23] N. Gupta *et al.*, “Long-term effectiveness of intra-articular injectables in patients with knee osteoarthritis: a systematic review and Bayesian network meta-analysis,” *J. Orthop. Surg. Res.*, vol. 20, no. 1, Dec. 2025, doi: 10.1186/S13018-025-05574-W.

- [24] A. Alzarooni *et al.*, “A Comprehensive Review of Operative Considerations, Surgical Techniques, Outcomes, and Future Perspectives in Total Knee Arthroplasty,” *Cureus*, vol. 17, no. 10, Oct. 2025, doi: 10.7759/CUREUS.94345.
- [25] D. D. Chlorogiannis, A. Vasilopoulou, C. I. Konstantinidis, A. E. Pagona, and D. K. Filippiadis, “Knee pain improvement after genicular artery embolization for the management of knee osteoarthritis: an updated systematic review and meta-analysis of 21 studies,” *Radiologie (Heidelberg, Germany)*, vol. 64, no. Suppl 1, pp. 32–46, Nov. 2024, doi: 10.1007/S00117-024-01388-9.
- [26] Y. Epelboym *et al.*, “Genicular Artery Embolization as a Treatment for Osteoarthritis Related Knee Pain: A Systematic Review and Meta-analysis,” *Cardiovasc. Intervent. Radiol.*, vol. 46, no. 6, pp. 760–769, Jun. 2023, doi: 10.1007/S00270-023-03422-0.
- [27] T. Hong, H. Wang, G. Li, P. Yao, and Y. Ding, “Systematic Review and Meta-Analysis of 12 Randomized Controlled Trials Evaluating the Efficacy of Invasive Radiofrequency Treatment for Knee Pain and Function,” *Biomed Res. Int.*, vol. 2019, 2019, doi: 10.1155/2019/9037510.
- [28] J. Liu, T. Wang, and Z. H. Zhu, “Efficacy and safety of radiofrequency treatment for improving knee pain and function in knee osteoarthritis: a meta-analysis of randomized controlled trials,” *J. Orthop. Surg. Res.*, vol. 17, no. 1, Dec. 2022, doi: 10.1186/S13018-021-02906-4.