



Journal of the Asociación Argentina de Ortopedia y Traumatología

AN ORGAN OF THE ASOCIACIÓN ARGENTINA DE ORTOPEDIA Y TRAUMATOLOGÍA

VOL. 91, N.º 5 / OCTOBER 2026 PP. 406-523

GUEST ASSOCIATION:



President: Dr. Gabriel Vindver
Section Editor: Dr. Carlos Lucero

406	EDITORIAL The Value of Scientific Societies <i>Dr. Lisandro Carbó, Dr. Carlos M. Lucero</i>
408	POSTGRADUATE ORTHOPEDIC INSTRUCTION – IMAGING Case Presentation <i>Fabián Caruso, Natalia Promizio, Diego Korol</i>
410	CLINICAL RESEARCH Efficacy of Multimodal Analgesia With or Without Periarticular Infiltration in Total Knee Arthroplasty: Is Infiltration Worth the Risk? A Prospective Randomized Comparative Study <i>Igor V. Orsolini Tejerina, Facundo Fazzone, Victor H. Sosa, Joao M. J. Flores Garcia, Juan Bautista Salerno, Marcos J. Castaña Robles, Mark Garrett, Javier Ugalde, Claudio Mingo Saluzzi, Mariano G. Silva, Ricardo Santiago</i>
420	Artificial Intelligence-Assisted Radiographic Diagnosis of Developmental Dysplasia of the Hip in Children: A Retrospective Study <i>Melina I. Luna, Román Bertolotti, Gerardo M. Ferrer, Miguel C. González, Antonio E. Pedro Maraude</i>
427	Clinical and Radiographic Evaluation of the OMICRON 2® Total Knee Prosthesis: A Multicenter Study With Long-Term Follow-up <i>Carlos Vega, Favio Moruno, Javier Megey, Wilmer Jimenez, Carlos F. satragno</i>
438	Impact of Joint Space Narrowing on Functional Outcomes After Hip Arthroscopy <i>Damián Arroquy, María Pla Silvestrini, Sergio Ruiz, Martín Rubado, Martín Botta, Luciano Mañero, Juan Manuel Barrios</i>
448	SYSTEMATIC REVIEW Comparative Efficacy of PFNA Versus DHS for Intertrochanteric Hip Fractures: An Umbrella Review <i>Nelson Vidal Chang, Humbert C. Kelsey Gary, Miguel A. Vidal Campo, Natalia A. Gómez Palencia</i>
455	Mid-Flexion Instability in Total Knee Arthroplasty: A Systematic Review of Risk Factors, Diagnosis, and Strategies <i>Walter F. Martínez, Eduardo Bochaty, Fernando Lobreite</i>
467	Preoperative Use of GLP-1 Receptor Agonists and Postoperative Outcomes in Patients Undergoing Arthroplasty: A Systematic Review With Exploratory Meta-analysis <i>Héctor A. Rivadeneira Jurado, Elías A. Rivadeneira Jurado</i>
472	CASE REPORTS Induced Membrane Technique for Aseptic Recalcitrant Nonunion of the Femur: A Case Report <i>Rafael Amadei, Gonzalo M. Violaz</i>
483	Anteroinferior Hip Dislocation: A Case Report <i>Victor A. Avendaño Arango, Ricardo Londoño García, Camilo González, Miguel Ángel Cano</i>
488	Failure of Femoral Neck System Fixation Due to Suboptimal Reduction in a Young Adult With a Garden Type IV Subcapital Fracture: Conversion to Total Hip Arthroplasty. A Case Report <i>Humbert C. Kelsey Gary, Nelson Vidal Chang, Natalia A. Gómez Palencia, Cristian D. Tinoco Cervantes, José D. Alonso Cogollo</i>
496	SPECIAL PAPER 100 Years of History of the Department of Orthopaedics and Traumatology at Hospital Italiano de Buenos Aires <i>Martín Buttaró</i>
503	TECHNICAL NOTE Modification of the Micheli-Kocher Technique with Anterior Cruciate Ligament Remnant Preservation and Augmentation in Pediatric Patients: A Technical Note <i>Genaro R. Cucalón, Gerardo Fernández-Staudacher, Daniel Veloz Serrano</i>
510	POSTGRADUATE ORTHOPEDIC INSTRUCTION Hip Growth Disturbances in Childhood <i>María Gabriela Miranda, Claudio A. Fernández</i>
519	POSTGRADUATE ORTHOPEDIC INSTRUCTION – IMAGING Case Resolution <i>Fabián Caruso, Natalia Promizio, Diego Korol</i>

The Value of Scientific Societies

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We live at a time when accessing knowledge has never been easier. In seconds, we can read a scientific article, attend a webinar from anywhere in the world or exchange views with colleagues on other continents. Information is no longer a scarce resource, it has become a constant stream. Yet this new reality raises a question that may at first seem provocative: do we still need scientific societies?

The answer is probably more emphatic today than ever.

Scientific societies are no longer simply organizations that hold conferences or present research. They are places where a professional community shares an identity, builds knowledge together and sets quality standards for practice within a specialty. They bring together those just beginning their training and those who, after decades of experience, remain convinced that teaching is a professional responsibility.

With so much unfiltered information available, the real challenge is no longer gaining access to knowledge. It is interpreting that knowledge, identifying the most reliable information so that our learning is more rigorous and effective, and translating it into better care for our patients. This is difficult to do alone. It requires an exchange of views, discussion, critical thinking and opportunities to test our ideas with colleagues who face the same challenges every day.

Scientific societies serve precisely this purpose:

- they promote continuing medical education,
- they encourage collaborative research,
- they build consensus,
- they support the training of new specialists,
- they create spaces where individual experience becomes collective knowledge.

Every course, scientific meeting, case discussion, and multicenter study is much more than an academic activity: each reflects a community committed to improving the quality of medical practice.

In our specialty, this commitment carries particular weight. Orthopedic surgery is constantly evolving. New techniques, implants, technologies, and treatment strategies are emerging at an unprecedented pace. Belonging to a scientific community therefore means more than staying up to date. It also means taking an active part in shaping the specialty's future.

This is the spirit we seek to strengthen. A scientific association is defined neither by its name nor by the number of activities it organizes. What defines it is the participation of its members, the generosity of those who teach, the enthusiasm of those who learn and the conviction that professional growth is always greater within a community.

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How to cite this article: Carbó L, Lucero CM. The Value of Scientific Societies. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):406-407. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2461>

Perhaps the greatest challenge in the years ahead will not simply be to develop better surgical techniques or adopt new technologies. It will be to keep alive the institutions that allow knowledge to circulate, experience to be shared, and new generations to find a place to train, conduct research, and grow. Ultimately, a scientific society is not a building, a governing board or an annual conference. It is a community of colleagues who understand that the best way forward is together.

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Case Presentation

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Case Resolution on page 519.

Knee Trauma with Restricted Range of Motion

ABSTRACT

A 36-year-old male athlete had undergone anterior cruciate ligament reconstruction at age 20. He later developed residual restriction in the range of motion of his left knee, with no preceding trauma.

Keywords: Knee; pain.

Level of Evidence: IV

Traumatismo de rodilla con limitación de la movilidad

RESUMEN

Hombre de 36 años de edad, deportista, sometido a una cirugía plástica del ligamento cruzado anterior a los 20 años. Evolucionó con limitación de la movilidad de la rodilla izquierda residual, sin traumatismo previo.

Palabras clave: Rodilla, dolor.

Nivel de Evidencia: IV

INTRODUCTION

A 36-year-old man presented with left knee pain, range of motion limited to 90°, and intermittent locking. At age 20, he had torn his anterior cruciate ligament (ACL) while playing sports and undergone ACL reconstruction using a bone-tendon-bone graft and a biodegradable screw. Three months later, he underwent a second procedure to remove the broken screw, during which an osteochondral lesion was identified.

Magnetic resonance imaging (MRI) was requested.

IMAGING FINDINGS AND INTERPRETATION

Proton density (PD)-weighted MRI showed magnetic susceptibility artifacts related to the ACL reconstruction. The graft had normal signal intensity and morphology. A rounded focal lesion was visible proximal to the graft, and another lay posterior to its proximal third. Other findings included increased joint fluid, normal patellar alignment with the femoral trochlea, intact cartilage, no meniscal tears, an intact posterior cruciate ligament with normal orientation, and intact medial and lateral collateral ligaments ([Figure 1](#)).

Received on July 3rd, 2026. Accepted after evaluation on July 7th, 2026 • Dr. FABIÁN CARUSO • Fabianpabloc@gmail.com  <https://orcid.org/0009-0000-7210-2725>

How to cite this article: Caruso F, Promizio N, Korol D. Postgraduate Orthopedic Instruction – Imaging. Case Presentation. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):408-409. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2427>

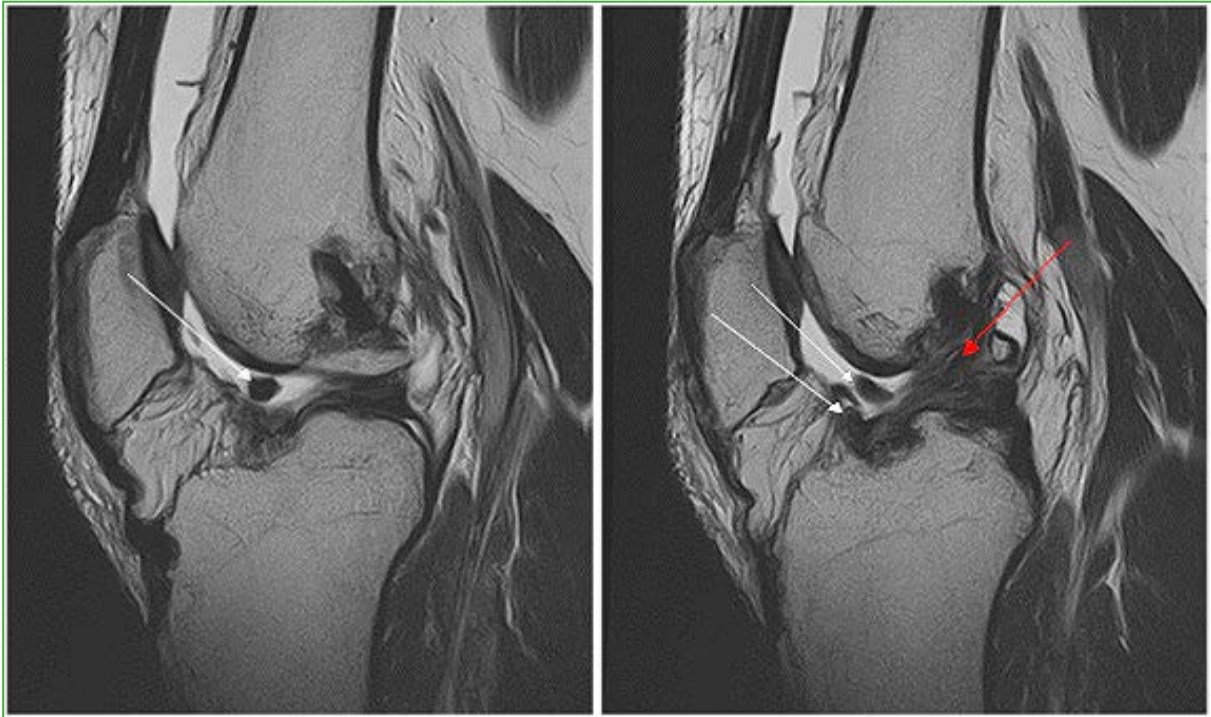


Figure 1. Sagittal proton density-weighted MRI of the knee showing magnetic susceptibility artifacts related to the anterior cruciate ligament reconstruction (red arrow) and well-defined focal intra-articular low-signal lesions (white arrows).

Conflicts of interest: The authors declare no conflicts of interest.

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Efficacy of Multimodal Analgesia With or Without Periarticular Infiltration in Total Knee Arthroplasty: Is Infiltration Worth the Risk? A Prospective Randomized Comparative Study

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ABSTRACT

Introduction: Postoperative pain following total knee arthroplasty (TKA) is a major clinical and surgical challenge. This study evaluated the efficacy of periarticular infiltration (PAI) as a key component of a multimodal analgesia protocol. **Objective:** To compare two multimodal pain management approaches in the immediate postoperative period following TKA. **Materials and Methods:** A prospective, randomized, controlled clinical trial was conducted in 130 patients with knee osteoarthritis. Patients were assigned to group 1 (multimodal analgesia plus PAI) or group 2 (multimodal analgesia alone). The primary outcomes were pain, rescue opioid consumption, time to ambulation, and length of hospital stay. **Results:** Patients in group 1 had better outcomes, with lower postoperative pain scores (0.88 ± 1.88 vs. 6.04 ± 0.90 at 24 hours; $p < 0.0001$), 63% lower tramadol consumption (66.41 ± 55.31 vs. 181.74 ± 57.71 mg; $p < 0.0001$), earlier ambulation (32 vs. 48 hours; $p < 0.0001$), a shorter hospital stay (72 vs. 76.19 hours; $p = 0.0003$), and less postoperative blood loss (229.77 ± 102.77 vs. 337.30 ± 91.61 mL; $p < 0.0001$). **Conclusions:** PAI provided superior analgesia and accelerated recovery without impairing muscle strength, unlike motor blockade. Omitting the posterior capsule from the infiltration was safe and effective. PAI is a highly effective analgesic strategy in TKA that reduces pain and opioid consumption and improves postoperative outcomes. Its inclusion in standard protocols could transform pain management in TKA.

Keywords: Knee arthroplasty; periarticular infiltration; multimodal analgesia; peripheral/femoral nerve block; posterior capsule.

Level of Evidence: II

Eficacia de la analgesia multimodal, con o sin infiltración periarticular en el reemplazo total de rodilla. ¿Merece el riesgo infiltrar? Estudio comparativo prospectivo aleatorizado

RESUMEN

Introducción: El dolor posoperatorio por una artroplastia total de rodilla (ATR) es un desafío clínico y quirúrgico importante. Se evaluó la eficacia de la infiltración periarticular (IPA) como componente clave en un protocolo multimodal de analgesia. **Objetivo:** Comparar dos modalidades de manejo multimodal del dolor en el posoperatorio inmediato de una ATR. **Materiales y Métodos:** Ensayo clínico prospectivo, aleatorizado y controlado en 130 pacientes con gonartrosis. Se los dividió en: grupo 1, analgesia multimodal más IPA y grupo 2, analgesia multimodal. Las variables principales fueron: dolor, consumo de opioides como rescate, tiempos hasta la deambulación y de internación. **Resultados:** Los pacientes del grupo 1 obtuvieron mejores resultados: menos dolor posoperatorio ($0,88 \pm 1,88$ vs. $6,04 \pm 0,90$ a las 24 h; $p < 0,0001$), un 63% menos de consumo de tramadol ($66,41 \pm 55,31$ vs. $181,74 \pm 57,71$ mg; $p < 0,0001$), una deambulación más temprana (32 vs. 48 h; $p < 0,0001$), una internación más corta (72 vs. 76.19 h; $p = 0,0003$), menos sangrado posoperatorio ($229,77 \pm 102,77$ vs. $337,30 \pm 91,61$ ml; $p < 0,0001$). **Conclusiones:** Con la IPA, la analgesia fue superior y la recuperación, acelerada, sin afectar la fuerza muscular, a diferencia de lo que ocurre con los bloqueos motores. La exclusión de la cápsula posterior resultó segura y efectiva. La IPA es una estrategia de analgesia altamente efectiva en la ATR, reduce el dolor y el consumo de opioides, y

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How to cite this article: Orsolini Tejerina IV, Fazzone F, Sosa VH, Flores Garcia MJ, Salerno JB, Castaño Robles MJ, et al. Efficacy of Multimodal Analgesia With or Without Periarticular Infiltration in Total Knee Arthroplasty: Is Infiltration Worth the Risk? A Prospective Randomized Comparative Study. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):410-419. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2193>

mejora los resultados posoperatorios. Su inclusión en protocolos estándar podría transformar el manejo del dolor en la ATR.

Palabras clave: Artroplastia de rodilla; infiltración periarticular; analgesia multimodal; bloqueo nervio periférico/femoral; cápsula posterior.

Nivel de Evidencia: II

INTRODUCTION

The favorable outcomes of total knee arthroplasty (TKA) are well established. Nevertheless, its use remains limited, mainly because of concerns about severe postoperative pain, prolonged recovery, and the extensive surgical approach.

Several strategies are now used to address these problems, and more effective pain control has been reported,¹ as our understanding and management of pain generation improve.

Surgical patients who receive adequate analgesia adhere more closely to accelerated rehabilitation programs, which improves their quality of life in the immediate postoperative period.

Increasing life expectancy, participation in demanding physical activities, and knee injuries may lead to more TKAs in the coming years. This reinforces the need for early rehabilitation supported by effective and safe analgesia to restore function in the operated joint. Relieving pain with as few complications as possible has become a priority for our department and other arthroplasty centers.^{2,3} An estimated 60% of surgical patients experience severe pain and 30% experience moderate pain.⁴ To reduce adverse events, multimodal pathways have been developed to block pain at its source, maximize muscle control, promote rehabilitation, reduce venous stasis, and facilitate earlier discharge.⁵

Several intraoperative pain management algorithms are used in TKA. The most common include spinal anesthesia with or without intrathecal morphine, peripheral nerve blocks, particularly femoral nerve block (FNB), and periarticular infiltration (PAI).

This study aimed to compare two multimodal pain management strategies. We hypothesized that adding PAI to multimodal analgesia would significantly reduce postoperative pain, with lower associated morbidity.

The primary outcome was the pain score from the first hours of hospitalization through discharge. Secondary outcomes were rescue opioid use, time to initiation of ambulation, postoperative blood loss, and length of hospital stay.

MATERIALS AND METHODS

The study began after approval by the ethics committee. Patients provided informed consent before enrollment, and the anesthesiology team participated in medication management, including dosing and dilution.

All participants were selected and received preoperative information about the study protocol, patient-controlled analgesia, and pain assessment using the visual analog scale (VAS).

A prospective, comparative, randomized study was conducted from November 2022 to March 2024. Of the 153 patients selected, 130 met the inclusion criterion: a primary diagnosis of grade 2 or higher knee osteoarthritis according to the Kellgren–Lawrence classification.⁶ Exclusion criteria were bone defects requiring grafts or additional implants; psychiatric disorders; dependence on alcohol or illicit drugs; allergies to opioids, nonsteroidal anti-inflammatory drugs, or any local anesthetic; previous infection in the knee or other joints; systemic or systemic inflammatory diseases; congenital deformities or neurological disorders; and revision arthroplasty.

Patients were divided into two groups: group 1 (n = 67) and group 2 (n = 63). Patients in group 1 received preoperative and postoperative analgesia, neuraxial anesthesia, and an intraoperative analgesia protocol involving PAI without infiltration of the posterior capsule. Patients in group 2 received neuraxial anesthesia and the preoperative and postoperative multimodal regimen without PAI.

Patients were randomly assigned to the groups. During surgery, a member of the surgical team selected a sealed envelope indicating whether the patient would receive PAI. Neither the surgeon nor the surgical team knew the contents of the envelopes before selection.

The variables assessed were postoperative pain measured using the VAS, blood loss measured through the closed-suction drain, postoperative complications, time to initiation of ambulation, need for oral or intravenous rescue opioids, and length of hospital stay (Table).

Table. Pain characteristics, rescue analgesia, blood loss, length of hospital stay, and time to initiation of ambulation in patients with and without periarticular infiltration.

Characteristics	Group 1 – MLA with PAI (n = 67)	Group 2 - MLA without PAI (n = 63)	p
Pain (VAS, score)			
6 h	4.76 ± 2.45	7.57 ± 0.92	<0.0001
9 h	2.73 ± 2.53	6.52 ± 0.89	<0.0001
12 h	1.65 ± 2.49	7.15 ± 0.74	<0.0001
24 h	0.88 ± 1.88	6.04 ± 0.90	<0.0001
36 h	0.68 ± 1.67	5.31 ± 0.71	<0.0001
48 h	0.44 ± 1.24	4.49 ± 0.82	<0.0001
72 h	0.43 ± 1.23	1.34 ± 1.15	<0.0001
Rescue analgesia (tramadol. mg)			
Total at 24 h	66.41 ± 55.31	181.74 ± 57.71	<0.0001
Total at 48 h	67.16 ± 54.73	197.619 ± 60.52	<0.0001
Total at 72 h	67.16 ± 54.73	201 ± 62.19	<0.0001
Blood loss (ml)	229.77 ± 102.27	377.30 ± 91.61	<0.0001
Hospital stay (h)	72	76.19 ± 9.18	0.0003
Initiation of ambulation (h)	32 (IQR 23-48)	48 (IQR 34-48)	<0.0001

All variables are expressed as means and standard deviations, except time to initiation of ambulation, which is expressed as the median and interquartile range (IQR). MLA = multimodal local analgesia; PAI = periarticular infiltration; VAS = visual analog scale.

Multimodal Analgesia Protocol and Joint Surgery (Figure 1)

Oral analgesia was started 48 hours before surgery. On the day of surgery, neuraxial anesthesia was administered with the patient supine, achieving a complete block of the lower limbs. A tourniquet was applied, and a standard medial parapatellar approach was used. After the bone cuts and stability assessments were completed, the envelope was opened to determine whether the patient would receive PAI.

The analgesic “cocktail” was infiltrated, focusing on areas of tissue retraction and the sensitive regions described by Dye et al.,⁷ and Biedert et al.⁸ Infiltration targeted the quadriceps tendon, patellar tendon, lateral and medial ligaments and capsule, lateral and medial retinacula, pes anserinus, and suprapatellar and quadriceps bursae (Figure 2). The prosthetic components were then cemented into place. After surgery, patients received scheduled analgesics throughout their hospital stay and prophylactic antibiotics for 48 hours. At discharge, oral anti-inflammatory analgesics were prescribed, and the first follow-up visit was scheduled for postoperative day 15.

Multimodal Analgesia Protocol and Group Allocation Flowchart

Prospective randomized controlled clinical trial in total knee arthroplasty [TKA]

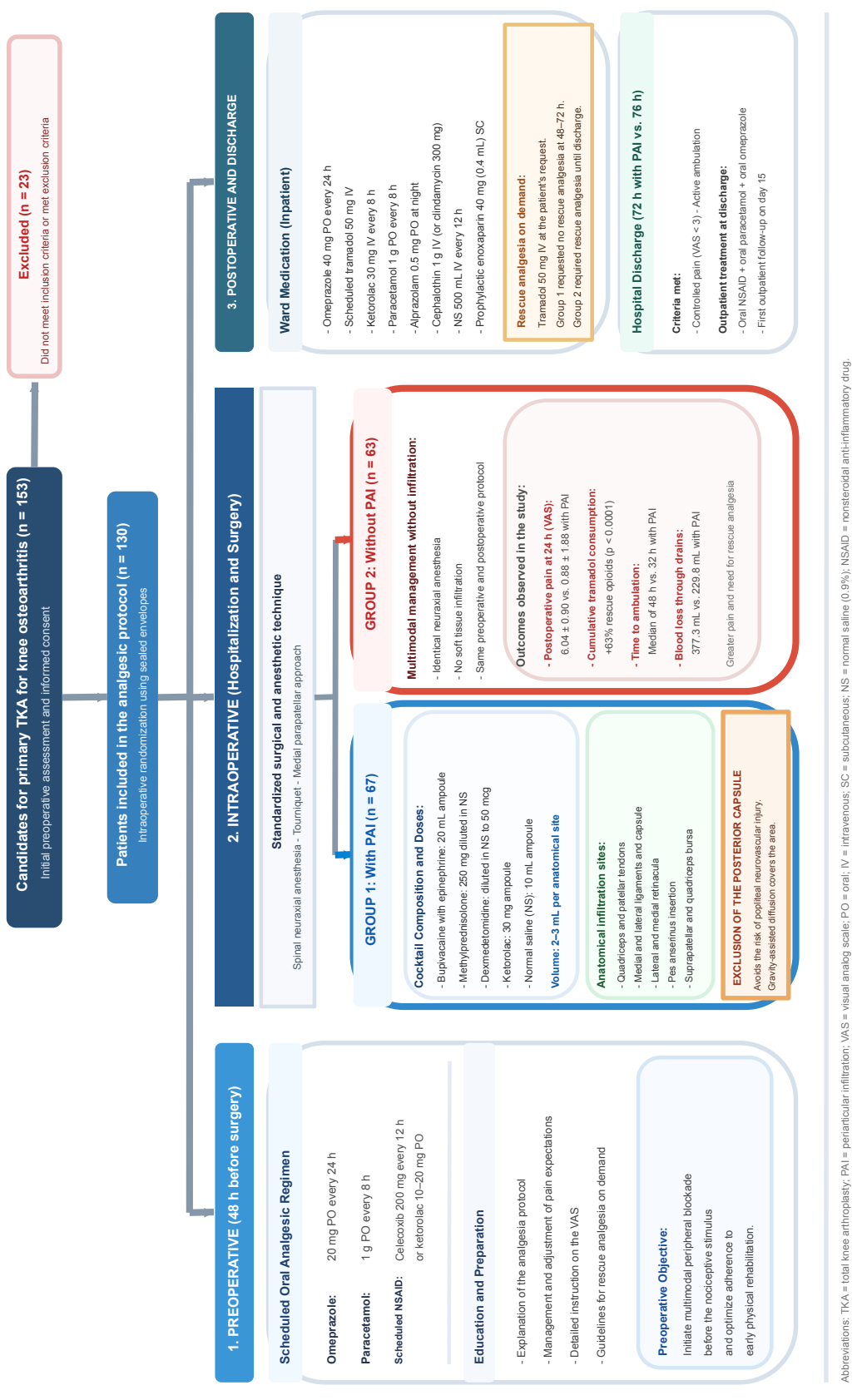


Figure 1. Multimodal analgesia flowchart.

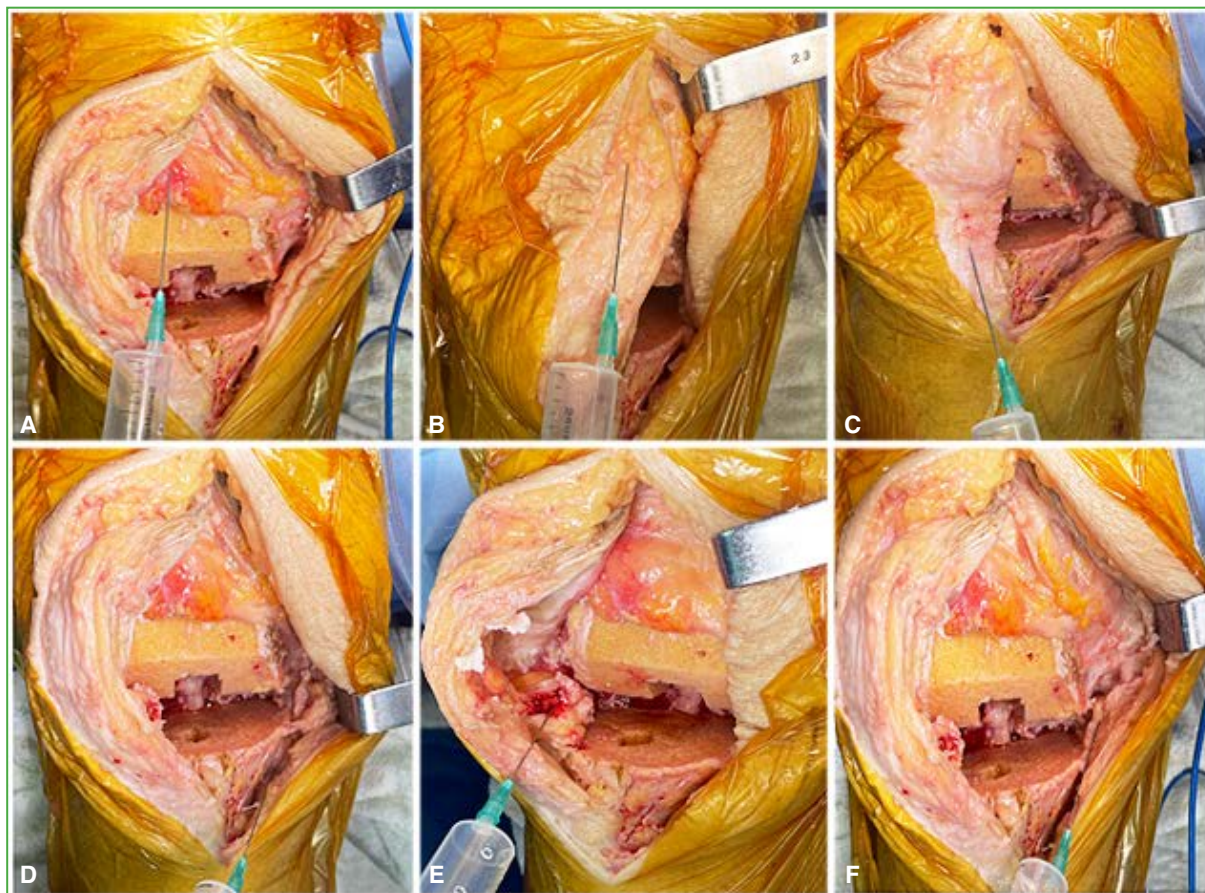


Figure 2. Periarticular infiltration. **A.** Quadriceps and suprapatellar bursae. **B.** Quadriceps tendon. **C.** Patellar tendon. **D.** Pes anserinus. **E.** Lateral ligament. **F.** Medial ligament.

Rehabilitation

The rehabilitation team was unaware of which patients had received PAI. Starting rehabilitation without pain allows patients to begin walking on the day of surgery and continue over the following days. No falls were recorded during hospitalization.

We combined the multimodal protocol with preoperative management of patient expectations and psychological preparation to help patients understand their condition and encourage postoperative adherence and mobilization.

Statistical Analysis

Categorical variables are presented as counts (n) and percentages and were compared using the χ^2 test or Fisher's exact test, as appropriate. Continuous variables are presented as means and standard deviations or medians and interquartile ranges (IQRs) and were compared using Student's t-test or the Wilcoxon test, depending on whether the distribution was normal. The corresponding 95% confidence intervals (95% CIs) are reported. A two-sided p-value <0.05 was considered statistically significant. Statistical analyses were performed using Stata 14.0.

RESULTS

Data from 130 patients were analyzed: 82 women (63.08%) and 48 men (36.92%). Seventy-seven patients received PAI (51.54%).

The proportions of women and men who received PAI were similar: 51.22% (42/82) and 52.08% (25/48), respectively ($p = 0.924$). Mean age did not differ between groups (group 1: 68.02 ± 0.9 years; group 2: 69.01 ± 0.55 years; $p = 0.3598$).

Statistically significant differences in VAS pain scores were observed at four time points during the first 24 hours: 6, 9, 12, and 24 hours. At 24 hours, mean VAS scores were 0.88 ± 1.88 in group 1 and 6.04 ± 0.90 in group 2 ($p < 0.0001$). These differences persisted at 36, 48, and 72 hours (Table, Figure 3).

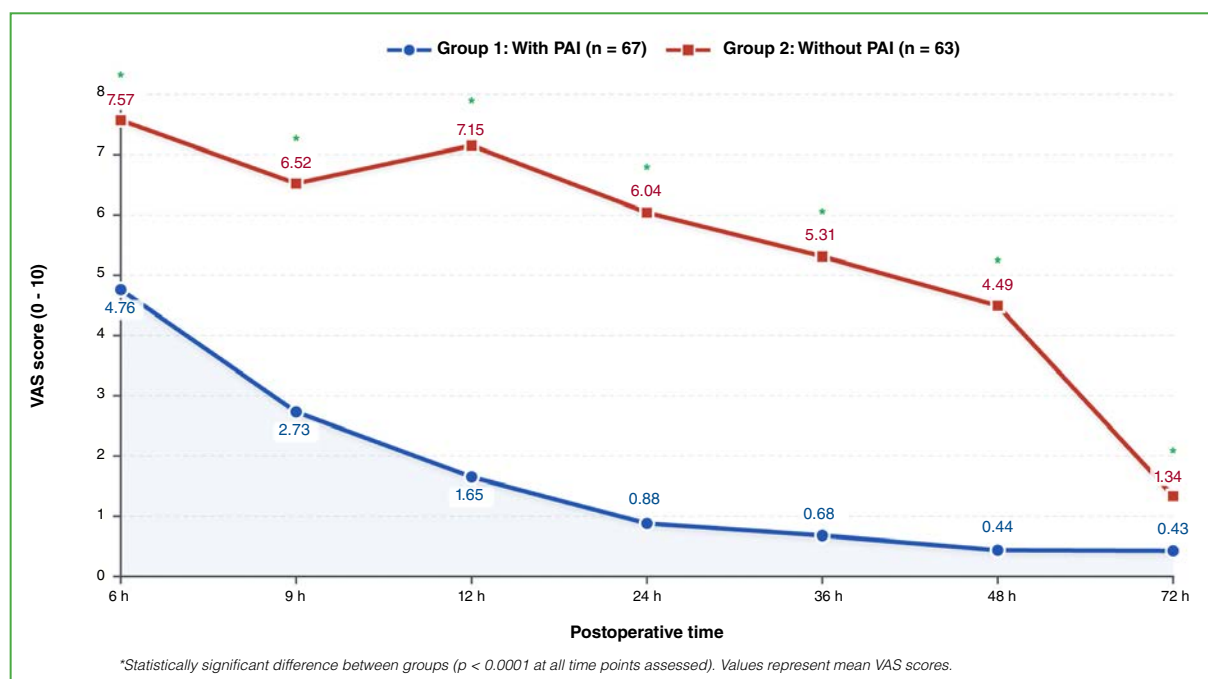


Figure 3. Mean visual analog scale scores in patients with and without periarticular infiltration at 6, 9, 12, 24, 48, and 72 hours.

Assessment of rescue analgesic requirements showed that patients who received PAI needed less rescue tramadol. At 24 hours, mean tramadol consumption per patient was 66.41 ± 55.31 mg in the PAI group and 181.74 ± 57.71 mg in the group without PAI ($p < 0.0001$). This difference persisted in cumulative tramadol consumption per patient at 48 and 72 hours. At both time points, no patients in group 1 requested substantial additional rescue doses, whereas 17.46% of patients in group 2 required rescue analgesia at 48 hours and 7.94% at 72 hours (Table, Figure 4).

All patients who received PAI were discharged at 72 hours, compared with a mean of 76.19 ± 9.18 hours among those who did not ($p = 0.0003$). Patients in group 1 had lower drain output than those in group 2 (229.77 ± 102.77 mL vs. 377.30 ± 91.61 mL; $p < 0.0001$) and began walking earlier (group 1: median 32 hours [IQR 23–48]; group 2: median 48 hours [IQR 34–48]; $p < 0.0001$) (Table). No neuropathies were observed in either group. Only two patients developed a local infection, with no involvement of the implant or effect on final function.

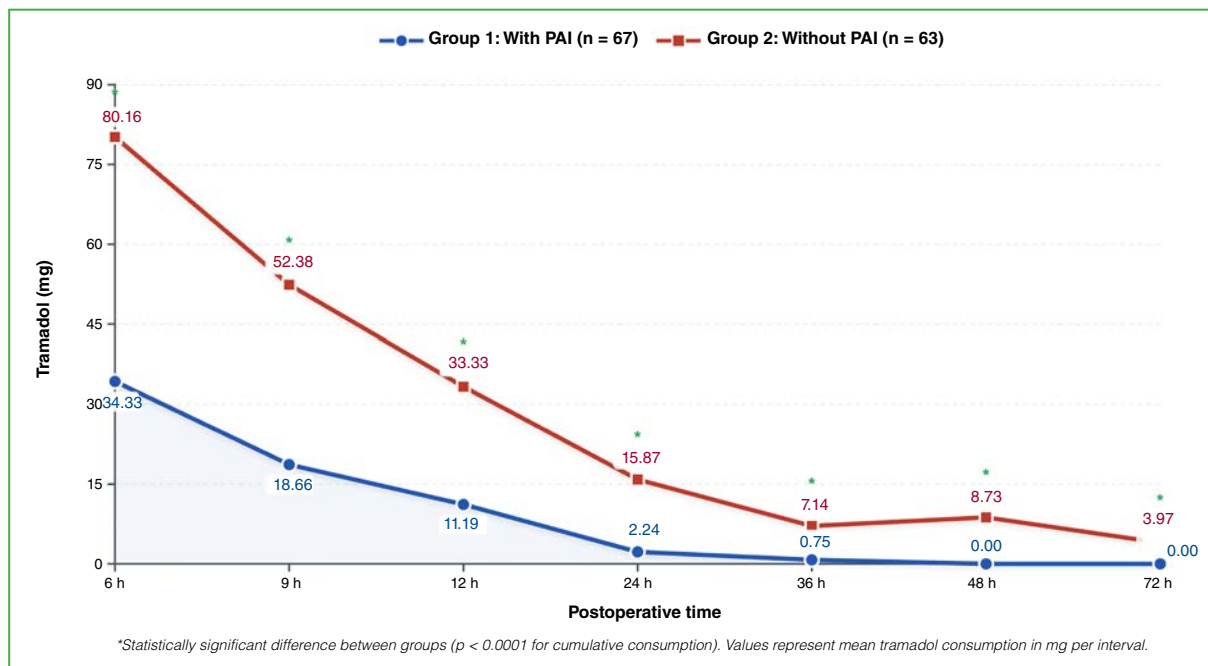


Figure 4. Mean tramadol requirements (mg) in patients with and without periarticular infiltration at 6, 9, 12, 36, 48, and 72 hours.

DISCUSSION

Pain control after TKA is essential to surgical success. Several strategies are available for effective pain management, including multimodal protocols with selective nerve blocks or periarticular injections.

The anterior⁹ and posterior innervation of the knee guides the technique and precautions used in PAI. This anatomical basis is supported by the studies of Dye et al., and Biedert et al.,^{7,8} who performed arthroscopy in conscious patients without anesthesia, identified areas of hyperalgesia on palpation, and documented significantly greater numbers of mechanoreceptors in specific regions.

Analgesic techniques such as spinal anesthesia with or without intrathecal morphine are associated with nausea, sedation, pruritus, urinary retention, constipation, and respiratory depression.¹⁰ Peripheral nerve blocks, particularly FNB, play an important role in postoperative pain management and avoid the adverse effects associated with parenteral and epidural opioids. However, local anesthesia can affect nerve function and cause transient neurological deficits,¹¹ with a risk of falls, nerve injury from needle trauma, and temporary loss of motor control. These complications can delay mobilization, increasing the risk of further complications such as deep vein thrombosis.¹²

In contrast, PAI provides excellent, reproducible analgesia,¹³ with minor limitations related to the short duration of action of the local anesthetic and the perception of insufficient relief beyond 24 hours. It is nevertheless simple to administer, allows faster recovery of lower-limb function,¹⁴ reduces the risk of complications, and is less costly. Its safety and efficacy have been demonstrated in prospective randomized studies.¹⁵

Anatomical studies confirm that the position of the popliteal vessels varies. With the knee flexed, they lie approximately 2 cm from the posterior capsule and are lateral to the midline in more than 95% of patients.¹⁶ This variability contributes to the controversy over including the posterior capsule in PAI. We excluded it from our study because potential risks have been identified, including cardiac arrhythmia from inadvertent intravascular injection and neurological injury from direct needle trauma. Anatomical variations in vascular branching and the arrangement of arteries, veins, and nerves, documented by computed tomography and femoral angiography,¹⁶ pose additional risks.

These concerns about potential harm have led several surgeons to stop including the posterior capsule in PAI.

Guler et al.¹⁷ investigated the benefits of PAI without posterior capsule infiltration compared with another anesthetic technique in patients undergoing bilateral TKA under epidural anesthesia. Knees treated with PAI without posterior capsule infiltration had lower pain scores at 6 and 12 hours on the first and second postoperative days. Neither group experienced neurovascular or wound-related complications.

Studies have reported that the volume of local anesthetic allows the solution to spread by gravity to the posterior aspect of the knee when the patient is supine, as well as during postoperative movement. We suspect that the local anesthetic spreads extensively into the posteromedial and posterolateral regions, blocking parts of the proximal branch of the posterior articular nerve.¹⁸

The efficacy of PAI depends on the technique used. The medical literature recommends infiltrating 2-3 mL at each anatomical site. This volume would optimize effectiveness by promoting tissue penetration and covering the sensory regions of the knee described by Mayrand.^{5,7}

When PAI was compared with intra-articular injections administered after capsular closure, pain scores favored PAI. Opioid consumption was lower in both groups, although the reduction was greater with PAI.²

Predictable complications associated with sudden postoperative pain are related to excessive opioid use. Terkawi et al.,¹⁹ and Busch et al.,²⁰ in a randomized trial of 64 patients receiving PAI, observed lower postoperative analgesic and opioid use at 6, 12, and 24 hours, together with lower VAS pain scores.

Most studies using PAI report substantial, clinically relevant improvements in postoperative pain, with an infection rate <2%.¹⁹

Vendittoli et al.²¹ documented lower morphine consumption for up to 40 hours after surgery in the PAI group than in the control group (FNB). Notably, patients assigned to FNB had greater difficulty performing a straight-leg raise, actively extending the knee, and walking effectively.

Comparisons of PAI and FNB showed similar pain scores and short hospital stays. PAI was associated with a lower likelihood of peripheral nerve dysesthesia but required more intraoperative opioids on the day of surgery than FNB.¹³ However, postoperative opioid consumption and pain scores were lower with PAI than with FNB.⁵

Combined sciatic and femoral nerve blocks can cause complications such as muscle weakness, nerve injury, and local infection (1–2.5%), as well as catheter colonization at 48 hours in continuous blocks (57%).¹³

In a randomized trial, Chaumeron et al.¹⁴ found that PAI provided equivalent analgesia for up to 120 hours while avoiding the motor blockade associated with FNB (37%). In the FNB group, motor deficits and opioid-related adverse effects prolonged hospitalization and increased hospital costs.

Recovery of quadriceps function was slower in patients who received FNB. PAI allowed early mobilization, halved the length of hospital stay, and improved walking distance on postoperative days 0, 1, and 2.²²

In a retrospective study, Duensing et al.²³ observed a risk of arthrofibrosis associated with pain, with an incidence of 7.7% when PAI was not used. In contrast, patients who received PAI as part of accelerated rehabilitation protocols had a significantly lower incidence of this complication, at 2.4%. This finding is particularly relevant given the increasing incidence of postoperative stiffness after TKA.

Regarding bleeding, Barrington et al.²⁴ documented lower blood loss in patients receiving PAI during TKA, although other authors have not replicated this difference.²⁵ This suggests that PAI does not increase bleeding risk beyond that expected with the conventional surgical procedure.²⁵ In our study, including bupivacaine with epinephrine in the cocktail significantly reduced postoperative bleeding compared with the control group ($p < 0.05$). This difference could be attributed to the vasoconstrictive effect of epinephrine. The finding is consistent with that of Barrington et al.,²⁴ but differs from those of other published studies.²⁵ Thus, in addition to providing analgesia, PAI may influence bleeding complications in specific settings.

Our results demonstrate a significant reduction in pain, with the greatest efficacy at 6, 12, and 24 hours after surgery and a sustained analgesic effect for 48-72 hours, validating our multimodal protocol.

The strengths of this study include its randomized controlled design, which minimized selection bias, and its standardized preoperative and postoperative care protocol, applied consistently to both groups.

We acknowledge important limitations. The lack of long-term follow-up prevents assessment of the actual impact of PAI on quality of life and functional recovery beyond the immediate postoperative period. In addition, PAI protocols vary across centers, with substantial differences in cocktail composition (drugs, doses, and adjuvants), infiltration technique, and anatomical sites targeted. This methodological variability, common in the current literature, makes it difficult to compare results directly and reproduce them.

Based on our findings and the literature, we have implemented the multimodal protocol with PAI excluding the posterior capsule for all TKAs performed in our department.

CONCLUSIONS

PAI in TKA proved to be a superior analgesic strategy, providing more effective analgesia (VAS <1 at 24 hours), lower opioid consumption (<63% for tramadol), faster recovery (ambulation at 32 hours), and reduced hospitalization and costs (discharge at 72 hours). Its safety profile and reproducible technique make it an optimal alternative to systemic analgesia or nerve blocks. Its use in enhanced recovery protocols is recommended to optimize postoperative outcomes.

Conflicts of interest: The authors declare no conflicts of interest.

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Artificial Intelligence-Assisted Radiographic Diagnosis of Developmental Dysplasia of the Hip in Children: A Retrospective Study

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ABSTRACT

Introduction: Developmental dysplasia of the hip (DDH) is the most common pediatric musculoskeletal disorder, and its radiographic diagnosis may be affected by technical and interpretive variability. Artificial intelligence (AI), particularly through automated machine learning (AutoML) platforms, offers tools to standardize image assessment and assist in diagnostic classification. **Objectives:** To develop and evaluate an AI model for distinguishing between normal pediatric pelvic radiographs and those showing DDH using the Landing Lens platform. **Materials and Methods:** A retrospective study included 328 pelvic radiographs from patients aged 1 month to 14 years. Four pediatric orthopedic surgeons with varying levels of experience independently labeled the images. The final diagnosis was established by a simple majority, with consensus reached in cases of disagreement. The radiographs were divided into training (70%), validation (20%), and test (10%) sets. Model performance was assessed using accuracy, recall, specificity, F1 score, and agreement coefficients. **Results:** The model correctly classified 320 images (accuracy, 97.6%; recall, 92.8%; specificity, 98%; F1 score, 86.6%). Interobserver agreement was almost perfect (Fleiss' kappa, 0.86), and agreement between the model and specialists increased with clinical experience (Cohen's kappa, 0.85 for the senior observer). **Conclusions:** These findings support the use of AI as an adjunctive tool to standardize the radiographic diagnosis of DDH and reduce interobserver variability. External validation and multicenter studies are required before routine clinical implementation.

Keywords: Developmental dysplasia of the hip; artificial intelligence; AutoML; pelvic radiography; children; deep learning.

Level of Evidence: III

Diagnóstico radiográfico de displasia del desarrollo de la cadera infantil asistido por inteligencia artificial: estudio retrospectivo

RESUMEN

Introducción: La displasia del desarrollo de la cadera (DDC) es la alteración musculoesquelética pediátrica más frecuente y su diagnóstico radiográfico puede verse afectado por variaciones técnicas e interpretativas. La inteligencia artificial (IA), particularmente mediante plataformas AutoML, ofrece herramientas para estandarizar la evaluación de imágenes y asistir en la clasificación diagnóstica. **Objetivos:** Desarrollar y evaluar un modelo de IA para diferenciar radiografías panorámicas de pelvis de niños normales o con DDC utilizando la plataforma Landing Lens. **Materiales y Métodos:** Se realizó un estudio retrospectivo de 328 radiografías de pelvis de pacientes de entre 1 mes y 14 años. Cuatro ortopedistas infantiles con distintos niveles de experiencia realizaron el etiquetado independiente de las imágenes. El diagnóstico final se definió mediante mayoría simple y consenso en casos discordantes. Las radiografías se dividieron en conjuntos de entrenamiento (70%), validación (20%) y prueba (10%). El rendimiento del modelo se evaluó mediante exactitud, sensibilidad, especificidad, F1 score y coeficientes de concordancia. **Resultados:** El modelo clasificó correctamente 320 imágenes (exactitud 97,6%, sensibilidad 92,8%, especificidad 98%, F1 score 86,6%). La concordancia interobservador fue casi perfecta (kappa de Fleiss 0,86), y el acuerdo entre el modelo y los especialistas aumentó con la experiencia clínica (kappa de Cohen 0,85 con el observador *senior*). **Conclusiones:** Estos resultados respaldan el uso de la IA como herramienta complementaria para estandarizar el diagnóstico radiográfico de la DDC y reducir la variabilidad interobservador. Se requieren validaciones externas y estudios multicéntricos antes de su implementación clínica rutinaria.

Palabras clave: Displasia del desarrollo de la cadera; inteligencia artificial; AutoML; radiografía de pelvis; niños; aprendizaje profundo.

Nivel de Evidencia: III

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How to cite this article: Luna MI, Bertolotti R, Ferrer GM, González MC, Pedro Maraude AE. Artificial Intelligence-Assisted Radiographic Diagnosis of Developmental Dysplasia of the Hip in Children: A Retrospective Study. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):420-426. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2281>

INTRODUCTION

Developmental dysplasia of the hip (DDH) results from an abnormal relationship between the femoral head and the acetabulum in the immature hip joint. It encompasses a spectrum ranging from mild acetabular dysplasia to subluxation or complete dislocation. DDH is the most common pediatric musculoskeletal disorder, with an estimated incidence of 0.1–11%, and is more frequent in girls and in the left hip.¹⁻¹⁰ Pelvic radiography is the first-line imaging modality for diagnosing DDH in children older than 4-6 months.^{1,3-6,8,9,11,12}

Artificial intelligence (AI) is increasingly used in medicine, particularly for image analysis. Computer vision and machine learning techniques allow algorithms to be trained to recognize complex patterns and assist with diagnostic classification, helping to reduce interobserver variability.^{13,14}

In recent years, several studies have used deep learning models for the radiographic diagnosis of DDH, with encouraging results in terms of accuracy, recall, and specificity.^{3,5-7,9,11,12,15-17} Automated machine learning (AutoML) allows predictive models to be developed without advanced programming or data science expertise, making them more accessible in clinical settings. Landing Lens is an AutoML-based computer vision platform that provides intuitive interfaces for training and validating image classification models.^{13,18}

This study aimed to develop and evaluate an AutoML model using the Landing Lens platform to classify pediatric pelvic radiographs as normal or showing DDH.

MATERIALS AND METHODS

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Informed consent was waived because of the retrospective design and the use of radiographs previously obtained during routine clinical care. All images were anonymized before analysis to ensure confidentiality and protect patients' personal data.

A retrospective search was conducted for all pelvic radiographs obtained at the institution between March 1, 2023, and March 1, 2025, in pediatric patients aged 1 month to 14 years and 11 months. Radiographs were excluded if the children had traumatic conditions (fractures or acute dislocations), infections (septic arthritis or osteomyelitis), tumors, neurological conditions (chronic nonprogressive encephalopathy or myelomeningocele), a diagnosis of arthrogryposis, slipped capital femoral epiphysis, or Legg-Calvé-Perthes disease, or a history of hip surgery.

The demographic variables analyzed were age in months and sex. Radiographic images were converted from DICOM (*Digital Imaging and Communications in Medicine*) to JPG format before being uploaded to the AI platform. Standardized display settings (window width and level) were maintained during conversion to preserve relevant anatomical information and ensure consistency across the dataset. Although DICOM format offers greater control over image parameters, conversion to JPG was necessary for compatibility with the AutoML platform.

Four pediatric orthopedic specialists independently labeled the radiographs as DDH or normal: one had less than 5 years of experience, two had 10–15 years, and one had more than 15 years.

The final diagnosis for each radiograph (DDH or normal) was determined by a simple majority among the four independent observers. When their assessments differed, the final diagnosis was established through joint review and consensus, with the most experienced specialist (more than 15 years in pediatric orthopedics) acting as the final adjudicator. This approach served as the reference standard for training and evaluating the AI model.

The predictive model was implemented using Landing Lens, an AI platform available on the Landing.ai website. The following metrics were used to evaluate the machine learning model's performance and are detailed in Figure 1.

- Confusion matrix: A tool that displays an algorithm's performance, allowing a more comprehensive assessment of the model.
- Precision: The proportion of correct predictions in a test dataset. It is the ratio of the number of correct predictions to the total number of input examples (positive cases detected).

$$\text{Recall} = \frac{TP}{TP + FN}$$

$$\text{Specificity} = \frac{TN}{TN + FP}$$

$$\text{Precision} = \frac{TP}{TP + FP}$$

$$\text{F1 score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

$$\text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN}$$

Figure 1. Formulas for the metrics used to evaluate the artificial intelligence model.

TP = true positive; TN = true negative; FP = false positive; FN = false negative.

- Recall: The proportion of positive cases correctly identified by the algorithm. It represents the true positives (radiographs showing DDH).
- F1 score: Combines precision and recall into a single metric to assess the model's ability to minimize false positives and false negatives. A higher F1 score indicates a good balance between these two factors.
- Accuracy: The proportion of correctly identified positive and negative cases relative to the total number of images.
- Specificity: Measures how many normal radiographs are correctly identified as such (true negatives).

Fleiss' kappa coefficient was also calculated to assess agreement among specialists, and Cohen's kappa coefficient was used to assess agreement between each specialist and the AI model.

RESULTS

A total of 328 pelvic radiographs were obtained: 152 from girls (46.34%) and 176 from boys (53.65%). The mean age was 66 months (5.5 years; range 2–179 months). The largest number of radiographs came from patients younger than 24 months (118 images).

For model development, 230 radiographs (70%) were used for training, 65 (20%) for validation, and 33 (10%) for testing. The AI model correctly classified 320 of the 328 radiographs and misclassified eight (Figure 2).

The model achieved an overall accuracy of 97.6%, a precision of 81.2%, and a recall of 92.8%, correctly identifying most cases of DDH (high recall). The F1 score was 86.6%, indicating an adequate balance between precision and recall. Specificity was 98%, indicating a very good ability to identify normal radiographs (high specificity) (Figure 3).

Interobserver agreement, assessed using Fleiss' kappa, was 0.86, corresponding to almost perfect agreement (Table). Cohen's kappa between the least experienced specialist (less than 5 years) and the AI model was 0.75. It was 0.81 for each of the two specialists with 10–15 years of experience and 0.85 for the most experienced specialist (>15 years).



Figure 2. Heatmaps generated by the artificial intelligence model, highlighting key areas in each image to visualize its decision-making process.

Figure 3. Overall confusion matrix for the artificial intelligence model, including precision and recall.

Ground truth			Ground truth	
Normal	294	6	0	98.0%
DDC	2	26	0	92.90%
No label	0	0	—	
Precision	99.3%	81.30%		
	Normal	DDC	No prediction	Prediction

Table. Interpretation of the kappa coefficient (Landis and Koch, 1977).

Kappa coefficient	Strength of Agreement
0.00	Poor
0.01-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost perfect

DISCUSSION

Several studies have evaluated AI-assisted radiographic diagnosis of DDH in pediatric populations with broad age ranges. This heterogeneity, also present in our sample, reflects the anatomical changes that occur during growth and poses an additional challenge for automated classification models.^{2-5,7,9,10,12,15,16}

Consistent with the medical literature, most publications report a higher frequency of DDH in girls. Boys predominated in our series, however, which may reflect institutional referral patterns rather than the actual prevalence of the disease.^{3,5,6,8,9,11,16}

Our sample size is comparable to those of several previous studies,^{2,4,16} although smaller than those of large multicenter series. The largest studies are those by Zhang, with 10,219 radiographs, and Liu, with 10,000 images.^{6,8}

Radiographs are labeled by pediatric orthopedic specialists with varying years of experience or by radiologists with different levels of training in pediatric radiology.⁷ In some studies, pediatric orthopedists and pediatric radiologists work together.^{3,6,12} In our study, four pediatric orthopedists performed the labeling: one with less than 5 years of experience (junior), two with 10-15 years (intermediate), and one with more than 15 years (senior). This approach has also been used in other publications.^{3,5,7,11}

The kappa coefficient measures the degree of agreement among observers. Agreement in our study was almost perfect (Fleiss' kappa 0.86), similar to that reported by Xu et al.³ When agreement between the AI model and individual specialists is assessed, the highest Cohen's kappa values are found for the senior specialist,⁵ consistent with the value of 0.85 in our study.

Our AI model achieved high overall accuracy, high recall, and very high specificity, in line with values reported in systematic reviews and recent studies. The difference between accuracy and precision may be explained by the relative class imbalance and the low number of false positives, a phenomenon previously described in models used to diagnose DDH.^{3-7,11,16,19,20}

This study is limited by its retrospective, single-center design, sample size, lack of external validation, and conversion of images to JPG format. Future prospective, multicenter studies should address these limitations to validate the findings and assess their generalizability.^{3,6,19-21}

CONCLUSIONS

Accessible AutoML platforms such as Landing Lens offer an opportunity to expand access to diagnostic support tools in resource-limited settings, helping to standardize radiographic interpretation and reduce interobserver variability. Although external validation is needed before routine clinical use, AI shows promise as a valuable complement to expert clinical judgment in the radiographic diagnosis of DDH, without requiring advanced training in data science.

Use of Artificial Intelligence

ChatGPT (OpenAI) was used to generate 25% of the content of the abstract and conclusion. The authors verified the accuracy and originality of the AI-generated content.

Conflicts of interest: The authors declare no conflicts of interest.

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Clinical and Radiographic Evaluation of the OMICRON 2® Total Knee Prosthesis: A Multicenter Study With Long-Term Follow-up

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ABSTRACT

Introduction: Total knee arthroplasty is the ideal treatment for severe osteoarthritis. The OMICRON 2® system, introduced in Argentina in 2009, incorporated improvements in implant design and instrumentation to optimize and prolong implant survival.

Materials and Methods: A retrospective, longitudinal, observational study included 1,346 total knee arthroplasties performed between 2009 and 2024 at three hospitals in the province of Buenos Aires. Complete clinical and radiographic follow-up data are presented for 616 patients. The Knee Society Score (KSS) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) were used to assess function over time, together with standardized radiographs. Implant survival was defined as retention of the implant without revision and was assessed using Kaplan-Meier curves. **Results:** The mean age was 71.6 years. The most common diagnosis was primary knee osteoarthritis (86%). Implant survival at 15 years was 92.4%. The KSS improved from 37.5 preoperatively to 85.1 at 15 years, and the WOMAC score improved from 89.2 to 15.5 over the same period. At the end of follow-up, 89.8% of patients had no signs of loosening, and only 2% showed minimal femoral changes. Complications included infections (2.7%), septic loosening, periprosthetic fractures, and instability. **Conclusion:** The OMICRON 2® system demonstrated good clinical and radiographic performance, with high long-term implant survival, and is a reliable option for total knee arthroplasty.

Keywords: Knee arthroplasty; osteoarthritis; OMICRON 2®; survival.

Level of Evidence: IV

Análisis clínico-radiológico de la prótesis total de rodilla OMICRON 2®. Estudio multicéntrico con seguimiento a largo plazo.

RESUMEN

Introducción: La artroplastia total de rodilla es el tratamiento ideal para la artrosis severa. El sistema OMICRON 2®, introducido en la Argentina, en 2009, desarrolló mejoras en el diseño e instrumental destinadas a optimizar y aumentar la supervivencia del implante. **Materiales y Métodos:** Se llevó a cabo un estudio observacional, longitudinal y retrospectivo sobre 1346 artroplastias totales de rodilla realizadas entre 2009 y 2024, en tres hospitales de la provincia de Buenos Aires. Presentamos el seguimiento clínico-radiológico completo de 616 pacientes. Se utilizaron los cuestionarios KSS y WOMAC para valorar la funcionalidad en el tiempo con radiografías estandarizadas. La supervivencia se definió como la permanencia del implante en el sitio, sin revisión, evaluado mediante curvas de Kaplan-Meier. **Resultados:** La media de edad era de 71.6 años. El diagnóstico más frecuente fue gonartrosis primaria (86%). La supervivencia del implante a los 15 años fue del 92,4%. El puntaje KSS mejoró de 37,5 antes de la cirugía a 85,1 a los 15 años, y el puntaje WOMAC, de 89,2 a 15,5. El 89,8% no tenía signos de aflojamiento al final del seguimiento; solo un 2% presentó cambios mínimos femorales. Las complicaciones fueron infecciones (2,7%), aflojamiento séptico, fracturas periprotésicas e inestabilidad. **Conclusión:** El sistema OMICRON 2® tuvo un buen rendimiento clínico y radiológico, con una alta supervivencia a largo plazo; es una opción confiable en la artroplastia total de rodilla.

Palabras clave: Artroplastia de rodilla; artrosis; OMICRON 2®; supervivencia.

Nivel de Evidencia: IV

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How to cite this article: Vega C, Moruno F, Megey J, Jimenez W, Satragno CF. Clinical and Radiographic Evaluation of the OMICRON 2® Total Knee Prosthesis: A Multicenter Study With Long-Term Follow-up. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):427-437. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2225>

INTRODUCTION

Total knee arthroplasty (TKA) is currently the gold standard for treating severe osteoarthritis.^{1,2} As the procedure has become increasingly common over the past 30 years, implants and instrumentation have improved significantly.³ Outcomes are assessed using several variables, including implant survival, kinematics, function, and patient satisfaction.⁴⁻⁶

The profile of patients considered candidates for TKA varies widely across publications in terms of age and disease progression, with increasingly younger patients undergoing the procedure.^{7,8}

For patients with osteoarthritis who have a life expectancy of 20–40 years, reliable long-term follow-up data on TKA provide a sound basis for decision-making. Long-term follow-up studies of TKA performed within the past decade therefore warrant greater attention, despite the logistical challenges and limitations.^{9,10} Evidence on implants with an established record of long-term use can also help assess the quality and performance of new devices.¹¹

Implant designers and surgeons continue to develop new implants and surgical techniques that may increase implant survival and improve outcomes after TKA.

The OMICRON 2® TKA system, manufactured by Ortopedia IMECO S.A., was introduced to the Argentine market in 2009 with certification from the National Administration of Drugs, Food and Medical Devices (ANMAT). It has since been distributed nationwide.

This study aimed to evaluate the long-term clinical and radiographic outcomes and implant survival rates of the OMICRON 2® knee prosthesis.

MATERIALS AND METHODS

Implant

The implant has a posterior-stabilized design with an integrated post that compensates for the absence of the posterior cruciate ligament (Figure 1).



Figure 1. OMICRON 2® prosthesis.

The design was refined from its predecessor, the OMICRON 1® prosthesis, to achieve mechanical alignment while balancing bone resection (bone balancing) with the balancing of ligamentous and capsular structures (gap balancing). It features more anatomically shaped components designed for cemented fixation.

The femoral components are made of a cobalt-chromium-molybdenum alloy and have a single radius of rotation to improve tibiofemoral joint congruity. The femoral component was modified to provide a more anatomical shape and trochlear orientation, with distinct right and left components. The trochlear groove was deepened to allow smoother patellar tracking. A smaller intercondylar box, proportional to the size of the femoral component, helps preserve bone stock.

The tibial components are also made of a cobalt-chromium-molybdenum alloy and are modular, with a short central stem.

The tibial baseplate is bilaterally symmetrical, with curved posterior edges that provide an appropriate fit to the tibia (Figure 2).

The keel has two antirotation fins and is smaller than that of the previous implant. The inner surface of the femoral component and the undersurface of the tibial component are macrotextured to improve cement fixation (Figure 3).

Figure 2. Tibial baseplate of the OMICRON 2® prosthesis.



Figure 3. Macrotextured surfaces for cemented fixation of the OMICRON 2® prosthesis.



The polyethylene is highly cross-linked to prevent early wear and incorporates 3° of posterior slope. Femoral alignment was established using an intramedullary guide, and tibial alignment using an extramedullary guide. The posterior slope could be increased to 7° according to the patient's characteristics and the surgeon's judgment.

The instrumentation is based on an anatomical technique guided by mechanical alignment, allowing sequential soft tissue release.

Study Implementation

Implant survival depends not only on implant design but also on several factors related to surgical technique. Hospitals in the province of Buenos Aires were therefore considered using uniform selection criteria.

During much of the study period, the OMICRON 2® prosthesis was supplied to 16 public hospitals in the province of Buenos Aires through the Comprehensive Medical Care Program (PAMI), allowing large-volume distribution. Hospitals from this group were selected according to the following criteria:

- Availability of clinical and radiographic records throughout follow-up.
- Use of the same surgical approach, implant, and instrumentation.
- Use of the same measured resection technique with balancing of the flexion and extension gaps in all cases.
- A standardized cementing technique aimed at optimizing preparation of the bone bed.
- Use of the transepicondylar axis to determine external rotation of the femoral component in all procedures.
- Tibial component rotation guided by the tibial tubercle.
- Use of the same brand of domestically manufactured bone cement.

Based on these criteria, a retrospective longitudinal observational study was conducted at three hospitals in the province of Buenos Aires: Hospital Municipal Central de San Isidro "Dr. Melchor Á. Posse," Hospital Zonal de Agudos "Dr. Carlos A. Bocalandro," and Hospital Municipal "Bernardo Houssay."

A total of 1,346 TKAs were performed between 2009 and 2024. Only 616 patients completed the clinical and radiographic assessment; the remaining patients were lost to follow-up or had died. Patients were classified as lost to follow-up when they missed follow-up visits and could not subsequently be contacted. Deaths that could be confirmed were documented through hospital records and telephone contact with relatives or acquaintances.

Patients who underwent primary TKA were included, and revision procedures were excluded. Implant survival was defined as retention of the implant in situ at the final follow-up visit.

Statistical Methods

Clinical and functional outcomes were recorded in a standardized manner at each hospital by multiple examiners who were blinded during the study. Assessments used questionnaires specifically intended for these patients, administered before and after surgery. The database was combined with a retrospective review of medical records to collect demographic data (age, sex, and body mass index) and surgical data.

A Kaplan–Meier curve was used to determine implant survival at 15 years after implantation. Patient function was assessed using the Knee Society Score (KSS) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).

Permission to obtain patient data was requested from the ethics committee at each hospital.

In terms of implant survival, the success rate was 92.4% ($p = 0.924$) among the 616 patients followed in this study. The minimum required sample size was $n = 300$ patients, yielding a margin of error of 0.03%, a standard level of precision for clinical studies.

Patient Population

The mean age at implantation was 71.6 years; 67.2% of patients were women and 32.8% were men. Mean weight was 80.9 kg, and mean body mass index was 29.2 kg/m² (Table 1).

Table 1. Demographic data.

	n = 616
Mean age	71.6 years
Sex	Female 67.2% (414 patients)
	Male 32.8% (202 patients)
Mean weight	80.9 kg
Mean body mass index	29.2 kg/m ²
Implant laterality	Left knee 48.2% (297 patients)
	Right knee 51.8% (319 patients)
Malalignment	Varus 63.6% (392 patients)
	Valgus 36.4% (224 patients)

Surgery was performed on the left knee in 48.2% of cases and the right knee in 51.8%. Varus was the most common malalignment (71.1%), followed by valgus (28.9%). All patients had competent ligaments, allowing the use of primary knee prostheses.

The most common diagnosis leading to surgery was primary knee osteoarthritis (86%), followed by rheumatoid arthritis (6%), posttraumatic osteoarthritis (4%), sequelae of femoral osteonecrosis (2.5%), and osteoarthritis secondary to septic arthritis (2%) (Table 2).

Table 2. Indications for total knee replacement.

Preoperative diagnosis	Percentage	Number of implants n = 616
Primary knee osteoarthritis	86.2%	531
Rheumatoid arthritis	5.3%	33
Posttraumatic osteoarthritis	3.9%	24
Avascular necrosis	2.5%	16
Sequelae of septic arthritis	2.1%	12

The 730 patients without complete follow-up were slightly older than those who completed follow-up, with a mean age of 73.8 years. There were no statistically significant differences in sex distribution or body mass index ($p > 0.05$).

Surgical Technique

Preoperative planning included weight-bearing anteroposterior radiographs of both knees, a lateral view at 30° of flexion, and an axial patellar view to provide a comprehensive assessment of the affected joint.¹²

Standard prophylaxis included antibiotics 30 minutes before skin incision and antithrombotic prophylaxis in the immediate postoperative period.

All procedures were performed through a medial parapatellar approach.

The prostheses were implanted using a measured resection technique and standard instrumentation. The patella was everted and resurfaced at the surgeon's discretion, depending on the characteristics of the bone. As a general rule, resurfacing was performed in cases of extensive patellar cartilage destruction. It was contraindicated when patellar thickness was <20 mm because of the risk of fracture.¹³ The patella was resurfaced in 61.5% of patients.

All components were cemented, with particular attention to preparing a clean, dry cancellous bone bed to improve cement interdigitation. Cement was applied to both the bone surface and the implant, including the keel, which was cemented in all cases. }

RESULTS

Two independent surgeons at each hospital performed the radiographic assessments. Implant survival and stability were assessed by examining standardized zones around the components for signs of loosening.

The system described by Meneghini et al. and Kumar et al. was used to assess implant stability radiographically (Figure 4).^{9,14}

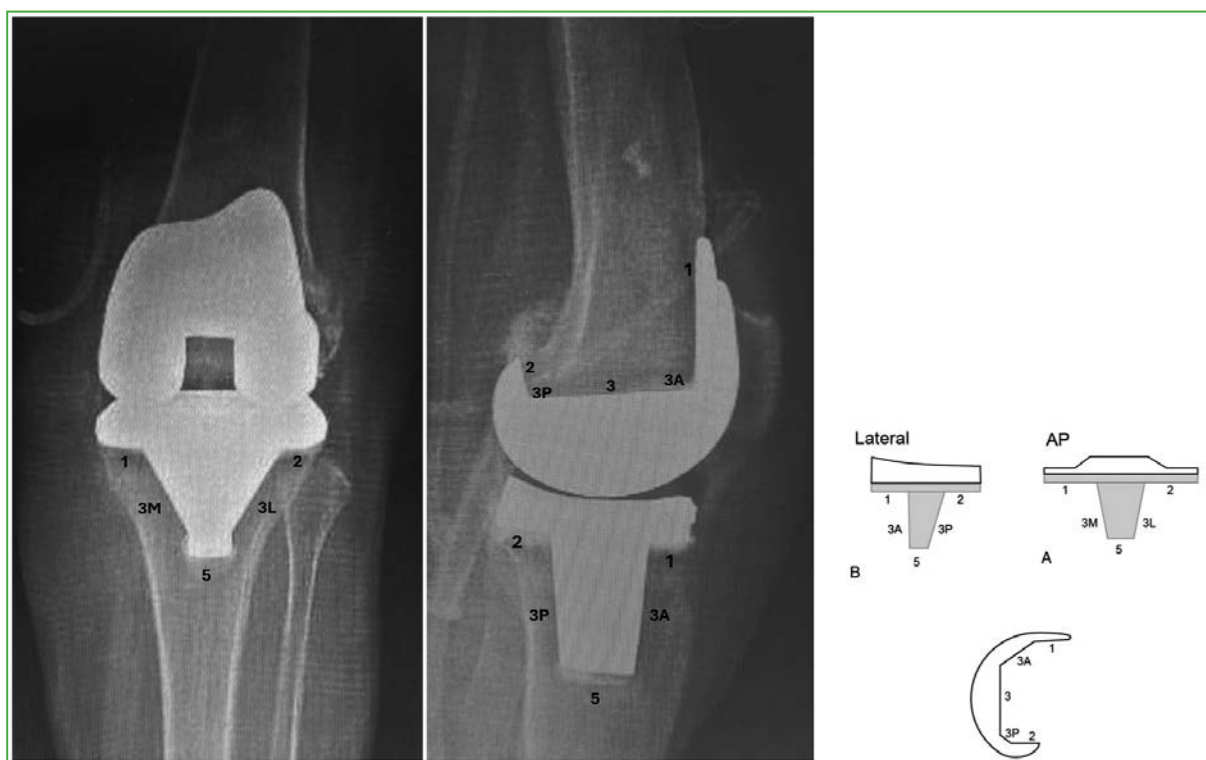


Figure 4. Meneghini radiographic zones.

Radiographic findings at the final follow-up were retrieved from each hospital's digital database for the 616 patients in the study population. Radiographs for the remaining patients were unavailable because of loss to follow-up. Deaths during follow-up were identified through hospital records and confirmed by telephone contact with relatives.

At the final follow-up, 89.8% of implants showed no radiographic changes or signs of loosening. Changes suggestive of osteolysis measuring <1 mm were observed in zones 1 and 2 around the tibial component in 8.2% of implants. The remaining 2% showed minimal changes measuring <2 mm in zone 1 around the femoral component, without clear signs of loosening.

Functional outcomes were assessed using the KSS (Table 3). The total score (maximum, 100) improved significantly from a preoperative mean of 37.5 to 91.6 at 1 year ($p < 0.001$), 90.2 at 5 years ($p < 0.001$), 87.9 at 10 years ($p < 0.001$), and 85.1 at 15 years. Our findings are consistent with those reported in the current literature. The WOMAC score (worst possible score, 96) also improved, from a preoperative mean of 89.2 to 15.5 at the final follow-up.

Table 3. Functional outcomes assessed using the Knee Society Score.

<i>Knee Society Score</i> functional assessment	Score	p
Preoperative	37.5	
1-year follow-up	91.6	<0.001
5-year follow-up	90.2	<0.001
10-year follow-up	87.9	<0.001
15-year follow-up	85.1	<0.001

A key strength of our findings on KSS and WOMAC score improvements is that they are based on long-term clinical and radiographic follow-up.

The main limitation was the progressive loss of patients to follow-up. Although substantial, this loss is unsurprising and consistent with that reported in other long-term studies. Nevertheless, the 95% confidence interval for implant survival at 15 years was 90.31%–94.49%, indicating high statistical precision, with a margin of error of 2.09%, and supporting the robustness of the study.

The design features of the OMICRON 2® total knee replacement system have remained unchanged over the years. Its favorable functional outcomes and 15-year implant survival reflect the success of its design. The OMICRON 2® prosthesis therefore serves as the benchmark for comparing TKA systems at the participating institutions.

Complications

Complications are detailed in Table 4, although most were unrelated to the implants.

Twenty-three revision procedures were performed. Five were for septic loosening and were managed with two-stage revision.

Table 4. Complications.

Intraoperative	Systemic postoperative	Local postoperative	Revision surgery
Femoral condyle fracture (internal fixation): 3	Pneumonia: 4	Stiffness: 21	Septic loosening: 5
Patellar tendon rupture: 2	Ileus: 2	Hematoma: 2	Periprosthetic fracture: 3
Varus malalignment of the tibial component: 15	Deep vein thrombosis: 9	Quadriceps weakness: 1	Aseptic loosening: 4
Femoral component malrotation: 13	Urinary tract infection: 12	Delayed wound healing: 14	Instability: 3
		Early infection (debridement, antibiotics, and implant retention): 12	Persistent pain: 2

Three periprosthetic fractures involved substantial loss of bone stock and required revision to a more constrained prosthesis.

Aseptic loosening led to revision in 10 patients. The tibial component had been placed in varus in seven patients, and the femoral component was malrotated in three, resulting in osteolysis and early loosening.

Three patients required further surgery for instability and two for persistent anterior knee pain. Neither of the patients with anterior knee pain had undergone patellar resurfacing.

The infection rate was 2.7%, with chronic infections in five patients and acute infections in 12. The acute infections resolved with early debridement, antibiotics, and implant retention.

DISCUSSION

This study reports the long-term outcomes of a consecutive series of 616 patients treated between 2009 and 2024. Overall, the 15-year implant survival rate of 92.4% is favorable (Figure 5).

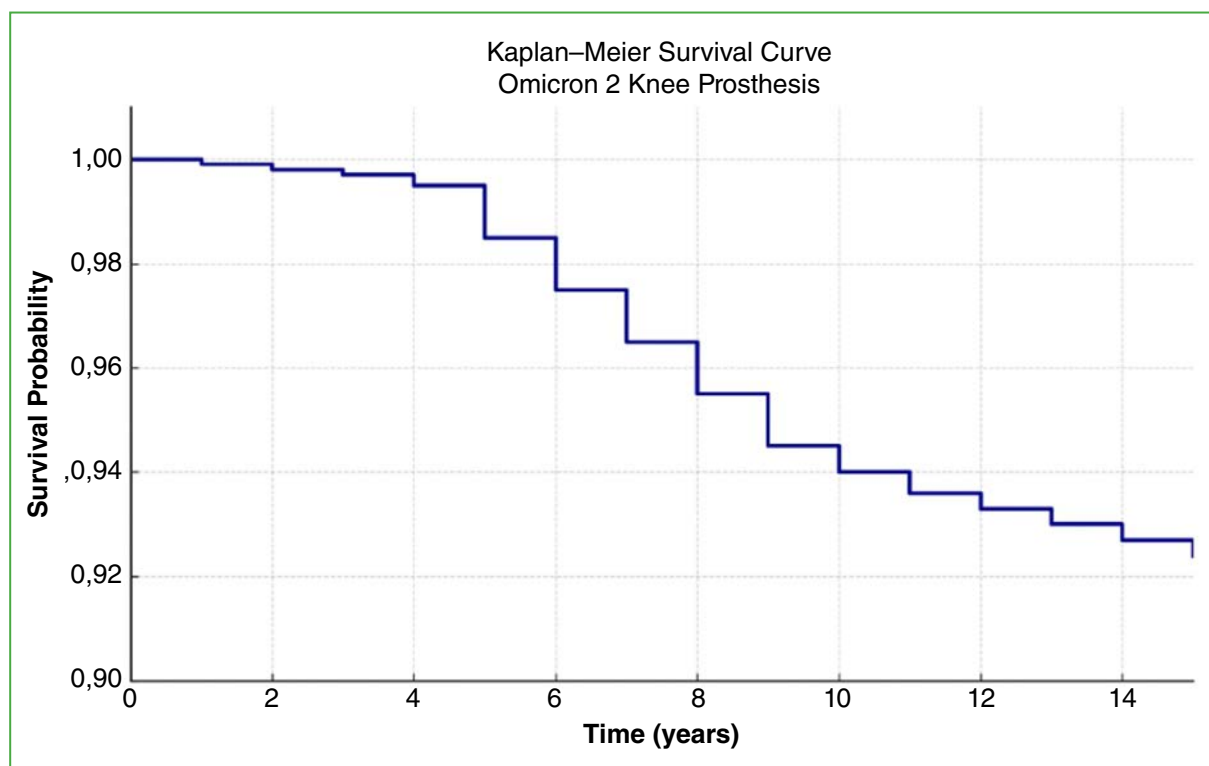


Figure 5. Kaplan–Meier survival curve.

Plain radiographs are the most widely used imaging modality for assessing component alignment, although three-dimensional computed tomography is the reference standard.^{15,16} We used the Knee Society TKA roentgenographic evaluation and scoring system,¹⁷ an accepted tool for radiographic assessment.^{18,19}

We believe that restoring alignment plays an important role in improving implant survival²⁰ and functional outcomes.^{21,22} Patient age may also influence implant survival. Some series of cemented knee replacements in young patients with rheumatoid arthritis have reported excellent long-term survival rates.^{23,24} However, these favorable results may be influenced by the lower activity levels of patients with inflammatory arthritis.

Younger patients generally have greater physical demands and a longer life expectancy, placing greater mechanical stress on the implants.

Roberts et al. found that implant survival was significantly higher in women and older patients.²⁵ Julin et al. reported 5-year survival rates of 92% and 95% in patients aged <55 years and 56–65 years, respectively, compared with 97% in those aged >65 years.²⁶ Younger patients had higher revision rates for noninfectious reasons. Keenan et al. reported 10-year survival after cemented TKA in patients aged <55 years at surgery and compared their functional outcomes with those of patients aged >55 years.²⁷

The original cohort of 1,346 patients decreased over the study period. By 12–15 years, 106 patients had died and 624 had been lost to follow-up. Those lost to follow-up were older than 85 years at the time of assessment, so it is reasonable to assume that many had died.

Declining patient numbers are common in long-term joint replacement studies, reducing the usefulness of functional scores as a discriminating measure.^{28,29} Some studies report that 82% of TKAs last approximately 25 years.³⁰ Callaghan et al. reported on the 26 surviving patients from an initial cohort of 86. Despite an excellent KSS of 89, the function score had declined to 67.³¹ Reports with a minimum follow-up of 15 years after TKA are scarce, and several concern implants that are no longer commonly used. Van Loon et al. followed 102 cemented kinematic TKAs for 10–15 years and reported a survival rate of 62% at 14 years. The main reasons for revision were deep infection and wear.³² Buechel reported a survival rate of 83% at 16 years.³³ Ito et al. examined 36 knees in 25 patients with rheumatoid arthritis and reported a 15-year survival rate of 93.7%.³⁴

Our results are therefore comparable with those reported in the international literature. However, we could not compare them with findings from Argentina, as no long-term studies of domestically manufactured prosthetic implants have been reported.

This study has several strengths and limitations that should be considered when interpreting its findings. A major strength is the length of follow-up, which allows assessment of the implant's long-term durability, with implant survival serving as a key indicator of clinical success. The observational design provides information on how the prosthesis performs under routine clinical conditions, encompassing a diverse population and reflecting everyday surgical practice. Finally, the sample size and availability of longitudinal data allow reliable statistical analyses.

Nevertheless, the study has limitations inherent to its design. The main limitations are the absence of a control group and the high rate of loss to follow-up, which may introduce bias, particularly selection and information bias. Reliance on retrospective clinical records also poses a risk of bias because these records may contain inaccurate data.

Changes or errors in the surgical techniques used during the study period may also have influenced the outcomes. For example, the five cases of aseptic loosening were associated with surgical errors involving incorrect component orientation.

These factors should be considered when assessing the validity and applicability of the findings. Although the retrospective design provides valuable insight into the prosthesis's performance in routine clinical practice, studies with more controlled designs are needed to support its conclusions and confirm the findings.

CONCLUSIONS

We report a favorable implant survival rate of 92.4% in a series of 616 TKAs using the OMICRON 2® system after 15 years of follow-up.

The system's distinctive design features have remained unchanged throughout its relatively long clinical history. In other systems, these features are often modified before long-term results are published.

The OMICRON 2® system continues to show favorable long-term implant survival at a mean follow-up of 15 years.

Conflicts of interest: Drs. Carlos Vega and Favio Moruno are paid medical consultants for IMECO S.A. The rest of the authors declare no conflicts of interest.

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Impact of Joint Space Narrowing on Functional Outcomes After Hip Arthroscopy

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ABSTRACT

Introduction: Femoroacetabular impingement syndrome (FAIS) can often progress to hip osteoarthritis. Although advanced osteoarthritis is a contraindication to arthroscopy, a subgroup of patients without advanced disease who have only mild joint space narrowing may be candidates for this procedure. **Objectives:** To evaluate and compare functional outcomes in patients undergoing hip arthroscopy for FAIS with joint space narrowing (Tönnis grade 1) and those with FAIS without joint space narrowing (Tönnis grade 0). **Materials and Methods:** A retrospective review included 46 hip arthroscopies performed in 44 patients. Patients were divided into two groups according to the Tönnis classification: group A (grade 0) and group B (grade 1). Functional outcomes were assessed using the modified Harris Hip Score (mHHS) and the activities of daily living (HOS-ADL) and sports-specific (HOS-SSS) subscales of the Hip Outcome Score. **Results:** Patients in group A (without joint space narrowing) had better functional outcomes, reflected in higher functional scores, than those in group B (with joint space narrowing) ($p < 0.001$). **Conclusions:** This study suggests that joint space narrowing in patients with FAIS is associated with poorer functional outcomes after hip arthroscopy. This finding may be explained by the higher prevalence of severe chondral lesions and the difficulty of labral repair in patients with joint space narrowing.

Keywords: Hip arthroscopy; Tönnis classification; functional outcomes; cam lesion.

Level of Evidence: IV

Impacto del estrechamiento articular en los resultados funcionales de la artroscopia de cadera

RESUMEN

Introducción: El síndrome de fricción femoroacetabular (SFFA), frecuentemente puede evolucionar hacia la artrosis de cadera y, si bien la artrosis avanzada contraindica la artroscopia, existe un subgrupo de pacientes que, a pesar de no tener artrosis avanzada, muestran una leve disminución del espacio articular, lo que los convierte en candidatos para este procedimiento. **Objetivos:** Evaluar y comparar los resultados funcionales de pacientes tratados con artroscopia de cadera por SFFA con estrechamiento del espacio articular (grado 1 de Tönnis) y pacientes con SFFA sin alteración (grado 0 de Tönnis). **Materiales y Métodos:** Se llevó a cabo una revisión retrospectiva de 46 artroscopias de cadera realizadas en 44 pacientes. Se los dividió en dos grupos según la clasificación de Tönnis: grupo A (grado 0) y grupo B (grado 1). Los resultados funcionales se evaluaron con el *Harris Hip Score* modificado (HHSm), el *Hip Outcome Score-Activity of Daily Living* (HOS-ADL) y su subescala, orientada al deporte (*Sport-Specific Subscale*). **Resultados:** Los pacientes del grupo A (sin estrechamiento del espacio articular) obtuvieron mejores resultados funcionales, reflejados en puntajes más altos en las escalas funcionales, comparados con los del grupo B (con estrechamiento del espacio articular) ($p < 0.001$). **Conclusiones:** El estudio sugiere que el estrechamiento del espacio articular en pacientes con SFFA se asocia con peores resultados funcionales después de la artroscopia de cadera. Esta observación podría explicarse por la mayor prevalencia de lesiones condrales severas y la dificultad para reparar el labrum en pacientes con estrechamiento del espacio articular.

Palabras clave: Artroscopia de cadera; clasificación de Tönnis; resultados funcionales; lesión tipo CAM.

Nivel de Evidencia: IV

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How to cite this article: Arroquy D, Silvestrini MP, Ruiz S, Rubado M, Botta M, Mañero L, et al. Impact of Joint Space Narrowing on Functional Outcomes After Hip Arthroscopy. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):438-447. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2422>

INTRODUCTION

Femoroacetabular impingement syndrome (FAIS) results from abnormal contact between the acetabulum and femoral neck and can frequently cause labral or cartilage injury, leading to hip osteoarthritis. Numerous studies have shown that osteoarthritis adversely affects outcomes after hip arthroscopy. However, some patients with FAIS have mild joint space narrowing without advanced osteoarthritis and may be treated arthroscopically. A recent study with 20-year follow-up after hip arthroscopy for labral tears identified chondral damage to the femoral head and acetabulum as the most important risk factor for conversion to total hip arthroplasty (THA).¹⁻⁴

Patients with moderate or severe hip osteoarthritis, corresponding to Tönnis grades 2 and 3, have consistently had poorer outcomes after hip arthroscopy than those with no or mild osteoarthritis. Studies of patients with mild osteoarthritis (Tönnis grade 1), however, have not shown the same adverse effect on clinical outcomes as in patients with more advanced disease. In a systematic review, Domb et al. found that joint space <2 mm and Tönnis grade >1 were indicators of poor outcomes after hip arthroscopy and that THA may be justified in these patients. Based on these studies, current hip preservation practice has narrowed surgical indications to patients with good joint quality and preserved joint space, specifically joint space >2 mm and Tönnis grades 0 and 1.⁵⁻⁷

This study aimed to evaluate and compare functional outcomes after hip arthroscopy in patients with FAIS and joint space narrowing (Tönnis grade 1) and those with FAIS without joint space narrowing (Tönnis grade 0).

MATERIALS AND METHODS

Study Design, Population, and Inclusion and Exclusion Criteria

We conducted a retrospective, observational, comparative cohort study of hip arthroscopies performed in patients diagnosed with FAIS. All procedures were performed by the same surgeon.

Between January 2016 and June 2025, 55 hip arthroscopies were performed. The analysis included patients who underwent surgery for FAIS and had at least one year of follow-up. Cases with advanced joint space narrowing (Tönnis grade >1) or acetabular dysplasia were excluded. The final sample comprised 46 hip arthroscopies in 44 patients.

Indications for arthroscopic treatment were radiographic evidence of FAIS, clinical examination findings consistent with hip pain, and failure of conservative treatment. Conservative measures included relative rest, activity modification, analgesics, and muscle strengthening while avoiding deep flexion under load.

All patients underwent radiography and magnetic resonance imaging before surgery. Pincer-type deformity was defined as a center-edge angle >40°, and cam-type deformity as an alpha angle >50°. Osteoarthritis was graded according to the Tönnis classification: no joint space narrowing (grade 0) or definite narrowing (grade 1). Joint space was measured on weight-bearing anteroposterior hip radiographs using digital software (AGFA). Grade 1 was defined as narrowing <50% or residual joint space >2 mm in all regions. In total, 28 hips were classified as grade 0 and 18 as grade 1 (Figure 1).⁸⁻¹¹

Surgical Technique

All procedures were performed by the same surgeon under spinal anesthesia combined with a pericapsular block. Patients were positioned supine, with traction applied using a central post. Anterolateral and anterior portals were routinely used. An interportal capsulotomy was first performed using a banana knife. In patients with acetabular overcoverage (pincer morphology), a controlled acetabuloplasty was performed; in some cases, this was limited to creating a bleeding bone bed to promote labral repair.

Labral tears were repaired using 2.8-mm knotless PEEK anchors. Chondral lesions were graded according to the Outerbridge classification. After work in the central compartment was completed, traction was released to assess the femoral head-neck junction. In patients with cam-type deformity, osteochondroplasty was performed using a burr under fluoroscopic guidance.



Figure 1. Anteroposterior hip radiographs. **A.** Tönnis grade 0. **B.** Tönnis grade 1.

All patients were discharged on the day of surgery and instructed to maintain partial weight-bearing for three weeks. Physical therapy began in the third week, focusing first on restoring range of motion and then on muscle strengthening.

Assessment

The following variables were recorded: age, sex, deformity type, osteoarthritis grade (Tönnis), chondral lesions (Outerbridge), labral repair, and whether microfracture was performed. Functional outcomes were assessed at the final follow-up using the modified *Harris Hip Score* (mHHS), the *Hip Outcome Score–Activities of Daily Living* subscale (HOS-ADL), and its *Sport-Specific Subscale* (HOS-SSS). These instruments were administered in person, by telephone, or by email. Failure was defined as an HHS <70 or radiographic progression of osteoarthritis warranting THA. Advanced chondral lesions and the need for microfracture were also assessed as potential predictors of failure.^{1,12}

Statistical Analysis

Descriptive statistics were used to characterize the sample. Between-group comparisons of means were performed using Student's t-test or Welch's t-test, with ANOVA or the Kruskal–Wallis test used as appropriate according to whether the assumptions were met. Categorical variables were compared using the χ^2 test or Fisher's exact test, as appropriate.

To explore predictors of functional outcomes, multiple linear regression models were fitted with postoperative mHHS as the dependent variable. Covariates included age, sex, Tönnis grade, deformity type, chondral lesion grade, and HOS-ADL scores.

Kaplan–Meier curves were constructed to estimate failure-free survival, and the Tönnis groups were compared using the log-rank test. The small number of events ($n = 2$) precluded reliable estimation of a multivariable Cox regression model. A p-value <0.05 was considered statistically significant.

Analyses were performed using R version 4.5.0 (2025-04-11 ucrt; R Foundation for Statistical Computing, Vienna, Austria). The dplyr, ggplot2, and tidyr packages were used for data management and visualization; stats for comparisons of means and categorical associations; survival and survminer for survival analyses and Kaplan–Meier curves; and broom for tabular presentation of the regression models.

RESULTS

The study included 46 patients (25 men and 21 women), with a mean age of 33.9 ± 9.4 years (range 18-52) and a mean follow-up of 45.7 months (range 12-96). According to the Tönnis classification, 28 patients (60.9%) had grade 0 and 18 (39.1%) had grade 1 osteoarthritis. There were 17 cam, 20 mixed, and 9 pincer deformities. Intra-operative chondral lesions were classified as grade 0 ($n = 17$), grade 1 ($n = 1$), grade 2 ($n = 9$), grade 3 ($n = 8$), and grade 4 ($n = 11$) (Table 1).

Table 1. Baseline characteristics of the cohort by Tönnis grade.

Variable		Tönnis grade 0 (n = 28)	Tönnis grade 1 (n = 18)	p
Age (years, mean $\pm$ SD)		30.2 $\pm$ 9.7	39.6 $\pm$ 8.1	0.001
Sex (n; %)	Male	9 (32.1)	14 (77.8)	0.006
	Female	17 (60.7)	4 (22.2)	
Deformity (n; %)	Cam	8 (28.6)	9 (50.0)	0.126
	Pincer	8 (28.6)	1 (5.6)	
	Mixed	12 (42.9)	8 (44.4)	
Chondral lesion (%)	G 0-2	27 (96.4)	0 (0.0)	<0.001
	G 3-4	1 (3.6)	18 (100.0)	

Overall functional outcomes were favorable. The mean postoperative mHHS was 86.5 (median 87; range 59–91), the mean HOS-ADL was 84.9 (median 88.5), and the mean HOS-SSS was 83.9 (median 87) (Figure 2).

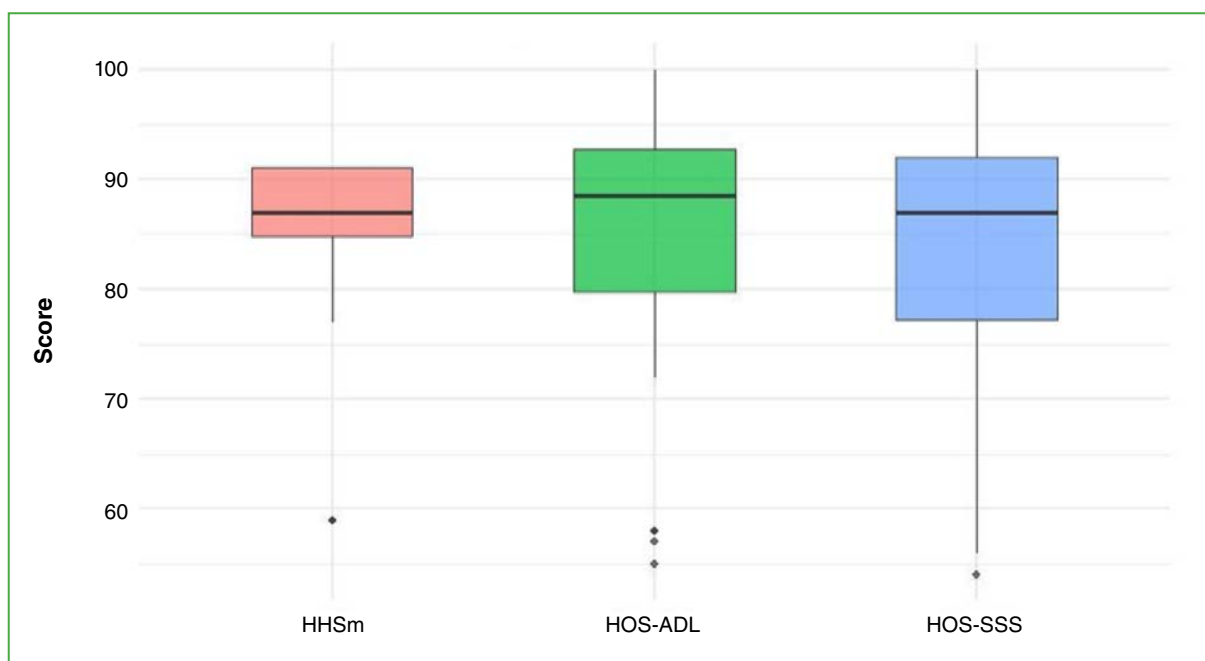


Figure 2. Distribution of postoperative HHS, HOS-ADL, and HOS-SSS scores.

HHS = Harris Hip Score; HOS-ADL = Hip Outcome Score–Activities of Daily Living; HOS-SSS = Hip Outcome Score–Sport-Specific Subscale.

When age was compared by Tönnis grade, patients with mild osteoarthritis (grade 1) were significantly older than those with grade 0 (39.6 ± 8.1 vs. 30.2 ± 9.7 years; $p = 0.001$). Patients with grade 0 also had higher functional scores: mHHS, 89.1 ± 2.5 vs. 82.3 ± 9.8 ($p = 0.010$); HOS-ADL, 91.9 ± 5.0 vs. 74.0 ± 10.5 ($p < 0.001$); and HOS-SSS, 91.2 ± 5.5 vs. 72.3 ± 10.0 ($p < 0.001$) (Table 2).

Table 2. Functional outcomes and comparisons.

Variable	Total (n = 46)	Tönnis grade 0 (n = 28)	Tönnis grade 1 (n = 18)	p
HHS (mean $\pm$ SD)	86.5 ± 7.5	89.1 ± 2.5	82.3 ± 9.8	0.01
HOS-ADL (mean $\pm$ SD)	84.9 ± 9.5	91.9 ± 5.0	74.0 ± 10.5	<0.001
HOS-SSS (mean $\pm$ SD)	83.9 ± 10.0	91.2 ± 5.5	72.3 ± 10.0	<0.001

SD = standard deviation; HHS = Harris Hip Score; HOS-ADL = Hip Outcome Score–Activities of Daily Living; HOS-SSS = Hip Outcome Score–Sport-Specific Subscale.

Confidence intervals and effect sizes confirmed the clinical relevance of these differences. The mHHS showed a large effect size (Cohen's d 1.05; 95% confidence interval [95% CI] 0.42–1.68), whereas the HOS-ADL (Cohen's d 2.34; 95% CI 1.57–3.10) and HOS-SSS (Cohen's d 2.49; 95% CI 1.69–3.27) showed very large effect sizes. These findings reinforce that patients without osteoarthritis achieve substantially greater functional benefits (Table 3).

Table 3. Effect sizes (Cohen's d) and 95% confidence intervals (95% CIs) for differences between Tönnis grades 0 and 1.

Variable	Mean difference (CI95%)	p	Effect size (Cohen's d, 95% CI)
HHS	1.8 to 11.7	0.010	1.05 (0.42–1.68)
HOS-ADL	12.4 to 23.4	<0.001	2.34 (1.57–3.10)
HOS-SSS	13.6 to 24.3	<0.001	2.49 (1.69–3.27)

HHS = Harris Hip Score; HOS-ADL = Hip Outcome Score–Activities of Daily Living; HOS-SSS = Hip Outcome Score–Sport-Specific Subscale.

In contrast, postoperative mHHS did not differ significantly among deformity types (ANOVA $p = 0.152$; Kruskal–Wallis $p = 0.114$) (Figure 3).

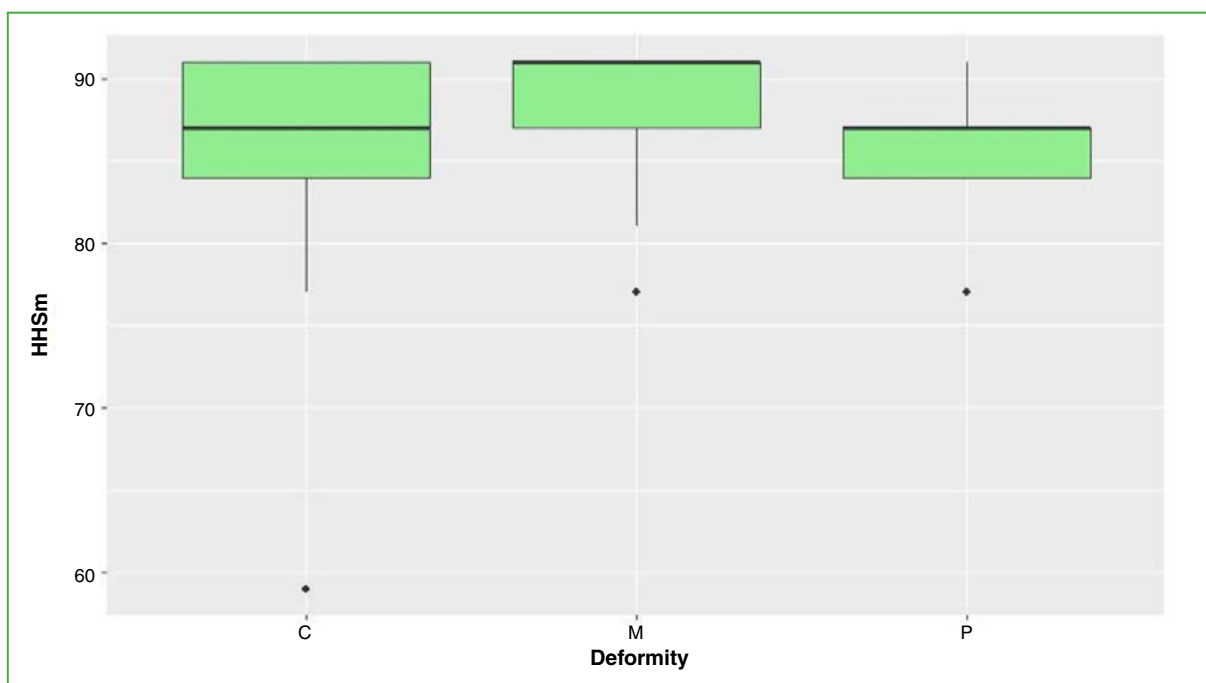


Figure 3. Postoperative Harris Hip Score by deformity type.

Chondral lesions were strongly associated with osteoarthritis grade. Advanced chondral lesions (grades 3-4) were more frequent in patients with Tönnis grade 1, and this difference was statistically significant (Fisher's exact test, $p < 0.001$) (Figure 4, Table 4). Deformity type, however, was not significantly associated with Tönnis grade (Fisher's exact test, $p = 0.126$).

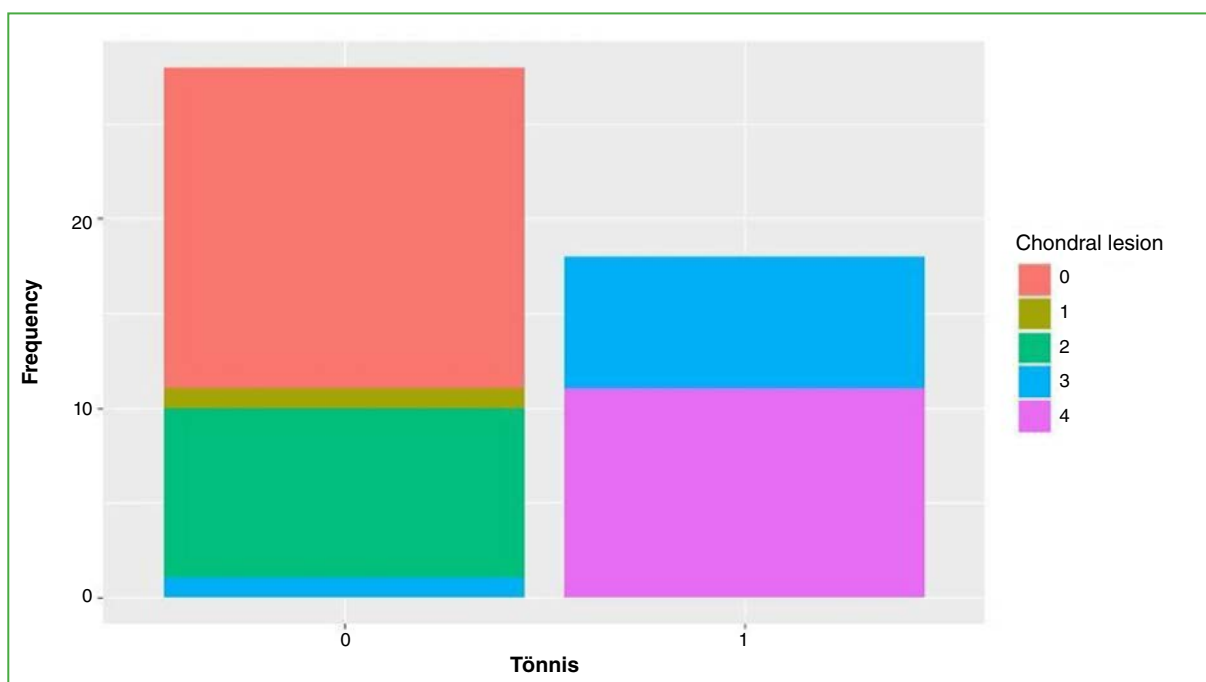


Figure 4. Distribution of chondral lesions by Tönnis grade.

Table 4. Associations between categorical variables.

Comparison	Test	p
Tönnis vs. deformity	χ^2	0.1145
Tönnis vs. chondral lesion	Fisher's	0.0001

In the multivariable linear regression analysis, no individual variable was significantly and independently associated with postoperative mHHS. The overall model explained 48% of the variability in outcomes (adjusted $R^2 = 0.48$; $p < 0.001$) (Table 5).

Table 5. Multiple linear regression model for postoperative HHS.

Variable		Beta	SE	t	p
Intercept		38.01	13.68	2.78	0.008
Tönnis grade 1		5.67	6.44	0.88	0.38
Age		0.044	0.13	0.33	0.74
Deformity	Mixed	2.57	2.21	1.16	0.25
	Pincer	1.05	3.64	0.29	0.77
Chondral lesion	1	2.63	6.77	0.39	0.70
	2	1.45	2.76	0.53	0.60
	3	-1.52	5.54	-0.27	0.78
	4	-4.72	6.35	-0.74	0.46
Sex	Male	1.49	2.50	0.59	0.55
HOS-ADL		0.46	0.37	1.25	0.22
HOS-SSS		0.05	0.39	0.13	0.89

SE = standard error; HHS = Harris Hip Score; HOS-ADL = Hip Outcome Score–Activities of Daily Living; HOS-SSS = Hip Outcome Score–Sport-Specific Subscale.

An expanded model that included sex and HOS scores slightly improved the fit, yielding an adjusted R^2 of 0.53 ($p < 0.001$). No individual covariate showed clear statistical significance. However, the interaction between Tönnis grade and HOS-ADL showed a statistical trend ($p = 0.075$), suggesting that radiographic severity may modify the effect of performance in activities of daily living on postoperative mHHS (Table 6).

Finally, survival analysis (event = mHHS < 70) showed failure-free survival of 100% in the Tönnis grade 0 group and 88.9% in the grade 1 group at 65 months of follow-up. The Kaplan-Meier curves showed a trend toward lower survival in patients with grade 1, but the log-rank test did not reach statistical significance, probably because of the small number of events ($n = 2$) (Table 7, Figure 5).

Table 6. Multiple linear regression model with a Tönnis grade × HOS-ADL interaction.

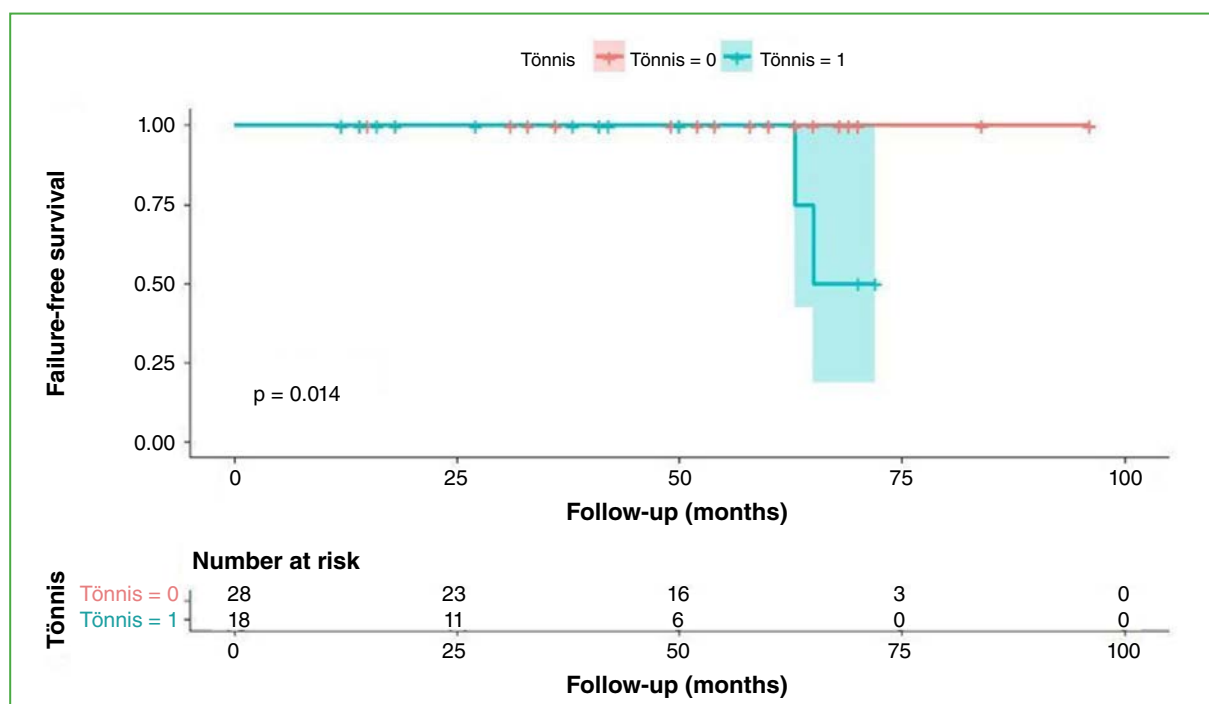
Variable		Beta	SE	t	p
Intercept		88.38	29.64	2.982	0.005
Tönnis grade 1		-53.23	32.65	-1.630	0.11
HOS-ADL		-0.00	0.30	-0.021	0.98
Age		-0.01	0.12	-0.123	0.90
Deformity	Mixed	3.02	2.11	1.428	0.16
	Pincer	-0.0	3.50	-0.027	0.97
Chondral lesion	1	-0.14	6.51	-0.021	0.98
	2	-1.44	3.06	-0.471	0.64
	3	-0.12	5.32	-0.023	0.98
	4	-2.26	6.14	-0.368	0.71
Sex	Male	2.48	2.43	1.017	0.31
Tönnis grade 1 HOS-ADL		0.62	0.34	1.838	0.07

HOS-ADL = Hip Outcome Score–Activities of Daily Living.

Table 7. Failure-free survival.

Time (months)	Tönnis grade 0 (n = 28)	Tönnis grade 1 (n = 18)	p*
65	100%	88.90%	0.1

*Log-rank test.

**Figure 5.** Survival curves for Tönnis grades 0 and 1, with the number-at-risk table.

DISCUSSION

This study compared the characteristics and functional outcomes of patients with FAIS who underwent hip arthroscopy, divided into two groups according to the degree of joint space narrowing (Tönnis classification). Patients without preoperative joint space narrowing (group A, grade 0) achieved better functional outcomes, measured using the mHHS, than those with narrowing (group B, grade 1). The predominant deformity type also differed between groups. Mixed, cam, and pincer deformities were more evenly distributed in group A, whereas cam-type deformity clearly predominated in group B.

These findings agree with the literature suggesting that osteoarthritis, even in its early stages manifested as joint space narrowing, may adversely affect outcomes after hip arthroscopy. Joint space narrowing has been associated with greater chondral damage and poorer hip function, which may explain the lower functional scores in group B. The higher prevalence of chondral lesions in this group (100% vs. 26%) further supports this observation and suggests that joint space narrowing may indicate greater intra-articular damage. Our findings are consistent with those of Domb et al. in showing that patients with Tönnis grade 1 can achieve statistically significant improvements in functional outcomes. However, the clinical relevance of these improvements remains uncertain: Nho et al. reported that patients with grade 1 osteoarthritic changes are less likely to achieve a minimally satisfactory outcome than those with grade 0.^{5,6,11,13-15}

The causal relationship between FAIS and hip osteoarthritis is well described, but whether correcting cam or pincer morphology prevents osteoarthritis progression remains debated. In a study assessing hips before and after cam resection, Van Houcke et al. found that peak contact forces were significantly elevated in patients with cam-type FAIS but returned to normal after resection. This suggests that cam resection may prevent further chondral injury. In our study, the observed difference in the distribution of bony deformities was not significantly associated with Tönnis grade. Failure-free survival at 65 months was 100% in the Tönnis grade 0 group and 88.9% in the grade 1 group. Vilaseca et al. reported a THA conversion rate of 2.43% in patients followed for more than 10 years.^{4,13,16}

Several limitations should be considered. The sample size, particularly in group B, may limit the statistical power to detect subtle differences. Longer-term follow-up would also help assess osteoarthritis progression and the need for THA. Despite these limitations, the study provides valuable information on the relationship between joint space narrowing, deformity type, and functional outcomes after hip arthroscopy.

CONCLUSIONS

These findings suggest that patients with joint space narrowing should be selected cautiously for hip arthroscopy. Although arthroscopy may relieve symptoms in some cases, patients with Tönnis grade 1 may face a higher risk of suboptimal functional outcomes and more rapid osteoarthritis progression. A thorough preoperative assessment, including careful evaluation of joint space and bony deformity, is therefore essential to counsel patients about their expectations and consider alternative treatments, such as THA, in selected cases.

Conflicts of interest: The authors declare no conflicts of interest.

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Comparative Efficacy of PFNA Versus DHS for Intertrochanteric Hip Fractures: An Umbrella Review

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ABSTRACT

Introduction: Intertrochanteric hip fractures are common in older patients and pose a major therapeutic challenge. The dynamic hip screw (DHS) and proximal femoral nail antirotation (PFNA) are the most widely used implants, but the evidence regarding their comparative efficacy remains controversial. **Objective:** To summarize evidence from systematic reviews and meta-analyses comparing PFNA with DHS for the treatment of intertrochanteric hip fractures. **Materials and Methods:** An umbrella review of systematic reviews and meta-analyses published between 2013 and 2025 was conducted. Reviews directly comparing PFNA or other proximal femoral nail variants with DHS and reporting at least one relevant clinical or perioperative outcome were included. Because of overlapping primary studies and methodological heterogeneity, a qualitative narrative synthesis was conducted without a new meta-analysis. **Results:** Ten systematic reviews (nine with meta-analyses) were included, encompassing data from more than 12,000 patients. PFNA showed consistent perioperative advantages, with shorter operative times and less intraoperative blood loss. There were no clinically relevant differences in long-term function or major complications. In unstable fractures, PFNA provided greater biomechanical stability and showed a trend toward less mechanical failure, varus collapse, or shortening. **Conclusions:** PFNA offers perioperative advantages over DHS, particularly in unstable fractures and in older or high-risk patients. In the long term, both implants yield similar functional outcomes and rates of major complications. Implant selection should therefore be individualized according to fracture pattern, patient condition, surgeon experience, and available resources.

Keywords: Intertrochanteric fracture; proximal femoral nail; PFNA; dynamic hip screw; umbrella review; meta-analysis.

Level of Evidence: I

Eficacia comparativa del clavo PFNA y el tornillo DHS en fracturas intertrocantericas de cadera: umbrella review

RESUMEN

Introducción: Las fracturas intertrocantericas de cadera son frecuentes en pacientes añosos y representan un importante desafío terapéutico. El tornillo dinámico de cadera (DHS) y el clavo femoral proximal antirrotatorio (PFNA) son los implantes más utilizados, pero la evidencia comparativa es aún controvertida. **Objetivo:** Sintetizar la evidencia de revisiones sistemáticas y metanálisis que comparan PFNA con DHS para tratar las fracturas intertrocantericas de cadera. **Materiales y Métodos:** Se realizó una *umbrella review* de revisiones sistemáticas y metanálisis publicados entre 2013 y 2025. Se incluyeron revisiones que compararan directamente PFNA o variantes de clavos femorales proximales con DHS y con, al menos, un desenlace clínico o perioperatorio relevante. Por solapamiento de estudios primarios y heterogeneidad metodológica, se efectuó una síntesis narrativa cualitativa sin nuevo metanálisis. **Resultados:** Se incluyeron 10 revisiones sistemáticas (9 con metanálisis) que agruparon datos de más de 12.000 pacientes. El PFNA mostró ventajas perioperatorias consistentes, con menor tiempo quirúrgico y menos pérdida sanguínea intraoperatoria. No hubo diferencias clínicamente relevantes en la función a largo plazo ni en las complicaciones mayores. En fracturas inestables, el PFNA tuvo mejor estabilidad biomecánica y menor tendencia a fallos mecánicos, colapso en varo o acortamiento. **Conclusiones:** El PFNA ofrece ventajas perioperatorias frente al DHS, especialmente en fracturas inestables y pacientes añosos o de alto riesgo. A largo plazo, ambos implantes logran resultados funcionales y tasas de compli-

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How to cite this article: Vidal Chang N, Kelsey Gary HC, Vidal Campo MA, Gómez Palencia NA. Comparative Efficacy of PFNA Versus DHS for Intertrochanteric Hip Fractures: An Umbrella Review. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):448-454. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2365>

caciones mayores similares; por lo tanto, la elección debe individualizarse según el patrón de fractura, la condición del paciente, la experiencia del cirujano y los recursos disponibles.

Palabras clave: Fractura intertrocantérica; clavo femoral proximal; PFNA; tornillo dinámico de cadera; *umbrella review*; metanálisis.

Nivel de Evidencia: I

INTRODUCTION

Intertrochanteric hip fractures are among the most common injuries in older adults and are associated with functional decline, increased morbidity and mortality, and substantial healthcare resource use. Surgical treatment aims to provide stable fixation that allows early mobilization, reduces complications associated with bed rest, and supports functional recovery.

The two most widely used devices are the dynamic hip screw (DHS), an extramedullary system long considered the standard treatment, and the proximal femoral nail antirotation (PFNA), an intramedullary system that offers greater biomechanical stability, particularly in unstable fractures.

Since 2013, several systematic reviews with meta-analyses have directly compared PFNA with DHS.¹⁻¹⁰ These reviews consistently report perioperative benefits with PFNA, including shorter operative time and lower blood loss, attributed to its minimally invasive approach. However, long-term functional outcomes, usually assessed using the *Harris Hip Score* (HHS), and major complications are generally similar between the two implants. Some reviews favor PFNA for unstable fractures, particularly because of a lower tendency toward cut-out, varus collapse, or mechanical failure. In stable fractures, outcomes appear equivalent.

The available evidence is spread across systematic reviews that differ to some extent in their populations, eligibility criteria, outcomes, and methods. This umbrella review aims to bring these findings together and provide a clinical interpretation that can guide implant selection for intertrochanteric hip fractures.

MATERIALS AND METHODS

This umbrella review of systematic reviews followed the recommendations of the PRISMA 2020 statement adapted for reviews of reviews and Chapter V of the *Cochrane Handbook for Systematic Reviews of Interventions*, which addresses overviews of reviews.^{11,12} The protocol was registered in PROSPERO [CRD420251182097].

The research question was structured using the PICO framework:

Population: Adults with stable or unstable intertrochanteric femoral fractures classified as AO/OTA 31-A1 to 31-A3.

Intervention: Intramedullary fixation with PFNA or variants of proximal femoral nails.

Comparison: Extramedullary fixation with DHS.

Primary Outcomes: Operative time, intraoperative blood loss, long-term function, preferably assessed using the HHS, and major complications such as cut-out, reoperation, peri-implant fracture, deep infection, or non-union.

Secondary Outcomes: Length of hospital stay, time to full weight-bearing, minor complications, and mortality.

Systematic reviews with conventional or network meta-analyses were included if they directly compared PFNA or variants of proximal femoral nails with DHS and reported at least one primary outcome. Eligible reviews had to document systematic methods, searches of at least two databases, and an assessment of the risk of bias or quality of the included studies.

We excluded reviews without a direct comparison between PFNA and DHS, narrative reviews without a meta-analysis or structured synthesis, studies focused exclusively on other implants or populations outside the scope of the review, and publications with insufficient information for analysis.

Reviews were identified from the documents available for analysis. Duplicates, methods, included populations, comparisons, and reported outcomes were checked manually. Ten systematic reviews published between 2013 and 2025 were ultimately included, nine of which contained a meta-analysis.

The methodological quality of the included reviews was assessed qualitatively, considering the comprehensiveness of the search, duplicate study selection or data extraction, risk-of-bias assessment, handling of heterogeneity, and transparency of the synthesis.¹³

Two reviewers independently extracted the following data: authors, publication year, review type, number of primary studies, approximate number of patients, fracture types included, reported outcomes, and main conclusions. Because of methodological heterogeneity and partial overlap among primary studies, we used a qualitative narrative synthesis with summary tables. No new quantitative meta-analysis was performed, to avoid double-counting patients or studies included in more than one review.

RESULTS

Characteristics of the Included Reviews

The 10 included reviews brought together data from 186 studies and more than 12,000 patients in total, with partial overlap across publications. Most included both stable and unstable mixed intertrochanteric fractures, although some analyzed these fracture types separately. Table 1 summarizes the main characteristics of the included reviews.

Table 1. Characteristics of the included systematic reviews. Level of evidence 1

Ref.	Authors (year)	Review type	Primary studies (n)	Total patients (n)	Fracture types	Main outcomes reported	Main conclusion regarding PFNA vs. DHS
1	Shen et al. (2013)	Conventional meta-analysis	5 RCTs	~500	Mixed	Operative time, blood loss, complications	PFNA: lower blood loss and fewer complications
2	Zhang et al. (2014)	Conventional meta-analysis	6 RCTs	669	Mixed	Operative time, blood loss, incision length	PFN: shorter operative time, lower blood loss, and shorter incision
3	Yuan et al. (2014)	Conventional meta-analysis	17 RCTs	1,344	Mixed (older adults)	Fixation failure, HHS, healing time	PFNA superior for fixation failure, healing, and function
4	Arirachakaran et al. (2017)	Network meta-analysis	36 RCTs	~3,000	Mixed (older adults)	Operative time, blood loss, complications	PFN: lower blood loss and shorter hospital stay
5	Hao et al. (2018)	Network meta-analysis	24 RCTs	3,097	Mixed	Blood loss, operative time	PFNA: lower blood loss and shorter operative time
6	Cheng and Sheng (2020)	Network meta-analysis	36 RCTs	~4,000	Mixed	Blood loss, HHS, complications	PFNA optimal (lower blood loss, higher HHS)
7	Xu et al. (2022)	Conventional meta-analysis	12 RCTs	1,889	Mixed	Operative time, blood loss, complications	PFN: shorter operative time and lower blood loss; similar complications
8	Zhang et al. (2023)	Conventional meta-analysis	17 (RCTs + observational studies)	~2,600	Unstable	HHS, healing time, complications	PFNA superior across multiple clinical outcomes
9	Mustamsir et al. (2024)	Conventional meta-analysis	10 (RCTs + observational studies)	1,149	Stable (A1)	Operative time, blood loss, HHS, complications	PFNA: better perioperative outcomes; similar long-term outcomes
10	Musa et al. (2025)	Systematic review	~23	~1,500	Stable	HHS, mobilization, complications	PFN: early advantages; similar costs and complications

RCT = randomized controlled trial; HHS = Harris Hip Score; PFNA = proximal femoral nail antirotation; PFN = proximal femoral nail; DHS = dynamic hip screw.

Assessment of Methodological Quality

The methodological quality of the reviews was generally moderate to high. Their main strengths were searches across multiple databases, the inclusion of randomized controlled trials or comparative studies, and the assessment of clinically relevant outcomes. The most common limitations were heterogeneity among primary studies, differences in fracture classification, overlap among studies included in different reviews, and the limited representativeness of some populations.

Summary of Findings

The reviews consistently reported perioperative advantages with PFNA or proximal femoral nails. Eight of the 10 reviews found shorter operative times with these devices, with approximate mean differences of 18-21 minutes. Nine of the 10 reported lower intraoperative blood loss, with approximate reductions of 89-250 mL. Some reviews also reported lower transfusion requirements, smaller incisions, and shorter hospital stays.

For functional outcomes, most reviews found no significant long-term differences between PFNA and DHS. HHS values were similar in most analyses, suggesting functional equivalence beyond the early postoperative period.

No consistent differences were observed between the two implants in major complications, including cut-out, reoperation, deep infection, nonunion, or mortality. However, PFNA showed a lower tendency toward varus collapse, shortening, limb length discrepancy, and fixation failure, particularly in unstable fractures.

Subgroup analysis suggests that fracture stability is a key factor in implant selection. In unstable fractures, PFNA showed biomechanical advantages and a lower risk of mechanical failure. In stable fractures, both devices achieved similar outcomes, although PFNA retained some perioperative advantages.

Overall, the evidence favors PFNA for perioperative outcomes and unstable fractures, while long-term safety and function appear comparable to those of DHS (Table 2).

DISCUSSION

The main findings of this umbrella review show that PFNA offers perioperative advantages over DHS. PFNA is associated with shorter operative time and lower intraoperative blood loss, without appearing to compromise long-term functional outcomes or increase major complications.

These advantages may be explained by the less invasive technique and intramedullary design of PFNA, which require less soft-tissue dissection than the more extensive approach used for DHS. The benefit was particularly evident in the included network meta-analyses, where PFNA ranked more favorably for operative time and blood loss.⁴⁻⁶ Reducing operative time by 15-30 minutes and blood loss by 89-250 mL may be clinically important in older or frail patients and those with cardiovascular comorbidities, preoperative anemia, or high anesthetic risk.

For functional outcomes, the available evidence shows similar long-term HHS results. This is consistent with the biomechanical principles of each device: DHS provides good compression in stable fractures, whereas PFNA offers greater rotational and axial stability in unstable fractures.^{9,10} Several studies also favor PFNA for early mobilization and weight-bearing in patients with unstable fractures, which may allow faster rehabilitation and shorter hospital stays.

No consistent significant differences were found between the two groups in cut-out, reoperation, deep infection, nonunion, or mortality. PFNA showed a lower tendency toward varus collapse and shortening, particularly in unstable fractures, where its intramedullary design provides better control of axial loading.^{3,8}

Subgroup analyses by fracture type help inform clinical practice. In unstable fractures, classified as AO/OTA 31-A2 and 31-A3, PFNA showed advantages in stability and a lower risk of mechanical failure. In stable fractures, classified as AO/OTA 31-A1, both devices achieved similar results. The choice may therefore depend on surgeon experience, implant availability, cost, and preference for a less invasive approach.^{9,10}

Table 2. Summary of outcomes comparing PFNA and DHS. Level of evidence 1

Outcome	Number of reviews reporting the outcome	Overall trend (favors PFNA/PFN, favors DHS, or similar)	Key evidence	Comment
Operative time	8/10	Favors PFNA/PFN (7/8)	MD of –18 to –21 min ($p < 0.01$ in most analyses); high ranking in network meta-analyses	Consistent advantage attributable to the minimally invasive approach
Intraoperative blood loss	9/10	Favors PFNA/PFN (8/9)	MD of –89 to –250 mL ($p \leq 0.01$); fewer transfusions; high SUCRA in the network meta-analysis	Clinically relevant benefit; higher ranking in the network meta-analysis
Length of hospital stay	3/10	Favors PFNA/PFN (3/3)	Mean of ~7–8 vs. 12 days in some reviews; shorter with PFNA	Reported in fewer reviews; perioperative advantage
Long-term Harris Hip Score (≥ 6 –12 months)	5/10	Similar (4/5)	MD of 0 to +7 points (not significant in most analyses); high SUCRA in the network meta-analysis	Long-term functional equivalence
Early mobilization/weight-bearing	3/10	Favors PFNA/PFN (3/3)	Earlier full weight-bearing; better outcomes in unstable fractures	Early advantage, particularly in unstable fractures
Major complications (cut-out, reoperation, infection)	10/10	Similar (9/10)	OR 0.4–1.2 (not significant in most analyses); similar nonunion and mortality	Equivalent safety profile
Varus collapse/shortening/fixation failure	3/10	Favors PFNA/PFN (3/3)	OR ~0.4 for coxa vara; fewer failures in unstable fractures	Greater biomechanical stability with PFNA, particularly in unstable fractures
Complications by subgroup	3/10	Favors PFNA in unstable fractures (3/3); similar in stable fractures (2/2)	Fewer mechanical failures in unstable fractures; comparable outcomes in stable fractures	Key difference according to fracture stability

MD = mean difference; OR = odds ratio; SUCRA = surface under the cumulative ranking curve; PFNA = proximal femoral nail antirotation; PFN = proximal femoral nail; DHS = dynamic hip screw.

The strengths of this review include the synthesis of recent systematic reviews and meta-analyses, the direct comparison of two widely used implants, and the practical interpretation of findings according to fracture stability. The decision not to perform a new quantitative meta-analysis also avoids double-counting caused by overlap among primary studies.

The main limitations are moderate overlap among primary studies, heterogeneity in outcome definitions, differences in fracture classification, and methodological variability across reviews. Other considerations include the limited representation of some populations and the scarcity of studies with long-term follow-up, cost-effectiveness analyses, and patient-reported outcomes.

Clinical Implications and Future Research

In clinical practice, PFNA appears preferable for unstable fractures and for older patients or those at greater perioperative risk, whereas DHS remains a valid option for stable fractures. In all cases, adequate reduction, early surgery, and early rehabilitation are key determinants of outcome.

Future research should include multicenter trials with longer follow-up, economic analyses, subgroups defined by fracture stability, evaluation of newer implant versions, and patient-reported outcomes.

CONCLUSIONS

PFNA offers perioperative advantages over DHS in the treatment of intertrochanteric hip fractures, chiefly shorter operative time, lower blood loss, and reduced transfusion requirements.

In unstable fractures, PFNA provides greater stability and a lower risk of mechanical failure. In stable fractures, both implants yield similar outcomes, although PFNA retains benefits in the immediate postoperative period.

PFNA may therefore be considered the preferred option for older patients, unstable fractures, and situations involving greater perioperative risk. DHS remains an acceptable alternative for stable fractures, depending on the clinical, technical, and economic context.

Recommendations

For unstable intertrochanteric fractures and older patients at high surgical risk, PFNA should be considered the first option when it is available and the surgical team has experience with its use.

For stable fractures, both PFNA and DHS are acceptable options. The choice should be individualized according to the fracture pattern, surgeon experience, implant availability, and institutional resources.

In all cases, surgery should be performed early, adequate reduction achieved, and rehabilitation started as soon as possible.

Use of Artificial Intelligence

During the preparation of this work, the authors used GROK to organize tables and synthesize information. They then reviewed and edited the content as needed and take full responsibility for the content of the manuscript.

Conflicts of interest: The authors declare no conflicts of interest.

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Mid-Flexion Instability in Total Knee Arthroplasty: A Systematic Review of Risk Factors, Diagnosis, and Strategies

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ABSTRACT

Objective: To critically evaluate the available evidence on mid-flexion instability (MFI) following total knee arthroplasty (TKA), its recognition as a distinct clinical entity, associated risk factors, diagnostic considerations, and preventive strategies. **Materials and Methods:** A systematic search of PubMed, Embase, Scopus, and the Cochrane Library was conducted through May 2025 in accordance with PRISMA guidelines. Clinical and biomechanical studies specifically evaluating MFI following TKA were included. **Results:** Thirteen studies met the inclusion criteria. The factors most consistently associated with MFI were anteroposterior translation ≥ 7 mm at 30° of flexion, changes in posterior condylar offset >2 mm, joint line elevation ≥ 4 mm, and preoperative ligamentous laxity. Medially stabilized implants provided greater mid-flexion stability than posterior-stabilized designs in the available randomized controlled trial. Surgical techniques aimed at optimizing ligament balance, particularly flexion-first balancing approaches, were associated with reduced mid-flexion laxity. However, considerable heterogeneity persists in the definition of MFI. **Conclusions:** The available evidence supports MFI as a distinct clinical entity with a multifactorial etiology. Prevention requires preserving the joint line and femoral geometry, optimizing ligament balance, selecting an appropriate implant design, and systematically assessing intraoperative stability between 30° and 60° of flexion. Higher-quality studies are needed to establish standardized diagnostic criteria and determine the true incidence of MFI.

Keywords: Total knee arthroplasty; mid-flexion instability; risk factors; implant design; surgical technique; robot-assisted surgery.

Level of Evidence: III

Inestabilidad en flexión media en la artroplastia total de rodilla: revisión sistemática de factores de riesgo, diagnóstico y estrategias

RESUMEN

Objetivo: Evaluar críticamente la evidencia disponible sobre la inestabilidad en media flexión (IMF) tras la artroplastia total de rodilla (ATR), su reconocimiento como una entidad clínica diferenciada, los factores de riesgo asociados, las consideraciones diagnósticas y las estrategias preventivas. **Materiales y Métodos:** Se realizó una búsqueda sistemática en PubMed, Embase, Scopus y Cochrane Library hasta mayo de 2025, según las directrices PRISMA. Se incluyeron estudios clínicos y biomecánicos que evaluaran específicamente la IMF tras la ATR. **Resultados:** Trece cumplieron los criterios de inclusión. Los factores asociados de manera más consistente con la IMF fueron una traslación anteroposterior ≥ 7 mm a 30° de flexión, alteraciones del *offset* condíleo posterior >2 mm, elevación de la línea articular ≥ 4 mm y laxitud ligamentaria preoperatoria. Los implantes con estabilización medial tuvieron más estabilidad en media flexión que los diseños posteroestabilizados en el ensayo clínico aleatorizado disponible. Las técnicas quirúrgicas destinadas a optimizar el balance ligamentario, particularmente los enfoques de balance de flexión primero (*flexion-first balancing*), se asociaron con una menor laxitud en media flexión. Sin embargo, persiste una considerable heterogeneidad en la definición de IMF. **Conclusiones:** La evidencia disponible respalda la IMF como una entidad clínica diferenciada y de etiología multifactorial. Su prevención requiere preservar la línea articular y la geometría femoral, optimizar el balance ligamentario, seleccionar adecuadamente el diseño de la prótesis y evaluar sistemáticamente la estabilidad intraoperatoria entre

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How to cite this article: Martínez WF, Bochaty E, Lopreite F. Mid-Flexion Instability in Total Knee Arthroplasty: A Systematic Review of Risk Factors, Diagnosis, and Strategies. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):455-466. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2274>

30° y 60° de flexión. Se necesitan estudios de mayor calidad para establecer criterios diagnósticos estandarizados y determinar la verdadera incidencia de la IMF.

Palabras clave: Artroplastia total de rodilla; inestabilidad en media flexión; factores de riesgo; diseño protésico; técnica quirúrgica; cirugía robótica asistida.

Nivel de Evidencia: III

INTRODUCTION

Instability after total knee arthroplasty (TKA) is one of the most common complications of joint replacement surgery, accounting for 10%–22% of all revisions.^{1,2} Traditionally, it has been classified as flexion, extension, recurvatum, or global instability, depending on the range of motion affected.^{3–5} In recent decades, however, mid-flexion instability (MFI) has emerged as a potentially distinct entity, characterized by symptomatic laxity at intermediate flexion angles (30°–60°), with preserved stability in full extension and deep flexion.^{6,7}

The concept of MFI originated in a cadaveric study by Martin and Whiteside, who observed increased laxity at intermediate flexion angles after elevation of the joint line.⁸ Since then, the phenomenon has gradually gained recognition in the orthopedic literature, although its clinical definition, relevance, and status as a distinct entity remain subjects of debate.⁹

MFI is primarily attributed to ligamentous incompetence in the mid-range of motion, often associated with changes in joint line height, preoperative ligamentous laxity, alterations in posterior condylar offset, and imbalances between the flexion and extension gaps.^{10–14} Patients may report a sense of instability, pain, or recurrent joint effusions, particularly during functional activities such as descending stairs or walking on slopes.¹²

Although some authors consider MFI simply a variant of flexion instability,⁹ others have documented it as a reproducible phenomenon with specific clinical implications.^{15,16} Despite growing interest, the available evidence remains fragmented, with no clear consensus on its pathophysiology, diagnosis, or optimal management. This systematic review aims to critically evaluate the available evidence on MFI after TKA, including the risk factors, diagnostic methods, and preventive strategies described in the medical literature, to clarify its clinical relevance and guide future research.

MATERIALS AND METHODS

Study design and methodological framework

A systematic review of the medical literature was conducted in accordance with the PRISMA 2020 (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) guidelines. Given the emerging nature of the MFI concept and the anticipated heterogeneity of the included study designs, a structured narrative synthesis without quantitative meta-analysis was planned from the outset.

The review protocol was not registered in PROSPERO because the primary aim was to explore a clinical syndrome that remains controversial and poorly standardized, drawing on both clinical and biomechanical evidence. This was considered to extend beyond the usual scope of reviews focused on comparative clinical interventions. Nevertheless, the methodology was defined *a priori* and applied systematically.

Information sources and search strategy

A systematic search was conducted in PubMed/MEDLINE, Embase, Scopus, and the Cochrane Library, from the inception of each database to May 31, 2025.

The search strategy combined controlled vocabulary terms (MeSH and Emtree, where applicable) with free-text keywords, adapted to the syntax of each database. The general Boolean structure was: (“total knee arthroplasty” OR “total knee replacement” OR TKA) AND (“mid-flexion instability” OR “midflexion instability” OR “mid-range instability” OR “mid range instability”) AND (instability OR “knee instability” OR “instability after TKA”).

Filters for English-language publications and human studies were applied where supported by each database. The reference lists of included studies were also searched manually (*snowballing*) to identify additional relevant literature not retrieved in the initial electronic search.

Operational definition of MFI

For eligibility purposes, MFI was defined as symptomatic laxity identified clinically, through instrumented assessment, or intraoperatively, occurring predominantly between 30° and 60° of flexion, with relative stability preserved in full extension (0°) and deep flexion (~90°). Laxity had to be reported in at least one plane of motion (coronal, sagittal, or axial).

Because no single diagnostic test or universally accepted criteria exist for MFI, definitions based on clinical assessment, physical examination, instrumented measurements, biomechanical models, or intraoperative confirmation were accepted, provided that the study explicitly stated the mid-flexion range assessed.

Inclusion criteria

Studies meeting all the following criteria were included:

- Randomized clinical trials, observational studies (cohort or case-control studies), or consecutive case series with more than 10 patients that specifically evaluated MFI after TKA.
- Biomechanical, cadaveric, *in vitro*, or computational studies that explicitly analyzed MFI as an independent phenomenon.
- Studies describing risk factors, pathophysiological mechanisms, diagnostic methods, or preventive strategies related to MFI.
- Articles published in English in peer-reviewed journals.

Exclusion criteria

The following exclusion criteria were applied:

- Individual case reports, letters to the editor, editorials, and technical notes without original data.
- Animal studies.
- Studies addressing only flexion or extension instability without specific reference to MFI.
- Gray literature (conference abstracts and unpublished theses).
- Systematic or narrative reviews, which were used only as secondary sources to identify references and were not included as primary studies.

Study selection

Two independent reviewers selected studies in three stages: 1) title and abstract screening, 2) full-text assessment of potentially eligible studies, and 3) final inclusion according to the predefined criteria.

Disagreements were resolved by consensus, with a third reviewer consulted when necessary. References were managed and duplicates removed using Zotero®, while screening was performed using Rayyan®.

Data extraction

Two reviewers independently extracted data using a standardized form. The following variables were collected: 1) author and year of publication, 2) study design and sample size, 3) implant type and prosthetic design evaluated, 4) MFI definition and diagnostic method, 5) risk factors analyzed, 6) clinical, radiographic, biomechanical, or instrumented outcomes, and 7) reported preventive strategies or surgical considerations.

Risk of bias and level of evidence assessment

Risk of bias was assessed according to study design:

- The Cochrane Risk of Bias 2 (RoB 2) tool was used for randomized clinical trials.
- ROBINS-I was used for comparative observational studies.
- The MINORS instrument was used for nonrandomized, noncomparative studies because no specific tools were available for these designs (Figure 1).

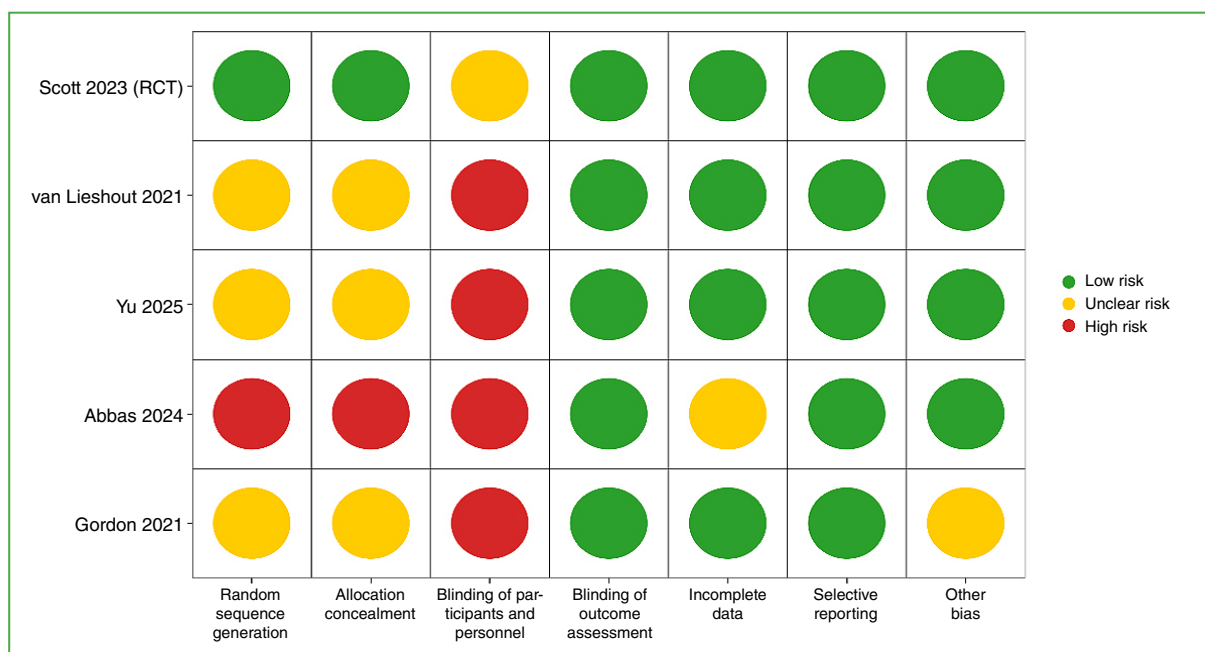


Figure 1. Risk of bias assessment of the included clinical studies, presented as a traffic light plot. Risk of bias domains were harmonized to allow randomized and nonrandomized studies to be assessed together. The Cochrane RoB 2 tool was used for the randomized clinical trial, and ROBINS-I/MINORS for observational studies, as appropriate. The plot does not include biomechanical, cadaveric, or computational studies.

- Biomechanical, cadaveric, and computational studies underwent a predefined qualitative assessment focusing on model validity, reproducibility, and the extent of experimental validation, as no universally accepted tool exists for these designs.

The level of evidence was also reported according to the *Oxford Centre for Evidence-Based Medicine* (OCEBM) classification, but was not used as a substitute for risk of bias assessment (Table).

Synthesis of results

Because study designs, MFI definitions, diagnostic methods, and reported outcomes varied substantially, a quantitative meta-analysis was not possible. A structured narrative synthesis was therefore conducted, with findings organized into the following domains:

1. Evidence on the existence and definition of MFI.
2. Biomechanical and surgical risk factors.
3. Clinical, instrumented, and intraoperative diagnostic methods.
4. Preventive strategies, surgical techniques, and assistive technologies.

Areas of agreement and disagreement between clinical and biomechanical studies were highlighted, along with the main methodological limitations.

Level of evidence of the review

According to the OCEBM classification, this systematic review provides level III evidence, as most included studies were observational, biomechanical, or experimental, with only one randomized clinical trial available.

Table. Methodological quality and level of evidence assessment of the included studies.

Author (year)	Study type	Level of evidence (OCEBM)*	Quality/risk of bias assessment	Comments/limitations
Scott and Hellie ¹⁷ (2023)	Randomized clinical trial	Level II (1b)	RoB 2: low–moderate risk	Potentially incomplete blinding; limited sample size
van Lieshout et al. ¹⁹ (2020)	Prospective observational study	Level III (2b)	ROBINS-I: moderate risk	Nonrandomized design; potential residual confounding
Abbas et al. ¹⁴ (2024)	Case series	Level IV (4)	MINORS: 14/24 (moderate quality)	Small sample size; no control group
Yu et al. ¹⁸ (2024)	Observational case series	Level III (2b)	MINORS: 15/24 (moderate quality)	Limited follow-up; clinical heterogeneity
Gordon et al. ²⁰ (2021)	Prospective consecutive series (robotics + sensor)	Level IV (4)	MINORS: 16/24 (moderate–high quality)	No comparison group; potential selection bias
Wang et al. ²³ (2008)	Bilateral comparative biomechanical study	Level V	Structured qualitative assessment	Very small sample (n = 8); no clinical correlation
Stoddard et al. ²⁴ (2013)	Comparative <i>in vitro</i> study	Level V	Structured qualitative assessment	Simplified experimental model; does not reproduce <i>in vivo</i> conditions
Incavo et al. ²⁵ (2013)	Comparative cadaveric biomechanical study	Level V	Structured qualitative assessment	Limited clinical extrapolation; small number of specimens
Luyckx et al. ²⁶ (2018)	Experimental cadaveric study + analytical model	Level V	Structured qualitative assessment	Experimental design; no direct clinical validation
Shalhoub et al. ²⁷ (2018)	Robotic cadaveric study (gap balancing)	Level V	Structured qualitative assessment	Highly controlled conditions; indirect clinical applicability
Chalmers et al. ¹⁶ (2021)	Experimental cadaveric study + analytical model	Level V	Structured qualitative assessment	Model-dependent results; no clinical correlation
Cross et al. ¹⁵ (2012)	Robotic cadaveric study	Level V	Structured qualitative assessment	Model does not fully reproduce physiological conditions; no clinical data
Elmasry et al. ²⁸ (2022)	Computational study (biomechanical modeling)	Level V	Structured qualitative assessment	Theoretical model; limited clinical validation

*Because no universally accepted tool exists for assessing the methodological quality of biomechanical, cadaveric, or computational studies, these studies were classified as level V evidence and assessed qualitatively using a structured approach focused on model validity, reproducibility, and clinical applicability.

RESULTS

Study selection

The systematic search of electronic databases (PubMed, Embase, Scopus, and the Cochrane Library) identified 124 records. After removing 23 duplicates, 101 unique articles remained for initial assessment. Of these, 41 underwent formal title and abstract screening, while 60 were excluded at this stage because they were unrelated to the review topic or did not report specific data on MFI.

The 41 selected articles were assessed in full text. Twenty-eight were excluded because they did not meet the predefined eligibility criteria, mainly because they were systematic or narrative reviews, provided no primary data on MFI, used ineligible study designs, or reported overlapping results. Ultimately, 13 studies met all inclusion criteria and were included in the qualitative synthesis. The selection process is summarized in the PRISMA flow diagram (Figure 2).

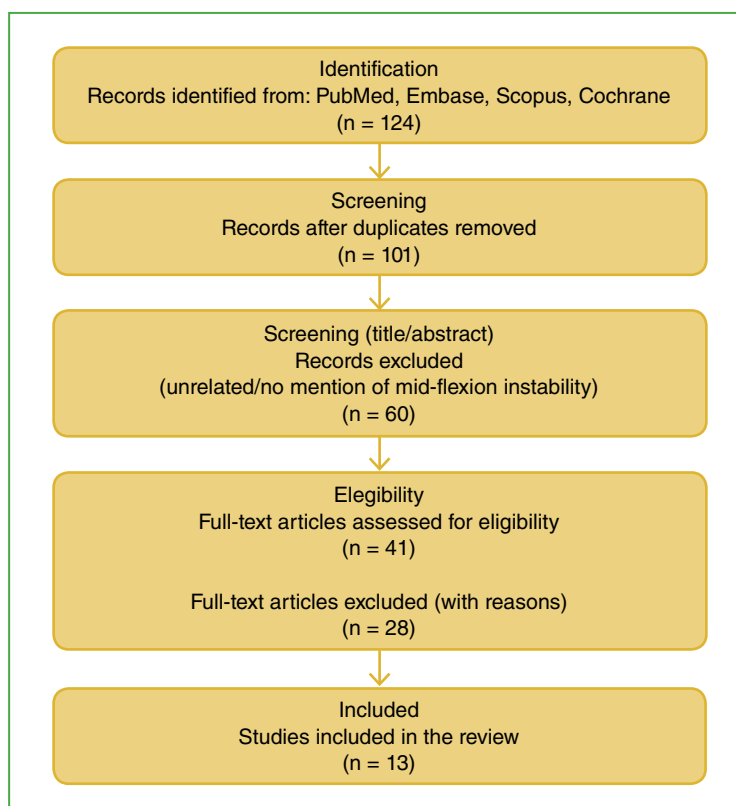


Figure 2. PRISMA 2020 flow diagram.

General characteristics of the included studies

The 13 included studies, published between 2008 and 2025, investigated MFI after TKA using clinical, biomechanical, cadaveric, robotic, and computational designs. According to the OCEBM classification, most provided level IV or V evidence. Only one randomized clinical trial was identified (Scott et al.).¹⁷

From a clinical point of view, the studies by Scott et al.,¹⁷ Yu et al.,¹⁸ van Lieshout et al.,¹⁹ Abbas et al.¹⁴ and Gordon et al.²⁰ evaluated surgical factors, balancing techniques, and assistive technologies in cohorts of patients undergoing TKA. Experimental and biomechanical studies also examined how prosthetic design, the joint line, and ligament behavior influenced stability in the mid-flexion range.^{15,16,21-28}

Risk factors associated with MFI

Several clinical and experimental studies identified common risk factors for MFI. In the sagittal plane, anteroposterior translation ≥ 7 mm at 30° of flexion was identified as an independent predictor of MFI after TKA, suggesting that small variations in anterior stability may be amplified in the mid-range of motion.^{12,13}

Changes in posterior condylar offset were another relevant determinant: alterations >2 mm were associated with a significantly greater likelihood of instability, highlighting the importance of preserving native femoral geometry.¹² Biomechanical studies consistently found that joint line elevation ≥ 4 mm substantially increased mid-flexion laxity. However, some clinical studies suggested that controlled elevation of up to 2 mm could be tolerated with adequate soft tissue balancing.¹⁴⁻¹⁶

Preoperative ligamentous laxity and smaller implant size were also consistently identified as predisposing factors for MFI after TKA.¹¹

Influence of prosthetic design

Implant design was one of the most consistently evaluated determinants. In the only available randomized clinical trial, Scott et al.¹⁷ demonstrated that medially stabilized implants provided greater anteroposterior control between 30° and 60° of flexion than posterior-stabilized designs, with a more pronounced effect in female patients. Yu et al.¹⁸ reported similar findings in an observational cohort.

In a biomechanical study, Wang et al.²³ observed that single-radius designs were associated with greater anteroposterior control during functional activities such as sitting down and standing up, whereas multi-radius designs showed greater transient laxity between 30° and 45°. In contrast, Stoddard et al.,²⁴ found no significant differences between the two designs in cadaveric models and questioned whether femoral geometry alone was the main determinant of MFI.

Surgical technique and assistive technologies

Surgical technique also significantly influenced mid-flexion stability. Comparative studies found that flexion-first balancing was associated with less mid-range laxity than conventional measured resection.^{29,30}

Regarding assistive technologies, Gordon et al.²⁰ evaluated a clinical cohort undergoing robot-assisted TKA with intraoperative load sensors. They observed a measurable improvement in stability, with 87% of knees balanced throughout the range of motion, including mid-flexion. However, experimental robotic and cadaveric studies demonstrated that residual mid-range laxity of 2–4 mm persisted even with assisted planning and adequate balancing in extension and at 90° of flexion.²⁷

The computational model developed by Elmasry et al.²⁸ supported these findings, showing that more constrained inserts could reduce axial rotation without fully eliminating the coronal laxity characteristic of MFI.

Biomechanical and experimental evidence

Cadaveric and biomechanical studies provided consistent evidence of the effects of small anatomical variations. Cross et al.,¹⁵ Chalmers et al.,¹⁶ Incavo et al.²⁵ and Luyckx et al.²⁶ demonstrated that raising the joint line by just 2–4 mm significantly increased coronal laxity between 30° and 70° of flexion, even in knees adequately balanced in extension and deep flexion.

Luyckx et al.²⁶ measured a 60%–110% increase in mid-flexion coronal laxity after joint line elevation, while Shalhoub et al.²⁷ documented persistent mid-range instability in robot-assisted TKA using a gap-balancing technique. These findings suggest that MFI depends not only on prosthetic design but also on joint line height and the isometric behavior of the capsuloligamentous structures.

Overall synthesis of findings

Taken together, the included studies indicate that MFI is a multifactorial phenomenon arising from the interaction between anatomical factors, prosthetic design, surgical technique, and ligament balance. Clinical and experimental evidence consistently shows that even apparently well-balanced knees may exhibit dynamic instability between 30° and 60° of flexion. This explains the diagnostic challenges and variability in reported outcomes.

Level and quality of evidence

The overall methodological quality of the included studies was low to moderate. The only randomized clinical trial provided level II evidence,¹⁷ while observational studies were classified as level III or IV, and biomechanical, cadaveric, and computational studies as level V. MFI definitions, diagnostic methods, and assessed outcomes varied substantially across studies, limiting the feasibility of a quantitative meta-analysis.

DISCUSSION

The findings of this systematic review indicate that MFI after TKA is a reproducible and clinically relevant biomechanical phenomenon that remains underrecognized. Although some authors have questioned its existence as a distinct entity, considering it a variant of conventional flexion instability,⁹ the clinical, biomechanical, and experimental evidence reviewed here supports a specific pattern of instability characterized by symptomatic laxity predominantly between 30° and 60° of flexion, with relative stability preserved in full extension and deep flexion.

The findings support a clearly multifactorial pathophysiological model. MFI does not appear to result from a single technical error or implant design alone, but from the interaction between patient-related predisposing factors, surgical variables, and prosthetic characteristics. Preoperative ligamentous laxity, changes in posterior condylar offset >2 mm, and excessive joint line elevation (≥4 mm) emerge as critical determinants that can destabilize the knee in its most vulnerable functional range.^{12-16,26} Anteroposterior translation ≥7 mm at 30° of flexion should therefore be interpreted as a “quantifiable marker” of an underlying biomechanical imbalance rather than an isolated causal factor.

Prosthetic design plays a central role in modulating this interaction. The greater stability observed with medially stabilized implants in the only available randomized clinical trial¹⁷ and confirmed in contemporary observational studies¹⁹ may reflect their ability to reproduce more physiological kinematics, with a stable medial pivot and progressive control of lateral rotation. This explanation is consistent with earlier observations summarized in narrative and systematic reviews, which suggested biomechanical advantages of medial-pivot or highly medially congruent designs over standard posterior-stabilized (PS) designs.^{11,12,20} Similarly, cruciate-retaining prostheses combined with medially congruent inserts have been proposed to provide better mid-flexion control than conventional PS systems.³¹

Nevertheless, the biomechanical and experimental findings caution against focusing exclusively on implant geometry. Comparisons of single-radius and multi-radius designs have yielded conflicting results,^{23,24} suggesting that MFI depends not only on femoral geometry but also on how it interacts with ligament balance and restoration of joint line height. This view is consistent with previous conceptual reviews emphasizing that MFI is primarily a problem of ligament isometry rather than prosthetic design alone.^{9,10,18}

Surgical technique is therefore a key element in preventing MFI. Approaches that prioritize flexion balancing, such as flexion-first balancing, have produced more stable knees in the mid-range than conventional measured resection techniques.^{19,29} Earlier narrative reviews had already highlighted this technical principle as an important conceptual shift in modern joint replacement surgery.^{11,12} The evidence suggests that perfectly symmetrical gaps in extension and at 90° do not guarantee functional stability in mid-flexion, and that even “well-balanced” knees may exhibit clinically significant dynamic laxity.

Assistive technologies add another dimension to this issue. Clinical and experimental studies have shown that robotic surgery combined with intraoperative load sensors allows mid-flexion laxity to be quantified and reduced.^{27,28} However, the persistence of residual laxity of 2–4 mm, even in highly controlled systems, suggests an inherent anatomical and viscoelastic component that cannot be fully eliminated through technical adjustments. Computational models have supported this hypothesis, showing that greater prosthetic constraint can reduce axial rotation without eliminating the coronal laxity characteristic of MFI.²⁸ These observations agree with earlier analyses that noted the limitations of technology in compensating for subtle anatomical alterations.²⁰

These findings have important implications for clinical practice. Intraoperative stability assessment should routinely include the range between 30° and 60° of flexion, using targeted manual maneuvers or, ideally, instrumented devices. In patients considered at high risk, such as women, those with preoperative ligamentous laxity,

or those requiring extensive distal resections, choosing implants with greater inherent mid-flexion stability and avoiding standard PS designs may be justified. Robotic surgery and kinematic alignment approaches have also been proposed as promising strategies for optimizing anatomical restoration and ligament balance, although definitive clinical evidence remains limited.^{26,32-36}

The true incidence of MFI remains difficult to establish. Large national registries, such as the UK *National Joint Registry* and the *Australian Orthopaedic Association National Joint Replacement Registry*, group revisions for instability into a broad category accounting for approximately 17%–18% of all TKA revisions.^{37,38} Without a specific MFI category, its actual impact is difficult to quantify. Nevertheless, growing recognition of the phenomenon in the medical literature suggests that a substantial proportion of revisions broadly classified as “instability” may involve unrecognized MFI.

This review has several strengths, including a comprehensive and up-to-date search, adherence to PRISMA guidelines, and the integration of clinical, biomechanical, and computational evidence. However, its conclusions should be interpreted in light of important limitations: the predominance of studies providing low- to moderate-level evidence, heterogeneity in MFI definitions, and the lack of standardized diagnostic criteria. These limitations highlight the need for well-designed randomized clinical trials, clinical validation of specific diagnostic tools, and registries that recognize MFI as a distinct reason for revision. These efforts are necessary to define the true clinical impact of MFI after TKA more precisely.

CONCLUSIONS

This systematic review supports MFI as a distinct clinical entity and a potentially important cause of failure after TKA. The available evidence suggests a multifactorial etiopathogenic model in which technical factors—particularly joint line elevation >2–4 mm and changes in posterior condylar offset—combine with preoperative ligamentous laxity and an inappropriate choice of prosthetic design to produce symptomatic laxity between 30° and 60° of flexion.

Preventing MFI requires a comprehensive approach that prioritizes: 1) systematic intraoperative assessment of mid-flexion stability, ideally using instrumented tools; 2) selection of implants with greater inherent stability in this range, such as medially stabilized designs; and 3) consideration of assistive technologies, such as robotic surgery, to improve the precision of ligament balancing. Standardized diagnostic criteria and higher-quality clinical evidence are also essential to establish the true incidence of this complication and rigorously validate the proposed preventive strategies.

Use of artificial intelligence

During the preparation of this manuscript, the author(s) used ChatGPT to improve readability and language. After using this tool, they reviewed and edited the content as needed and take full responsibility for the content of the publication.

Conflicts of interest: The authors declare no conflicts of interest.

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Preoperative Use of GLP-1 Receptor Agonists and Postoperative Outcomes in Patients Undergoing Arthroplasty: A Systematic Review With Exploratory Meta-analysis

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ABSTRACT

Introduction: Arthroplasty is a common procedure in older adults with multiple comorbidities. Glucagon-like peptide-1 (GLP-1) receptor agonists are used to treat diabetes mellitus and obesity. Their preoperative use may influence postoperative outcomes in patients undergoing different types of arthroplasty, although the available evidence is inconsistent. **Objective:** To evaluate the association between preoperative use of GLP-1 receptor agonists and postoperative complications in patients undergoing arthroplasty. **Materials and Methods:** A systematic review was conducted in accordance with the PRISMA 2020 guidelines, with artificial intelligence support to optimize the search strategy for PubMed, Scopus, and Web of Science. Studies of patients undergoing hip, knee, or shoulder arthroplasty who had received GLP-1 receptor agonists preoperatively were included if they reported data on postoperative complications and hospital readmission within 90 days. An exploratory meta-analysis was performed using a random-effects model, with results expressed as odds ratios (ORs), 95% confidence intervals (CIs), and p-values. Heterogeneity was assessed using the I^2 statistic. **Results:** Four observational studies were analyzed. Preoperative use of GLP-1 receptor agonists was associated with lower odds of surgical site infection (OR, 0.48; 95% CI, 0.35–0.66; $p < 0.001$; $I^2 = 0\%$). The analysis of hospital readmission showed high heterogeneity ($I^2 = 86\%$). **Conclusions:** Preoperative use of GLP-1 receptor agonists was associated with lower odds of postoperative infection in patients undergoing arthroplasty. However, given the small number of observational studies and the heterogeneity among arthroplasty types, these findings should be interpreted with caution and considered hypothesis-generating.

Keywords: GLP-1 receptor agonist; arthroplasty; systematic review.

Level of Evidence: III

Uso preoperatorio de agonistas del receptor del GLP-1 y resultados posoperatorios en pacientes sometidos a artroplastia: revisión sistemática con metanálisis exploratorio

RESUMEN

Introducción: La artroplastia es un procedimiento frecuente en adultos mayores con múltiples comorbilidades. Los agonistas del receptor del péptido similar al glucagón tipo 1 (GLP-1) se utilizan para tratar la diabetes mellitus y la obesidad. Su administración antes de la cirugía podría influir en los resultados posoperatorios de pacientes sometidos a distintas artroplastias, aunque la evidencia disponible es inconsistente. **Objetivo:** Evaluar la asociación entre uso preoperatorio de agonistas del GLP-1 y complicaciones posoperatorias en pacientes sometidos a una artroplastia. **Materiales y Métodos:** Se realizó una revisión sistemática siguiendo la guía PRISMA 2020, con apoyo de la inteligencia artificial para optimizar la búsqueda en PubMed, Scopus y Web of Science. Se incluyeron estudios de pacientes sometidos a una artroplastia de cadera, rodilla u hombro que habían recibido agonistas del GLP-1 y tuvieron complicaciones posoperatorias y un reingreso hospitalario dentro de los 90 días. Se realizó un análisis exploratorio mediante *odds ratio* (OR), IC95%, valor p e I^2 con un modelo de efectos aleatorios. **Resultados:** Se analizaron cuatro estudios observacionales. La administración preoperatoria de agonistas del GLP-1 se asoció con menor OR de infección del sitio quirúrgico (OR 0,48; IC95% 0,35-0,66; $p < 0,001$; $I^2 = 0\%$). El reingreso hospitalario obtuvo una elevada heterogeneidad ($I^2 = 86\%$).

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How to cite this article: Rivadeneira Jurado HA, Rivadeneira Jurado EA. Preoperative Use of GLP-1 Receptor Agonists and Postoperative Outcomes in Patients Undergoing Arthroplasty: A Systematic Review With Exploratory Meta-analysis. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):467-471. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2326>

Conclusiones: El uso preoperatorio de agonistas del GLP-1 se asoció con menor OR de infección posoperatoria en pacientes sometidos a una artroplastia. Sin embargo, los pocos estudios observacionales y la heterogeneidad entre artroplastias obligan a interpretar los hallazgos con cautela, considerándolos generadores de hipótesis.

Palabras clave: Agonista del receptor GLP-1; artroplastia, revisión sistemática.

Nivel de Evidencia: III

INTRODUCTION

Arthroplasty is more commonly performed in older adults. Garabano et al. report that, of approximately 80% of hip fractures, 77% require hip arthroplasty. They also note that patients in this group are older than 70 years and have multiple comorbidities, including diabetes, hypertension, obesity, and heart failure.¹ Glucagon-like peptide-1 receptor agonists (GLP-1 agonists) have changed the management of these conditions. These drugs have improved the clinical status of this patient population, and several studies have begun to examine the effects of their preoperative use in patients undergoing hip, knee, or shoulder arthroplasty.

Some studies suggest that GLP-1 agonists reduce infectious complications and hospital readmissions.^{2,4} However, the findings are inconsistent. Recent studies of shoulder arthroplasty have reported rudimentary findings, such as no significant differences or even an increase in certain perioperative complications.^{5,6}

This study therefore aimed to analyze the available evidence on the association between preoperative GLP-1 agonist use and postoperative complications in patients undergoing arthroplasty.

MATERIALS AND METHODS

A systematic review of the medical literature was conducted in accordance with the PRISMA 2020 guidelines, with artificial intelligence (ChatGPT 5.2G) used as a supporting tool to optimize the search strategy. These tools helped identify additional terms. The authors then reviewed, adjusted, and validated the resulting search strategies before implementing them in the databases. The authors also performed study selection, data extraction, and critical appraisal of the evidence.

The literature search was conducted in several databases, including PubMed, Scopus, and Web of Science. The authors reviewed the articles and included human studies evaluating patients who underwent total hip, knee, or shoulder arthroplasty and had received GLP-1 agonists before surgery.

The inclusion criteria were observational studies in humans, patients undergoing hip, knee, or shoulder arthroplasty, preoperative GLP-1 agonist use, availability of postoperative complication data, and a control group. Control groups comprised patients who underwent the same type of arthroplasty but had not received GLP-1 agonists preoperatively. In the included studies, group comparability was addressed using strategies specific to each database, mainly matching or adjustment for clinical variables such as diabetes, obesity, comorbidities, and baseline risk. However, these adjustments were not fully consistent across studies.

The outcomes analyzed were surgical site infection or periprosthetic infection as reported in the included studies, and hospital readmission within 90 days after surgery. These outcomes were selected because they were the clinical outcomes most consistently available across the included studies and were relevant to arthroplasty. Other complications reported in individual studies were excluded from the primary meta-analysis because they were not consistently available, event definitions differed, or comparable data were lacking. A systematic review was conducted using random-effects models. Between-study heterogeneity was assessed using the I^2 statistic. Results are expressed as odds ratios (ORs) with 95% confidence intervals (95% CIs) and p values.

RESULTS

Four observational studies evaluating patients undergoing hip, knee, or shoulder arthroplasty were included (Figure 1). The studies examined different populations undergoing total hip arthroplasty, total knee arthroplasty, or shoulder arthroplasty. Control groups comprised patients who had not received GLP-1 agonists within each study, with adjustment or matching procedures specific to each database. This variability limits direct comparisons between studies and warrants interpreting the pooled analysis as exploratory.

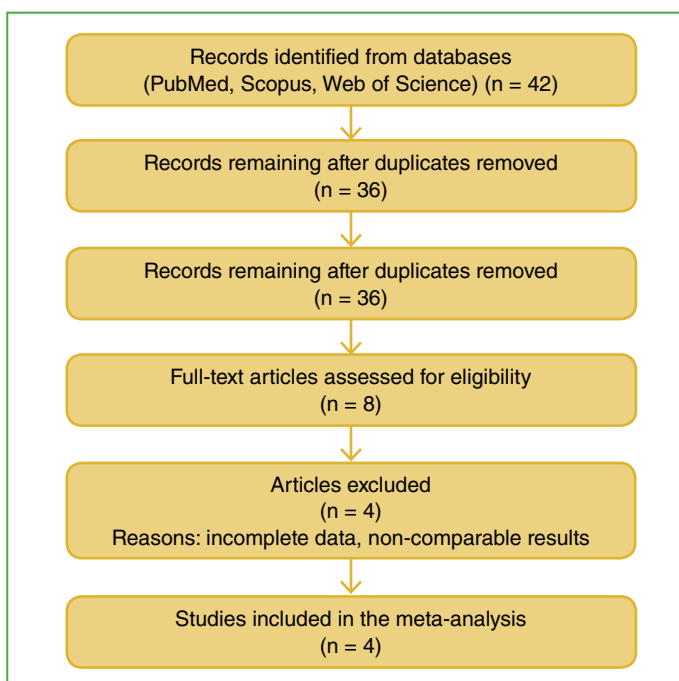


Figure 1. PRISMA flow diagram showing the identification, selection, and inclusion of studies.

The analysis showed an association between preoperative GLP-1 agonist use and lower odds of surgical site infection compared with the control group, with a pooled OR of 0.48 (95% CI 0.35–0.66; $p < 0.001$) using a random-effects model. Statistical heterogeneity was low ($I^2 = 0\%$). This finding should not be interpreted as an absolute reduction in incidence or as evidence of causality (Figure 2).

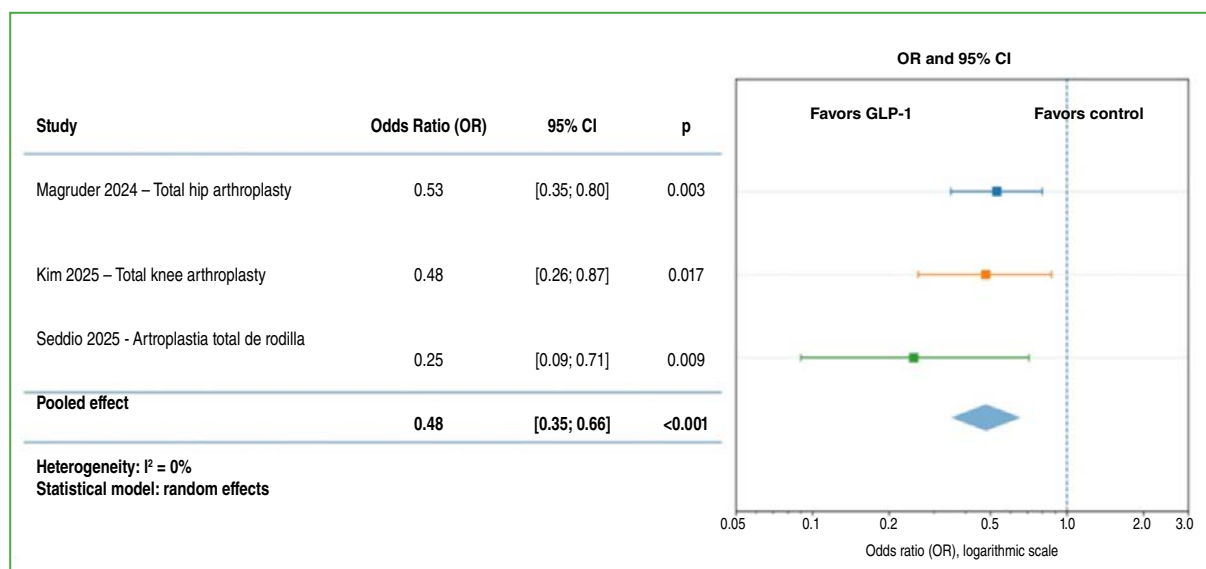


Figure 2. Forest plot of the association between preoperative GLP-1 receptor agonist use and postoperative infectious complications in patients undergoing arthroplasty. Squares represent individual study estimates, and the diamond represents the pooled effect.

For hospital readmission within 90 days after surgery, heterogeneity between studies was high ($I^2 = 86\%$). Studies of hip and knee arthroplasty reported lower odds of hospital readmission among patients treated with GLP-1 agonists, whereas studies of shoulder arthroplasty yielded more variable findings, including unfavorable results in one study. Under the random-effects model, the pooled effect estimate was an OR of 0.92 (95% CI 0.61–1.38; $p = 0.68$), which does not provide conclusive evidence of a reduction in 90-day hospital readmission (Figure 3).

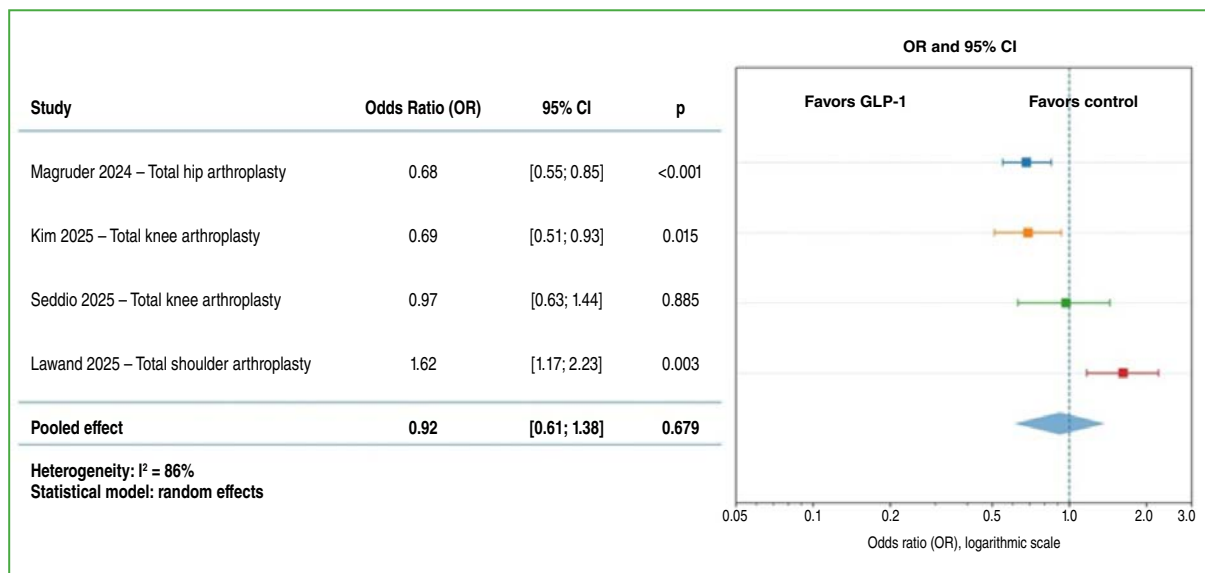


Figure 3. Forest plot of hospital readmission within 90 days after total hip, knee, or shoulder arthroplasty, comparing patients who received GLP-1 receptor agonists preoperatively with the control group. Each square represents an individual study's odds ratio (OR), shown with its 95% confidence interval. The diamond represents the pooled effect from the random-effects model (OR 0.92; 95% CI 0.61–1.38; $p = 0.68$; $I^2 = 86\%$).

DISCUSSION

The findings of this study show that preoperative GLP-1 agonist use was associated with lower odds of post-operative infection compared with the control group. Some recent studies have reported a lower frequency of periprosthetic infection and hospital readmission in patients treated with these drugs.¹ Studies such as that by Kim et al. have also reported reductions in certain surgical complications among patients with obesity receiving GLP-1 agonists who underwent knee arthroplasty.²⁻⁴ However, because these studies were observational, their findings do not establish a protective effect or causality.

The available evidence is not entirely consistent. Some studies of shoulder arthroplasty, including those by El-sabbagh et al. and Lawand et al., reported different findings, including a higher incidence of perioperative complications.^{5,6} In particular, Lawand et al. reported higher odds of complications such as myocardial infarction, pneumonia, anemia, deep vein thrombosis, and 90-day readmission among patients exposed to GLP-1 agonists. These outcomes were not included in the primary analysis because they were not consistently available across all included studies and their definitions were not comparable across populations. Differences in the populations studied, surgical procedures, patients' baseline risk, and study designs may explain these discrepancies.

This study has several limitations. The small number of included studies limits the statistical power of the meta-analysis. The evidence also consisted mainly of observational database analyses, introducing the potential for residual bias and selection bias. In addition, consistent absolute risk measures were unavailable, adjusted

analyses varied across studies, there was clinical heterogeneity between hip, knee, and shoulder arthroplasty populations, and causality could not be established. The findings should therefore be considered hypothesis-generating.

CONCLUSIONS

Preoperative GLP-1 agonist use was associated with lower odds of postoperative infection in patients undergoing arthroplasty. However, reported findings on hospital readmission differ according to the type of arthroplasty. Given the small number of available observational studies, clinical heterogeneity, and lack of consistent absolute risk measures, these findings should be interpreted cautiously and do not establish causality or support a definitive clinical recommendation.

Conflicts of interest: The authors declare no conflicts of interest.

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Induced Membrane Technique for Aseptic Recalcitrant Nonunion of the Femur: A Case Report

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ABSTRACT

In aseptic recalcitrant nonunion, failure of bone healing coexists with malalignment and limb length discrepancy. There is still no consensus on the management of these cases. We present the case of a 53-year-old man with aseptic recalcitrant nonunion of the femur treated with the induced membrane technique. He had a history of a closed fracture of the right distal femur (AO 33-A3.3) and two previous surgeries at another institution. He presented with a limb length discrepancy of 3.1 cm, 6° of varus malalignment in the coronal plane, and 8° of internal rotation. After removal of the previous implant and radical debridement, the bone defect measured 4.2 cm. Stabilization was achieved with a retrograde intramedullary nail, and the defect was filled with polymethylmethacrylate cement mixed with vancomycin. In the second stage, the cement was removed, and the defect was filled with a mixture of autograft and allograft. Bone union was confirmed six months after treatment initiation, with filling of the defect and correction of the deformities. **Conclusion:** The induced membrane technique is a viable option for treating bone defects resulting from aseptic recalcitrant nonunion of the femur.

Keywords: Nonunion; femur; aseptic; Masquelet technique.

Level of Evidence: IV

Técnica de membrana inducida para la pseudoartrosis aséptica recalcitrante de fémur. Reporte de un caso

RESUMEN

En las pseudoartrosis asépticas recalcitrantes, coexisten la ausencia de consolidación ósea, la mala alineación y la discrepancia de longitud de miembros. Aún no hay consenso sobre cómo manejar estos casos. Presentamos a un hombre de 53 años con pseudoartrosis aséptica recalcitrante de fémur tratada con la técnica de membrana inducida. Tenía antecedente de fractura cerrada del extremo distal del fémur derecho (AO33-A3.3) y dos cirugías en otro centro. Tenía una discrepancia de longitud de los miembros de 3,1 cm, mala alineación coronal en varo de 6° y rotación interna de 8°. Después de retirar el implante previo y el desbridamiento radical, el defecto óseo medía 4,2 cm. Se procedió a la estabilización con clavo endomedular retrógrado y el relleno del defecto con cemento de polimetilmetacrilato más vancomicina. En un segundo tiempo, se retiró el cemento y se relleno el defecto con mezcla de autoinjerto y aloinjerto. Se comprobó la consolidación ósea a los 6 meses del inicio del tratamiento, con relleno del defecto y corrección de las deformidades. **Conclusión:** La técnica de membrana inducida es una opción viable para tratar los defectos óseos resultantes en las pseudoartrosis asépticas recalcitrantes de fémur.

Palabras clave: Pseudoartrosis; fémur; aséptica; técnica de Masquelet.

Nivel de Evidencia: IV

INTRODUCTION

Femoral nonunion remains a challenging complication, reported in up to 10% of cases.¹ Various treatments have been described for aseptic nonunion, including decortication, revision fixation to improve stability, and bone grafting, with a union rate of 80%.²⁻⁴

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How to cite this article: Amadei R, Viollaz GM. Induced Membrane Technique for Aseptic Recalcitrant Nonunion of the Femur: A Case Report. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):472-482. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2148>

Nonunion is considered recalcitrant when surgical attempts fail to achieve union.⁵ Management is difficult because poor bone quality, bone defects, malalignment, limb length discrepancy (LLD), implant fatigue, joint stiffness, scar contractures, skin coverage defects, and infection often coexist.⁵⁻⁸ These factors cause prolonged disability, with adverse effects on social functioning, including job loss, depression, and anxiety, among other consequences. Repeated treatments also impose substantial financial costs on patients, their families, and the healthcare system.⁷⁻⁹

Although evidence on the management of recalcitrant aseptic nonunion (RAN) is limited, numerous surgical strategies have been described, and no consensus has yet been reached. Approaches that provide biological and mechanical stimulation include intramedullary canal reaming with exchange nailing, decortication and plate-and-screw fixation, vascularized bone grafting, and distraction osteogenesis, with variable clinical outcomes.⁹⁻¹³ The induced membrane technique (IMT), also known as the Masquelet technique, is a staged reconstructive procedure frequently used to treat infected bone defects.¹⁴

Since its initial description, the technique has gained popularity because of its effectiveness and reproducibility.¹⁴⁻¹⁸ In 2020, Masquelet reported its use in cases of RAN with malalignment.¹⁸ We therefore present this case to illustrate our experience with the IMT in patients with femoral RAN.



Figure 1. Clinical case: recalcitrant femoral nonunion.

CASE REPORT

A 53-year-old man had sustained a closed, extra-articular fracture of the right distal femur with diaphyseal extension and comminution (AO 33-A3.3). He had undergone two operations at another institution and presented with RAN 10 months after his last operation and 3 years after the injury. We defined nonunion as the absence of union in three of the four cortices on anteroposterior and lateral radiographs at 9 months after injury, with no radiographic progression of healing over the preceding 3 months (Figure 1).^{16,19} The nonunion was considered recalcitrant because one or more previous surgical treatments had failed.⁵

To identify any associated pathogens, laboratory testing, including acute-phase reactants, was performed on two successive occasions, and a needle bone biopsy was obtained. Five specimens were submitted for bacteriological analysis and enrichment culture for 15 days. Both investigations were negative and, according to the Weber classification,²⁰ the nonunion was classified as aseptic.²¹

A lower-limb scanogram was obtained to assess LLD. Analysis of the images using Synapse software revealed 3.1 cm of shortening of the right lower limb. Computed tomography (CT) was used to assess coronal, sagittal, and rotational alignment, revealing 6° of varus malalignment in the coronal plane and 8° of internal rotation (Figure 2).

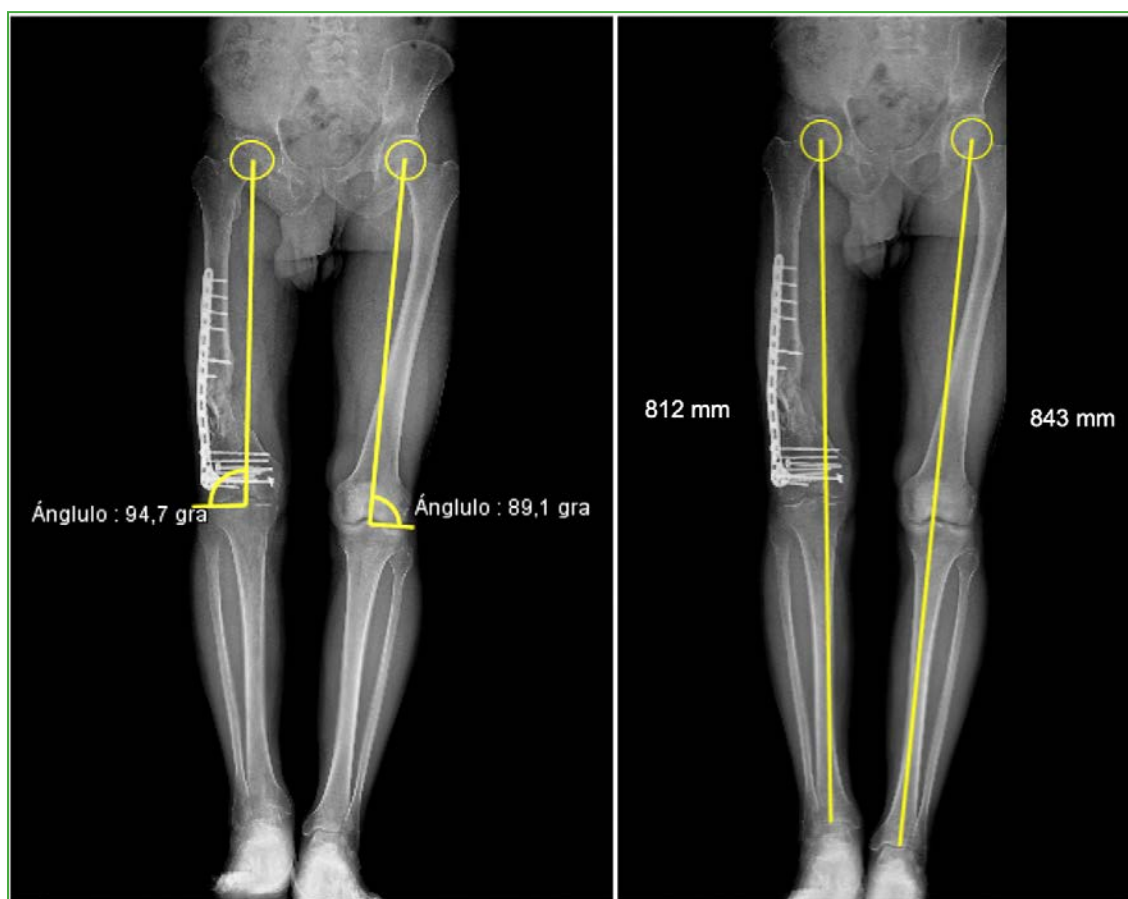


Figure 2. Lower-limb scanogram.

Malalignment and shortening were confirmed clinically ([Figure 3](#)). The assessment also included the limb's neurovascular status, the condition of the soft tissues and previous scars, and the patient's general health.



Figure 3. Limb shortening on clinical examination.

Surgical Technique

With the patient supine, the nonunion site was exposed through the previous lateral thigh incision, and the plate and screws were removed. The devitalized bone segment was resected en bloc until punctate bleeding was seen at the bone ends (paprika sign).²² No tissue findings suggested infection. Given the LLD and malalignment, the procedure was planned with the assistance of a universal femoral distractor (Synthes) ([Figure 4](#)).



Figure 4. Use of the distractor.

The bone defect measured 4.2 cm after debridement. Alignment and limb length discrepancy were corrected according to the preoperative plan using the technique described by Ganz.²³ The femur was then stabilized with a retrograde interlocking intramedullary nail (South American Implants). Five bone and soft tissue specimens were again collected for microbiological and histopathological examination. The defect was filled with two batches of polymethylmethacrylate (PMMA) bone cement, each containing 4 g of vancomycin, and the wound was carefully closed in layers (**Figure 5**). Weight bearing as tolerated was permitted immediately after the first surgical stage.



Figure 5. Radiographic result after the first stage.

The second stage was performed 8 weeks later, with no clinical or microbiological evidence of infection. The nonunion site was re-explored by opening the induced membrane, removing the PMMA spacer, and curetting the inner surface of the newly formed capsule to stimulate bleeding. Tissue specimens were again collected for bacteriological examination, and the defect was filled with autologous bone graft and allograft in a 1:1 ratio (Figures 6 y 7). The membrane was closed with absorbable sutures, followed by the remaining tissue layers. The implant was retained because it remained stable (Figure 8). Weight bearing was restricted for 30 days after the second stage, after which partial weight bearing was permitted until union was confirmed.



Figure 6. Opening of the induced membrane.

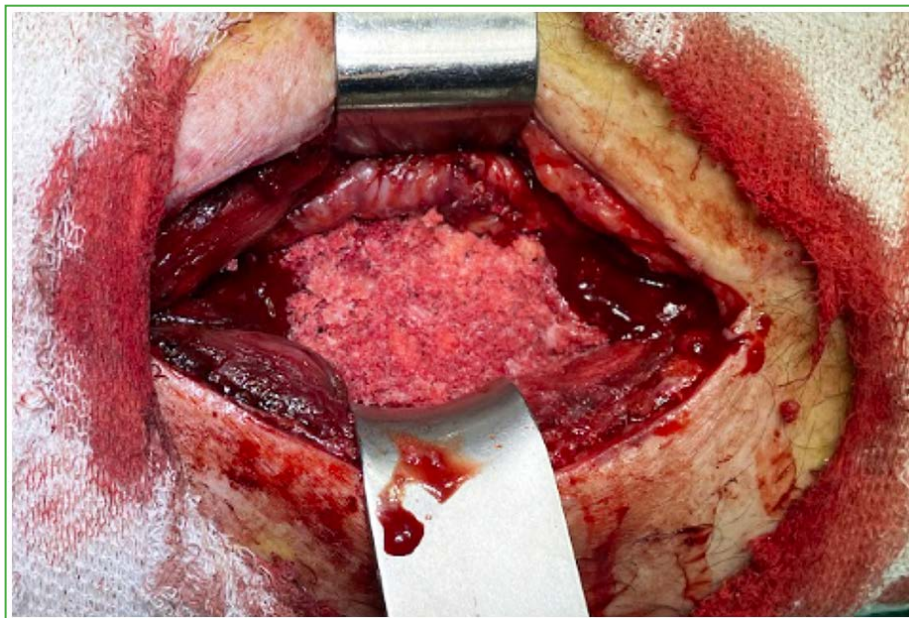


Figure 7. Filling the defect with morselized bone graft.



Figure 8. Radiographic result after the second stage.

At the final follow-up, 1 year after the last procedure, union and complete graft incorporation were observed, with complete filling of the defect. No further operations were required, and no graft resorption was observed. The LLD was partially corrected, with 1.6 cm of length restored, while coronal and rotational malalignment were fully corrected (Figure 9). The patient regained his functional status and returned to work after treatment (Figure 10).

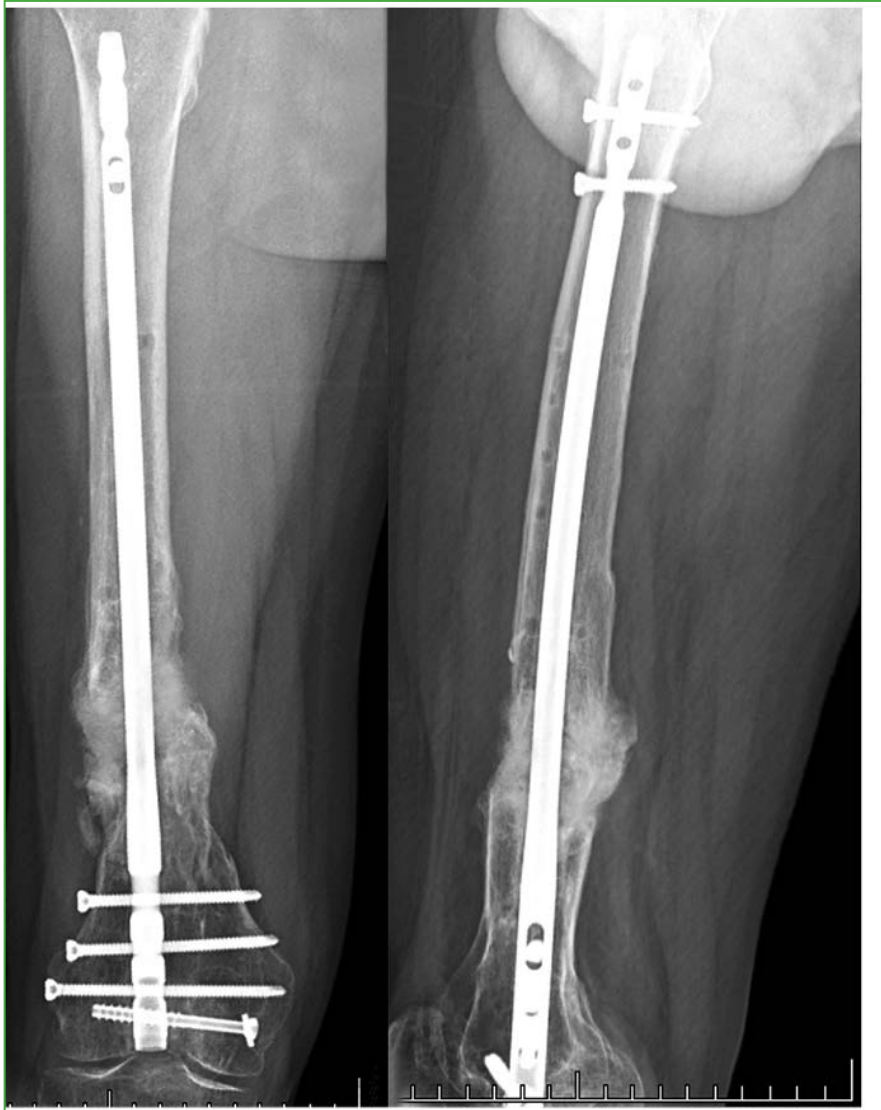


Figure 9. Final radiographic outcome.



Figure 10. Final clinical outcome.

DISCUSSION

This case illustrates a potential indication for the IMT in femoral RAN, with both bone union and correction of residual deformities achieved, as previously reported by Masquelet.¹⁵

The management of RAN remains a subject of debate. Wiss et al. analyzed 122 femoral nonunions treated with intramedullary nails or plate-and-screw fixation. The union rate was 83.6%, and the reoperation rate was 17.2%. The risk factors identified in that series were infection, smoking, metabolic disorders, and a history of three or more operations.^{24,25}

Since Masquelet first described it, the IMT has evolved to favor internal over external fixation and to incorporate antibiotics into the cement.¹⁴⁻¹⁹

In our case, an interlocking intramedullary nail was inserted during the first stage and retained thereafter, providing excellent stability while maximizing patient comfort and facilitating rehabilitation.^{26,27} Weight bearing was permitted from the outset to help maintain muscle condition and promote proprioception and joint mobility.²⁸ We added vancomycin to the cement because of concern about an undetected low-grade infection. This decision was

supported by studies that identified bacterial colonies through RNA sequencing in patients with negative bacterial cultures.²⁹ Some experimental studies also suggest that antibiotics may influence membrane thickness and vascularization,²⁹ both of which are crucial to establishing the microenvironment needed for bone healing, described by Giannoudis as a “bioreactor.”³⁰

This report illustrates another “evolution” of the IMT through its use in RAN. Supporting evidence remains limited; however, Ma reported good outcomes in 12 cases of distal femoral RAN treated with a modified three-stage IMT: 1) debridement and bone lengthening with an external fixator; 2) correction of alignment, placement of a cement spacer, and plate-and-screw fixation; and 3) replacement of the cement with bone graft within the pseudocapsule.³¹

In our case, a preliminary stage to create the space was unnecessary because we used a femoral distractor for lengthening and manipulation of the nonunion site. This allowed us to manage a 4.2-cm defect without neurovascular complications and correct the existing malalignment during the same procedure.

The main limitation of this report is the lack of scientific evidence supporting the technique. Studies with larger numbers of patients are therefore needed to corroborate this finding. Nevertheless, given the high rate of treatment failure in this condition, we believe that describing a reproducible and effective technique for managing bone defects is valuable. We therefore consider the IMT potentially effective for treating femoral RAN and encourage further investigation to provide stronger evidence supporting its use.

Conflicts of interest: The authors declare no conflicts of interest.

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Anteroinferior Hip Dislocation: A Case Report

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ABSTRACT

We report the case of a man with an anteroinferior hip dislocation who presented to the emergency department with severe pain, functional limitation, and external rotation and flexion of the left hip. Anteroposterior pelvic and lateral hip radiographs obtained during the initial evaluation confirmed the dislocation and ruled out associated fractures. An initial attempt at closed reduction in the procedure room was unsuccessful, but closed reduction was subsequently achieved under general anesthesia. A post-reduction noncontrast computed tomography (CT) scan confirmed joint congruity. **Conclusions:** Anteroinferior hip dislocation is a rare injury associated with high morbidity and requires urgent diagnosis and reduction to prevent complications such as avascular necrosis. This case underscores the need for post-reduction CT imaging, consideration of surgical management if the initial closed reduction fails, and close clinical follow-up, as time to reduction is the main prognostic factor. Early, progressive rehabilitation is essential for adequate functional recovery.

Keywords: Hip; dislocation; anterior.

Level of Evidence: IV

Luxación traumática anteroinferior de cadera: reporte de un caso

RESUMEN

Se presenta el caso clínico de un hombre con luxación anteroinferior de cadera, que acude al servicio de urgencias por dolor intenso, limitación funcional, rotación externa y flexión de la cadera izquierda. Durante la evaluación en urgencias, se tomaron radiografías anteroposterior de pelvis y lateral de cadera, que confirmaron la luxación, y se descartaron fracturas asociadas. Se intentó la reducción cerrada en la sala de procedimientos, que fue fallida, por lo cual se procedió a la reducción cerrada bajo anestesia general, con éxito. Una tomografía computarizada simple después de la reducción mostró la congruencia articular.

Conclusiones: La luxación anteroinferior de cadera es una lesión rara, pero de alta morbilidad, que requiere diagnóstico y reducción urgentes para evitar complicaciones, como la necrosis avascular. El caso presentado destaca la necesidad de realizar una tomografía computarizada después de la reducción, considerar el manejo quirúrgico si la reducción cerrada inicial falla y asegurar un seguimiento clínico riguroso, ya que el tiempo hasta la reducción es el principal factor pronóstico. La rehabilitación temprana y progresiva es clave para una recuperación funcional adecuada.

Palabras clave: Cadera; luxación; anterior.

Nivel de Evidencia: IV

INTRODUCTION

Hip dislocation is a traumatic injury in which joint congruity between the femoral head and the acetabulum is lost, compromising joint stability and function. These injuries typically result from motor vehicle collisions, falls from height, or sports-related trauma.¹

Hip dislocation is a medical emergency that requires immediate attention because of the serious associated complications, including vascular, nerve, and muscle injuries, as well as the risk of long-term posttraumatic osteoarthritis and avascular necrosis if treatment is delayed.² However, the hip joint is inherently stable owing to its bony, ligamentous, and muscular structures, and substantial force is required to dislocate it. Hip dislocations are therefore often associated with femoral head or acetabular fractures.³

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How to cite this article: Avendaño Arango VA, Londoño García R, González C, Cano MÁ. Anteroinferior Hip Dislocation: A Case Report. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):483-487. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.1924>

Hip dislocations may be classified as congenital or acquired, simple or complex, involving native or prosthetic hips, and according to the direction of dislocation.⁴

This report describes a rare case of simple anteroinferior dislocation of a native hip in a young adult. It aims to highlight this unusual clinical entity and emphasize the importance of prompt recognition and reduction, as well as timely exclusion of associated fractures.

CASE REPORT

A 23-year-old man with no comorbidities presented to the emergency department accompanied by his partner. He reported that, earlier that morning, the motorcycle he was riding had collided with a car. He stated that he had been under the influence of alcohol and psychoactive substances and could not describe the mechanism of injury to the limb.

At presentation, he reported direct trauma to the left hip, causing severe pain and restricted range of motion. On review of systems, he denied any other injuries or symptoms.

Physical examination revealed external rotation of the left lower limb and tenderness over the left hip. The hip was held in flexion, and the patient could not tolerate passive or active extension. No bruising was observed. The proximal third of the left thigh was tender to palpation, with no pain or signs of trauma elsewhere in the limb. Deep tendon reflexes in the lower limbs were intact and symmetrical. Neurovascular examination of both lower limbs was normal.

Anteroposterior pelvic and lateral left hip radiographs confirmed anterior dislocation of the left hip without associated fractures (Figure 1).



Figure 1. Anteroposterior pelvic and lateral left hip radiographs confirming anteroinferior dislocation of the left hip.

The patient was transferred to the procedure room, where closed reduction of the hip was attempted under moderate sedation but was unsuccessful. A decision was therefore made to proceed with closed reduction under general anesthesia.

During the procedure, the left hip was found to be dislocated anteriorly, with the femoral head displaced medially and entrapped within muscle tissue. Reduction was achieved after several attempts, leaving a stable hip joint with preserved flexion, extension, and rotation. A computed tomography scan of the pelvis obtained after the procedure confirmed joint congruity, with no fracture lines identified (Figure 2).

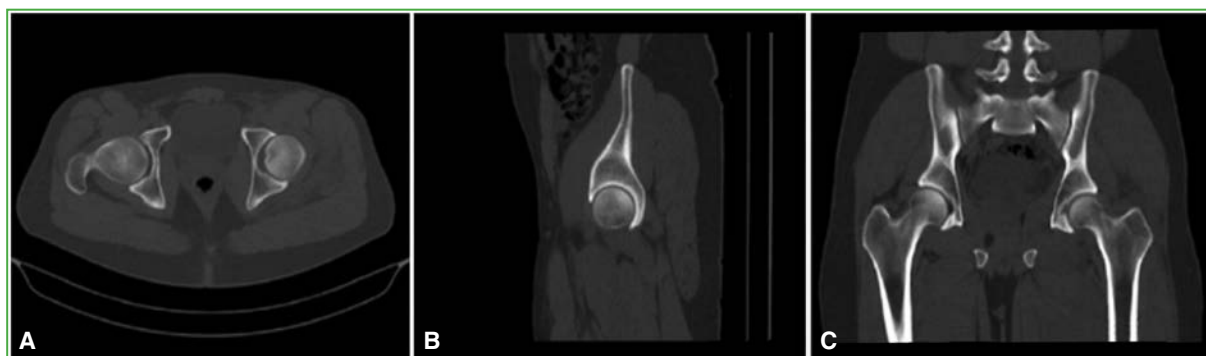


Figure 2. Axial (A), sagittal (B), and coronal (C) computed tomography images of the pelvis showing no associated acetabular or femoral head fractures and preserved joint congruity.

Physical examination ruled out neurovascular compromise. The patient was discharged with a scheduled follow-up appointment.

At outpatient follow-up, both lower limbs were well aligned, with no appreciable asymmetry. Flexion of the affected hip reached 100° , but pain prevented further movement. Hip rotation and full extension were also limited by pain. There was no evidence of a distal neurovascular deficit. Ecchymosis was noted over the posterior aspect of the right thigh, with no associated restriction of movement.

At the 6-month follow-up, the patient continued to report pain and functional limitations with movements involving full flexion and abduction of the affected hip. He reported no limitation or pain when walking and denied joint instability.

On physical examination, he walked without difficulty, both lower limbs were well aligned, and there was no bruising or deformity. Full passive flexion of the affected hip was painful, although the range of motion was unrestricted. Abduction was painful and limited to 40° because of discomfort. Extension and internal and external rotation of the affected hip were unrestricted.

DISCUSSION

Hip dislocation is relatively uncommon compared with other joint dislocations and usually results from high-energy trauma. Approximately 62–93% of hip dislocations are attributable to road traffic collisions.¹ They account for only about 5% of all traumatic dislocations; 85–90% are posterior, and the remainder are anterior or central.² Men aged 16–40 years are the most commonly affected group.

Anterior hip dislocations are associated with a 35% likelihood of concomitant bony injuries.³ They are classified as superior (pubic) or inferior (obturator), with the latter accounting for 69% of cases. Pubic dislocation involves hip abduction, extension, and external rotation, whereas obturator dislocation involves abduction, flexion, and external rotation,⁴ as occurred in our patient.

Few studies have addressed this injury because of its rarity. The largest study, conducted by Wojahn et al., included 32 patients with anterior hip dislocation. Only 22% had simple dislocations. The authors concluded that iliac dislocations are more often associated with fractures and more likely to require surgical management than obturator dislocations. Of the 16 patients followed for at least 18 months, only one required conversion to arthroplasty. The remaining 15 had favorable outcomes, with modified Harris Hip Scores >90 .⁵

Traumatic hip dislocation is a medical emergency because delayed treatment increases the risk of complications, including avascular necrosis of the femoral head, neurovascular injuries, and posttraumatic osteoarthritis.⁶ A meta-analysis by Ghalib et al. found a significant difference in the occurrence of osteonecrosis among patients treated within the first 6 hours after injury. Similarly, a meta-analysis by Kellam and Ostrum found that delaying treatment beyond 12 hours increased the risk of avascular necrosis of the femoral head 5.6-fold.⁷ In our case, reduction was performed 8 hours after presentation to the emergency department because of unsuccessful attempts at sedation and subsequent scheduling for closed reduction in the operating room.

Computed tomography is recommended after reduction to rule out associated fractures or other injuries that may require surgery.⁸ Chondral and osteochondral fragments commonly remain in the joint after reduction and may not be visible on radiographs. Computed tomography should therefore always be obtained after reduction to ensure adequate assessment, as these fragments can cause persistent subluxation.^{8,9} In our patient, computed tomography showed a congruent hip joint without fractures or other injuries. He was discharged once his pain had improved.

Early rehabilitation is advised to prevent complications. Partial weight bearing with crutches is recommended, with a gradual increase in weight bearing as tolerated. Movement should be restricted to specific angles until pain and muscle spasm allow a greater range of motion.¹⁰

Our patient was discharged with these recommendations and returned for follow-up at 2 weeks. He reported anterior thigh pain due to a soft tissue contusion. He tolerated weight bearing with crutches and retained hip flexion to 100°, although soft tissue pain limited hip extension and internal and external rotation.

At the 6-month follow-up, he was in good general health and could walk without limitation or pain. Physical examination revealed pain with full hip flexion but no restriction in this range of motion, as well as painful, restricted abduction. Magnetic resonance arthrography of the left hip was therefore requested to rule out complications.

In a study of long-term outcomes, Şahin et al. evaluated 62 patients, 57 with posterior dislocations and five with anterior dislocations. Fifty patients had undergone closed reduction, and the remainder had undergone open reduction. As in our case, partial weight bearing with crutches was permitted during recovery, with progression to full weight bearing between 2 and 10 weeks, as tolerated. Clinical and imaging follow-up over 14 years showed that 71% of patients achieved good outcomes, while 25% developed osteoarthritis or osteonecrosis. The authors concluded that time to reduction was the main factor contributing to complications.¹⁰

Traumatic anteroinferior hip dislocation is an uncommon joint dislocation, with a much lower incidence than posterior hip dislocation. Despite its rarity, early recognition and timely management are essential to prevent serious complications, such as avascular necrosis of the femoral head and posttraumatic osteoarthritis.

This case illustrates that, although closed reduction is the treatment of choice, intervention in the operating room may be necessary when initial attempts fail, particularly in the presence of soft tissue interposition. Routine computed tomography after reduction is also essential to rule out intra-articular fragments that may be missed on plain radiographs. Long-term clinical follow-up, together with a progressive rehabilitation plan, helps identify late complications and guide functional management. The medical literature reviewed consistently identifies time to reduction as the main prognostic factor. All medical personnel should therefore be aware of this orthopedic emergency, including atypical presentations such as anteroinferior dislocation.

Conflicts of interest: The authors declare no conflicts of interest.

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Failure of Femoral Neck System Fixation Due to Suboptimal Reduction in a Young Adult With a Garden Type IV Subcapital Fracture: Conversion to Total Hip Arthroplasty. A Case Report

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ABSTRACT

We report the case of a 38-year-old nonsmoking man with a body mass index of 31.1 kg/m² who sustained a low-energy Garden type IV subcapital fracture after a ground-level fall. Radiographs showed a Garden type IV fracture and a neck-shaft angle of 119°. Internal fixation with the *Femoral Neck System* was performed 12 days after injury. Postoperative radiographs revealed suboptimal reduction and off-center screw placement. At 8 months, mechanical failure, loss of fixation, nonunion, and avascular necrosis were documented. Conversion to total hip arthroplasty was performed at 18 months. One month later, the *Harris Hip Score* was 82/100, and the patient had resumed daily activities without complications. **Conclusions:** Suboptimal reduction and off-center implant placement, in the setting of delayed surgery, contributed to implant failure. Even with modern implants, the quality of anatomical reduction remains the most important determinant of successful femoral head preservation in young adults. Conversion to total hip arthroplasty is an effective salvage strategy when internal fixation fails.

Keywords: Femoral neck fracture; Femoral Neck System; suboptimal reduction; total hip arthroplasty; young adult.

Level of Evidence: IV

Fallo de la osteosíntesis con un FNS por reducción subóptima en un adulto joven con una fractura subcapital tipo IV de Garden: conversión a artroplastia total de cadera. Presentación de un caso

RESUMEN

Se presenta el caso de un hombre de 38 años, no fumador, con un índice de masa corporal de 31,1 kg/m² que sufrió una fractura subcapital tipo IV de Garden de baja energía tras una caída de propia altura. En las radiografías, se observó una fractura tipo IV de Garden y un ángulo cervicodiafisario de 119°. Se realizó una osteosíntesis con el *Femoral Neck System* a los 12 días. Las radiografías posoperatorias revelaron una reducción subóptima y una posición no central del tornillo. A los 8 meses, se documentaron fallo mecánico, desanclaje, pseudoartrosis y necrosis avascular. A los 18 meses, se realizó la conversión a artroplastia total de cadera. Al mes, el *Harris Hip Score* era de 82/100 y el paciente se reintegró a las actividades diarias sin complicaciones. **Conclusiones:** La reducción subóptima y la posición no central del implante, en un contexto de retraso quirúrgico, condicionaron el fallo del implante. Incluso con implantes modernos, la calidad de la reducción anatómica es el determinante más importante del éxito de la preservación cefálica en el adulto joven. La conversión a artroplastia total de cadera es una estrategia de rescate efectiva cuando la fijación interna fracasa.

Palabras clave: Fractura de cuello femoral; Femoral Neck System; reducción subóptima; artroplastia total de cadera; adulto joven.

Nivel de Evidencia: IV

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How to cite this article: Kelsey Gary HC, Vidal Chang N, Gómez Palencia NA, Tinoco Cervantes CD, Alonso Cogollo JD. Failure of Femoral Neck System Fixation Due to Suboptimal Reduction in a Young Adult With a Garden Type IV Subcapital Fracture: Conversion to Total Hip Arthroplasty. A Case Report. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):488-495. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2414>

INTRODUCTION

Coxa vara is defined as a femoral neck–shaft angle below 120° (normal range, 125°–135°).¹ This morphology redistributes forces across the femoral neck and increases the shear component.^{1,2}

In young adults, subcapital fractures following a fall from standing height are uncommon. The patient described here had a neck–shaft angle of 119°, a borderline value interpreted radiographically as apparent coxa vara morphology.^{1,3}

Femoral neck fractures are classified according to the orientation of the fracture line using the Pauwels classification. Pauwels type III fractures have a vertical fracture line (>50°), with predominantly shear forces that increase the risk of instability, nonunion, and fixation failure.^{4,5}

In young patients with Garden type III–IV fractures, the primary goal is to preserve the femoral head through internal fixation, provided that anatomical reduction can be achieved. Reduction is considered suboptimal when there is residual femoral neck shortening >5 mm, rotation of the femoral head fragment, or noncentral positioning of the implant's head element.⁶

The *Femoral Neck System* (FNS) has been proposed as a fixed-angle option that provides rotational stability.^{4,6,7} Its success, however, depends critically on reduction quality and implant positioning. Some multicenter series report a 10% early failure rate in Garden type III–IV fractures with suboptimal reduction.^{5,6,8} Rates of nonunion, avascular necrosis, and fixation failure are not consistently lower than those reported with cannulated screws.⁹

Avascular necrosis of the femoral head results from disruption of the retinacular vessels. The main risk factors are initial displacement (Garden types III–IV), delayed fixation, and inadequate reduction.^{10,11} These factors increase the risk of varus collapse, cut-out, nonunion, and avascular necrosis, potentially requiring conversion to total hip arthroplasty.^{10,11}

We present a case of a low-energy Garden type IV subcapital fracture in a young adult with a borderline neck–shaft angle of 119°. Suboptimal reduction and implant malposition led to FNS failure, followed by nonunion and avascular necrosis requiring conversion to arthroplasty. This case illustrates how severe initial displacement, inadequate reduction, and poor implant positioning can lead to internal fixation failure, emphasizing the importance of not accepting a nonanatomical reduction.

CASE REPORT

A 38-year-old male motorcycle taxi driver with a body mass index of 31.1 kg/m² and no smoking history presented with left hip pain and loss of function lasting 3 days after a ground-level fall. The patient provided informed consent for publication of the case and images.

Clinical examination revealed limb shortening, external rotation, and pain on movement, with no neurovascular deficit.

Radiographs showed a Garden type IV subcapital fracture with a neck–shaft angle of 119°, a borderline value interpreted as radiographically apparent coxa vara morphology (Figure 1). The fracture line was vertical (Pauwels type III) (Figure 2).

Internal fixation with the FNS was performed 12 days after the injury under spinal anesthesia. The implant was selected for its fixed-angle design and rotational stability in fractures subjected predominantly to shear forces. Closed reduction was performed under fluoroscopic guidance in two planes. Shortening and rotation persisted, preventing an optimal reduction. Nevertheless, the reduction obtained was accepted and fixation was completed.

Postoperative radiographs confirmed suboptimal reduction, with residual femoral neck shortening >5 mm, rotation of the femoral head fragment, and noncentral positioning of the main screw (Figures 3 and 4).

At 8 months, mechanical failure of the FNS was documented, with cut-out, nonunion (absence of union and sclerosis of the fracture margins), and avascular necrosis (loss of femoral head sphericity and subchondral collapse) (Figures 5 and 6).

At 18 months, conversion to a complex primary total hip arthroplasty was performed through a posterolateral (Gibson) approach. A 52-mm uncemented acetabular cup with two screws, an 11-mm uncemented stem, and a 36-mm ceramic head were implanted without intraoperative complications. Radiographs confirmed satisfactory component positioning (Figures 7 and 8).

One month after arthroplasty, limb length had been restored, the Harris Hip Score was 82/100, and the patient had resumed his daily activities without complications.

Figure 1. Anteroposterior pelvic radiograph showing a left femoral neck–shaft angle of approximately 119° (borderline value). Relative femoral neck shortening and an altered head–shaft relationship are consistent with a Garden type IV subcapital fracture and posterior wall comminution.



Figure 2. Lateral radiograph of the left hip showing posterior rotation and sagittal shortening of the femoral head fragment, loss of the spherical head contour, and irregular subchondral cortical lines. These findings support the interpretation of mechanical instability and a low-energy fracture.

Figure 3. Anteroposterior radiograph of the left hip after internal fixation with the *Femoral Neck System*. Femoral neck shortening and rotation of the femoral head fragment about the transverse axis indicate suboptimal reduction.



Figure 4. Lateral radiograph of the left hip after internal fixation. The main screw lies markedly anterior to the sagittal center of the femoral head. The head is rotated posteriorly, and the neck appears shortened.



Figure 5. Follow-up anteroposterior radiograph of the left hip after internal fixation. Femoral neck shortening, loss of center-center positioning of the head screw, and changes in femoral head morphology (sclerosis/collapse) are consistent with mechanical failure of the *Femoral Neck System* and progression toward nonunion/necrosis.



Figure 6. Follow-up lateral radiograph of the left hip showing posterior migration of the main screw and posterior rotation of the femoral head fragment, with partial cut-out through the posterosuperior pole of the femoral head. These findings are consistent with loss of femoral head support and implant failure.



Figure 7. Anteroposterior pelvic radiograph showing the left total hip prosthesis. The acetabular component is appropriately positioned and secured with two superior screws. The prosthetic head is centered in the cup, and the femoral stem is aligned within the canal. There is no evidence of dislocation, periprosthetic fracture, or immediate postoperative radiolucencies around the implant.

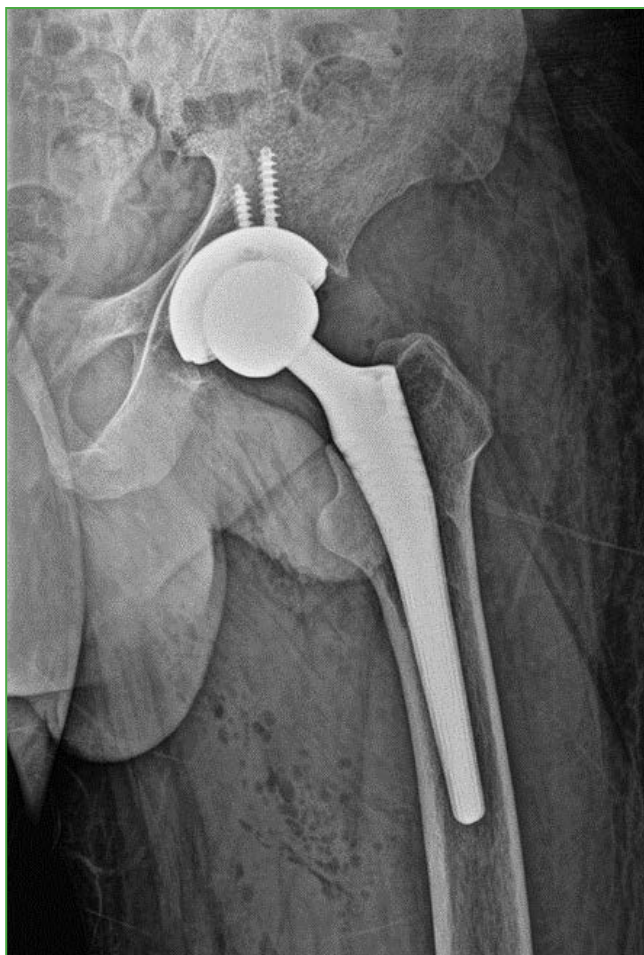


Figure 8. Lateral radiograph of the left hip after total hip arthroplasty, confirming appropriate cup orientation with the liner in functional anteversion, a centered head, and a well-positioned femoral stem. No signs of loosening or early postoperative complications are present.

DISCUSSION

A low-energy subcapital fracture in a young adult is uncommon. This patient had a borderline neck–shaft angle of 119°, a radiographic finding consistent with apparent coxa vara morphology.^{1,3}

In young patients with completely displaced intracapsular fractures (Garden type IV), the primary goal is to preserve the femoral head through internal fixation, provided that anatomical reduction and stable fixation can be achieved.^{10,11} Success depends critically on several concurrent factors: time to surgery, reduction quality, and implant positioning.^{6,9}

Surgery was performed 12 days after the initial injury. Although the evidence on the precise effect of delayed surgery on avascular necrosis is not entirely consistent, most series agree that displaced femoral neck fractures in young adults should be treated urgently, ideally within the first 24 hours, to minimize the risk of nonunion and avascular necrosis.^{12,13} A 12-day delay falls well outside this recommended window and represents an additional risk factor.¹²

The FNS offers theoretical biomechanical advantages over cannulated screws, including rotational stability and a fixed-angle design.^{4,5} However, recent publications indicate that these advantages do not consistently translate into fewer serious complications when reduction is nonanatomical. A comparative meta-analysis concluded that, although the FNS may be associated with shorter time to union and less femoral neck shortening, rates of nonunion, avascular necrosis, and fixation failure are similar to those reported with cannulated screws.^{8,9} Multicenter series have identified initial displacement (Garden types III–IV), suboptimal reduction, a large tip–apex distance, and excessive device sliding as the main predictors of early FNS failure.^{5,6,8}

In this case, immediate postoperative radiographs showed nonanatomical reduction, with residual femoral neck shortening and rotation of the femoral head fragment, together with noncentral positioning of the main FNS screw. These technical findings, combined with the 12-day surgical delay and initial Garden type IV displacement, provide a multifactorial explanation for the mechanical failure, cut-out, nonunion, and avascular necrosis documented at 8 months.⁵⁻⁹

When internal fixation fails and femoral head viability is lost in a young patient, conversion to total hip arthroplasty offers a predictable and effective salvage strategy. Available series report high rates of reoperation and conversion to arthroplasty after failed internal fixation in young adults. They also show that arthroplasty provides better medium-term functional outcomes than repeated attempts at internal fixation in this setting.^{10,11,14}

This case is noteworthy because several unusual factors occurred in a single patient: a low-energy Garden type IV subcapital fracture in a young nonsmoking adult with a borderline neck–shaft angle, delayed treatment at 12 days using a modern fixed-angle implant (FNS), suboptimal reduction, and noncentral positioning of the implant's head element. This combination led to mechanical failure and the need for conversion to total hip arthroplasty 18 months after the initial injury.

The main lesson from this case is that, even with advanced fixation devices such as the FNS, anatomical reduction and correct implant positioning remain the most important technical determinants of successful femoral head preservation in young patients. Suboptimal reduction should not be accepted. Surgical delay may increase biomechanical risk, but failure is primarily explained by the reduction and fixation technique. When these factors coexist and avascular necrosis or nonunion develops, conversion to total hip arthroplasty is a valid salvage option with good short-term functional outcomes.

CONCLUSIONS

A low-energy Garden type IV subcapital fracture in a young adult carries a high risk of complications. FNS failure occurred in the setting of delayed surgery, suboptimal reduction, and noncentral implant positioning. The latter two were identified as the main technical factors.

Successful femoral head preservation depends primarily on anatomical reduction and correct fixation. When fixation fails and femoral head viability is lost, conversion to total hip arthroplasty is an effective salvage strategy.

This case reinforces that reduction quality remains the most important technical determinant of success, even with modern fixed-angle implants.

Use of artificial intelligence

ChatGPT (OpenAI) was used as a supporting tool to improve the wording and clarity of the manuscript, contributing approximately 20% of the text editing. Before submission, the authors reviewed, verified, and approved all content for accuracy and originality and accepted full scientific responsibility for it.

Conflicts of interest: The authors declare no conflicts of interest.

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100 Years of History of the Department of Orthopaedics and Traumatology at Hospital Italiano de Buenos Aires

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ABSTRACT

Introduction: In 2026, the Department of Orthopaedics and Traumatology of Hospital Italiano de Buenos Aires celebrates 100 years since its foundation. From its origins, its development was linked to the orthopaedic school of the Rizzoli Institute in Bologna and to figures such as Vittorio Putti, José Valls, and Carlos E. Ottolenghi. **Objective:** To describe the main historical, clinical, educational, scientific, and technological milestones that shaped the evolution of the Department during its first 100 years. **Historical Overview:** Since its establishment in 1926, the Department has undergone sustained growth and reached several milestones that contributed to the development of the specialty in Argentina and the region. These include the establishment of the Bone Bank and the first massive bone transplantation in 1948; the creation of Argentina's first residency program in Orthopaedics and Traumatology in 1964; the first Charnley total hip arthroplasty in the Americas in 1967; the development of bone allograft reconstruction techniques; and the progressive introduction of arthroscopy, surgical navigation, and robotic surgery. The Department also consolidated its academic and scientific activity and its participation in international networks. **Conclusions:** Over the course of a century, the Department has made sustained contributions to the development of the specialty through patient care, professional training, research, and the adoption of surgical and technological innovations.

Keywords: Orthopaedics; traumatology; history of medicine; medical education; Hospital Italiano de Buenos Aires.

Level of Evidence: Not applicable.

100 años de Historia del Servicio de Ortopedia y Traumatología del Hospital Italiano de Buenos Aires

RESUMEN

Introducción: En 2026, el Servicio de Ortopedia y Traumatología del Hospital Italiano de Buenos Aires celebra 100 años desde su creación. Su desarrollo estuvo vinculado desde sus orígenes con la escuela ortopédica del Instituto Rizzoli de Bologna y con figuras, como Vittorio Putti, José Valls y Carlos E. Ottolenghi. **Objetivo:** Describir los principales hitos históricos, asistenciales, docentes, científicos y tecnológicos que marcaron la evolución del Servicio durante sus primeros 100 años. **Desarrollo:** Desde su creación en 1926, el Servicio experimentó un crecimiento sostenido y alcanzó diversos hitos relevantes para el desarrollo de la especialidad en la Argentina y la región. Entre ellos, se destacan la creación del Banco de Huesos y la realización del primer trasplante óseo masivo en 1948; la creación de la primera residencia de Ortopedia y Traumatología del país en 1964; la primera artroplastia de cadera tipo Charnley en América, en 1967; el desarrollo de técnicas de reconstrucción con aloinjertos óseos, y la incorporación progresiva de la artroscopia, la navegación quirúrgica y la cirugía robótica. Asimismo, consolidó su actividad académica y científica, y su participación en redes internacionales. **Conclusiones:** A lo largo de un siglo, el Servicio ha contribuido sostenidamente al desarrollo de la especialidad mediante la asistencia, la formación profesional, la investigación y la incorporación de innovaciones quirúrgicas y tecnológicas.

Palabras clave: Ortopedia; traumatología; historia de la medicina; educación médica; Hospital Italiano de Buenos Aires.

Nivel de Evidencia: NA

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How to cite this article: Buttaró M. 100 Years of History of the Department of Orthopaedics and Traumatology at Hospital Italiano de Buenos Aires. *Rev Asoc Argent OrtopTraumatol* 2026;91(5):496-502. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2449>

The history of the Department of Orthopedics and Traumatology at Hospital Italiano de Buenos Aires dates back to 1926. That year, the renowned Italian surgeon Vittorio Putti, the father of modern orthopedics and a central figure in the orthopedic school of the Rizzoli Institute in Bologna, entrusted Dr. José Valls with establishing an orthopedic department at Hospital Italiano following a visit to the Rizzoli Institute. In August, Dr. Carlos E. Ottolenghi joined the hospital. He would become a pivotal figure and the driving force behind the development of modern orthopedics at our institution.¹

In 1928, Dr. Ottolenghi and other Latin American trainees continued their training in Bologna, strengthening their academic ties with the Rizzoli Institute tradition (Figure 1). This influence would leave a lasting mark on the Department's identity. From the outset, its work rested on surgical excellence, structured specialist training, and the advancement of scientific knowledge.



Figure 1. Dr. Vittorio Putti's pupils at the Rizzoli Institute in Bologna, circa 1929. From left to right: Drs. Ottolenghi, Valls, Allende, Putti, Otaño, and Dellepiane Rawson.

In 1944, Dr. Carlos E. Ottolenghi was appointed Head of the Department, beginning a period of institutional consolidation and growth. Under his leadership, the Department became a referral center for the treatment of musculoskeletal disorders.

A major milestone came in 1948 with the establishment of the Bone Bank and the first massive bone transplantation procedure. This pioneering advance placed Hospital Italiano at the forefront of bone reconstruction in the region (Figure 2).

Growing demand for care led to the opening of a separate 180-bed ward in 1956, dedicated exclusively to patients with orthopedic conditions and traumatic injuries. The new facility allowed the Department to expand its clinical and surgical work and strengthen professional training.

In 1964, Argentine orthopedics reached a historic milestone with the creation of the country's first residency program in orthopedics and traumatology. This innovative model of surgical training would shape the specialty for decades to come. Over the past 25 years, the Department has trained 180 residents and 160 fellows.

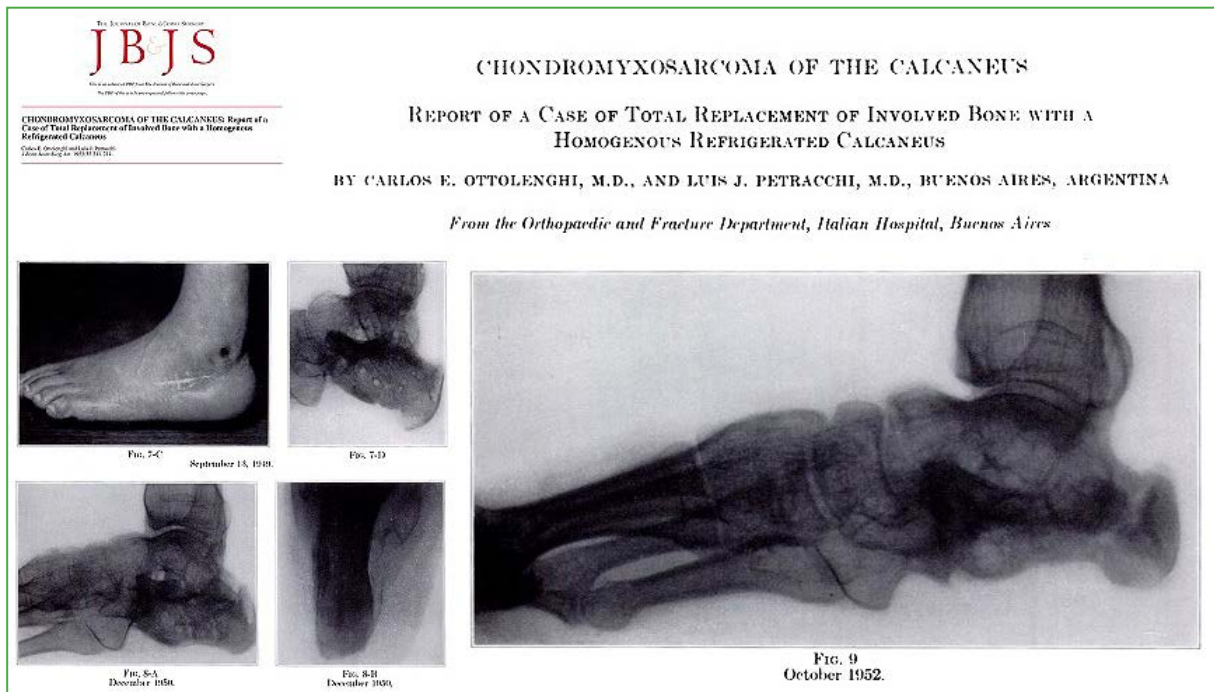


Figure 2. First massive bone transplantation performed by Drs. Ottolenghi and Petracchi in 1948.²

The Department's commitment to innovation continued through surgical advances with a lasting impact. In 1967, the first Charnley hip replacement in the Americas was performed, introducing a technique that would revolutionize reconstructive surgery in the region (Figure 3).



Figure 3. First Charnley hip replacement in the Americas, performed by Drs. Luis Petracchi and Rodolfo Pusso.

Following Dr. Ottolenghi's appointment as Head of the Department, the hospital hosted courses attended by leading international figures in orthopedics, including Professor Vittorio Putti himself in 1930, as well as Drs. Böhler, Trueta, Merle d'Aubigné, Scaglietti, Fineschi, and others. These activities helped establish Hospital Italiano as a leading academic center (Figure 4).



Figure 4. Dr. Ottolenghi and Dr. Robert Merle d'Aubigné in the Department of Orthopedics auditorium during a course in 1970.

The 1970s brought important developments. In 1970, the Scoliosis Center was established, and Dr. Vázquez Ferro performed Argentina's first knee replacement. In 1972, he also developed the treatment of shaft fractures with the Küntscher intramedullary nail in Argentina, contributing to the advancement of modern trauma surgery.

This spirit of innovation continued in 1976 with the first knee arthroscopy, introducing a minimally invasive technique that would transform the treatment of many joint disorders.

In 1987, the first hip impaction bone grafting procedure using allograft was performed. This complex technique allowed bone defects to be reconstructed during revision surgery.³

Technological progress continued in 1995 with the introduction of a laminar airflow operating room, improving safety standards with the aim of reducing infection risk in joint replacement, oncologic, and spinal surgery.

Between 1999 and 2007, Dr. Luis Muscolo led the Department, strengthening the international standing of its musculoskeletal oncology program and expanding its academic and scientific activities.

The following decade brought important new technologies. In 2010, surgical navigation was introduced for musculoskeletal tumors, improving the precision of oncologic resection. In 2012, a new surgical suite opened, expanding capacity to eight state-of-the-art operating rooms and modernizing the Department's infrastructure.

In 2020, the Department was invited to join the *International Society of Orthopaedic Centers* (ISOC), becoming part of a worldwide network of 25 centers of excellence.

In 2021, the first robot-assisted total knee replacement was performed, introducing advanced technology to optimize precision in reconstructive surgery.

The institution continued to grow with the opening of new premises for the Department of Orthopedics in 2024: a modern, 500-m² space designed to support the specialty's expanding clinical, educational, and scientific activities. Over the past 10 years, physicians in our Department have published more than 500 papers indexed in PubMed, many of which have had substantial scientific influence (Table).

Table. Most influential publications from the Department of Orthopedics and Traumatology at Hospital Italiano de Buenos Aires.

Author	Year	Journal	Study design	Level of evidence	Title	Key contribution	Citations*
Costa-Paz et al. ¹	2001	<i>Arthroscopy</i>	Case series	IV	Magnetic resonance imaging follow-up study of bone bruises associated with anterior cruciate ligament ruptures	Pioneering study describing the evolution of bone bruises over time in ACL injuries	260
Buttaró et al. ²	2007	<i>J Bone Joint Surg Am</i>	Case series	IV	Locking compression plate fixation of Vancouver type-B1 periprosthetic femoral fractures	Established locking plate fixation as an effective, reproducible strategy for treating type B1 periprosthetic fractures, influencing modern surgical practice	255
Muscolo et al. ³	2004	<i>Clin Orthop Relat Res</i>	Case series	IV	Intercalary femur and tibia segmental allografts provide an acceptable alternative in reconstructing tumor resections	Demonstrated that intercalary allografts are a viable biological option for reconstruction after tumor resection, with acceptable functional outcomes and survival	230
Muscolo et al. ⁴	2005	<i>J Bone Joint Surg Am</i>	Case series	IV	Use of distal femoral osteoarticular allografts in limb salvage surgery	Defined the technique and outcomes of distal femoral osteoarticular allografting, establishing its role in limb salvage surgery	215
Muscolo et al. ⁵	2005	<i>Orthop Clin North Am</i>	Narrative review	V	Massive allograft use in orthopedic oncology	Conceptual review providing a systematic account of the indications, techniques, and complications of massive allograft use	215
Buttaró et al. ⁶	2005	<i>J Bone Joint Surg Br</i>	Case series	IV	Vancomycin-supplemented impacted bone allografts in infected hip arthroplasty: two-stage revision results	Described antibiotic-supplemented impaction allografting in revision hip arthroplasty for infection, with good results in infection control through a two-stage approach and in bone reconstruction	160
Aponte-Tinao et al. ⁷	2012	<i>Clin Orthop Relat Res</i>	Case series	IV	Intercalary femur allografts are an acceptable alternative after tumor resection	Provided long-term results validating the use of intercalary femoral allografts and supporting their indication for biological reconstruction	165

(Continued)

Table. Cont.

Muscolo et al. ⁸	2004	<i>J Bone Joint Surg Am</i>	Case series	IV	Partial epiphyseal preservation and intercalary allograft reconstruction in high-grade metaphyseal osteosarcoma of the knee	Introduced the concept of epiphyseal preservation in osteosarcoma, allowing joint preservation and improved functional outcomes without compromising oncologic control	160
Aponte-Tinao et al. ⁹	2015	<i>Clin Orthop Relat Res</i>	Case series	IV	Survival, recurrence, and function after epiphyseal preservation and allograft reconstruction in osteosarcoma of the knee	Confirmed the oncologic safety and functional benefits of epiphyseal preservation combined with allograft reconstruction in larger series	150
Buttaro et al. ¹⁰	2008	<i>Clin Orthop Relat Res</i>	Case series	IV	Acetabular revision with metal mesh, impaction bone grafting, and a cemented cup	Described a reproducible technique for complex acetabular reconstruction using metal mesh and impaction bone grafting, widely adopted in revision arthroplasty	135

* Citation counts are approximate and based on Google Scholar/Scopus (2025–2026).

- Costa-Paz M, Muscolo DL, Ayerza MA, Makino A, Aponte-Tinao L. Magnetic resonance imaging follow-up study of bone bruises associated with anterior cruciate ligament ruptures. *Arthroscopy* 2001;17(5):445-9. PMID: 11337716
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This extensive academic and scientific work has also been consistently represented in the *Revista de la Asociación Argentina de Ortopedia y Traumatología*. Over the past two years, members of the Department's various divisions have regularly contributed original research, case reports, review articles, and other publications. Their contributions reflect the breadth of our scientific output and reaffirm a longstanding relationship with the Association and its journal that remains strong today.

In 2025, the DITTO unit (*Desarrollo, Innovación y Tecnología en Traumatología y Ortopedia*—Development, Innovation, and Technology in Traumatology and Orthopedics) was established as a cross-departmental initiative dedicated to technological development and innovation. Its work incorporates artificial intelligence, specialized software development, and the creation of innovative medical devices.

The Department currently comprises 174 professionals: 31 staff physicians, 50 residents, 16 fellows, and 77 affiliated physicians working at the main hospital, the San Justo site, and peripheral centers.

In 2026, the Department celebrates its centenary, marking a century of clinical and surgical excellence, the training of generations of specialists, and continuous innovation. As part of the celebrations, the Dr. Luis Muscolo Auditorium opened on March 3 as a space for education and academic exchange, carrying forward the teaching tradition that has defined the Department since its beginnings. During the Association's upcoming Congress, we will hold a Department Alumni Course on November 19, with all Congress registrants invited to attend.

Over these 100 years, the Department of Orthopedics and Traumatology at Hospital Italiano de Buenos Aires has trained hundreds of specialists, developed significant surgical advances, and contributed to the growth of orthopedics in Argentina and Latin America. Its history is that of a surgical school that has brought together tradition, innovation, and a commitment to training future generations.

Conflicts of interest: The author declare no conflicts of interest.

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Modification of the Micheli-Kocher Technique with Anterior Cruciate Ligament Remnant Preservation and Augmentation in Pediatric Patients: A Technical Note

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ABSTRACT

Objective: To describe a modification of the Micheli-Kocher technique that incorporates anterior cruciate ligament (ACL) remnant preservation and augmentation to enhance biological potential in skeletally immature patients. **Materials and Methods:** The surgical procedure is described in an 8-year-old boy (Tanner stage I) who competes in motocross. The key modification involves using an arthroscopic shaver to create an oblique opening in the superolateral portion of the remnant, through which the iliotibial band graft is passed. This allows the remnant tissue to provide biological support and guide the neoligament. **Results:** At the 12-month follow-up, the patient's knee was clinically stable (negative Lachman and pivot-shift tests), and radiographs showed no limb length discrepancies or angular deformities. He successfully returned to high-impact competitive sport (motocross), with marked proprioceptive recovery and full range of motion. **Conclusions:** This technical modification combines the mechanical safety of extrap-hyseal reconstruction with the potential biological benefits of remnant preservation. The technique was a safe alternative in this single case; however, studies with a higher level of evidence are needed to confirm its comparative advantages in ligamentization and proprioception.

Keywords: Anterior cruciate ligament; pediatrics; Micheli-Kocher technique; remnant preservation; iliotibial band.

Level of Evidence: IV

Modificación de la técnica de Micheli-Kocher con preservación y aumentación del remanente del ligamento cruzado anterior en pacientes pediátricos: nota técnica

RESUMEN

Objetivo: Describir una modificación de la técnica de Micheli-Kocher que integra la preservación y aumentación del remanente del ligamento cruzado anterior (LCA) para mejorar el potencial biológico en pacientes con inmadurez esquelética. **Materiales y Métodos:** Se detalla el procedimiento quirúrgico en un varón de 8 años (Tanner I), piloto de motocross competitivo. El paso distintivo consiste en realizar, con una rasuradora para artroscopia, un ojal oblicuo en la región superolateral del remanente para el pasaje del injerto de banda iliotibial, de modo que el tejido remanente actúe como soporte biológico y guía del neoligamento. **Resultados:** A los 12 meses de seguimiento, el paciente tenía una estabilidad clínica completa (pruebas de Lachman y del pivote negativas), sin disimetrías ni alteraciones angulares en las radiografías. Se reintegró, con éxito, a la competición de alto impacto (motocross), la recuperación propioceptiva fue notable y el rango de movilidad, completo. **Conclusiones:** Esta modificación técnica combina la seguridad mecánica de la reconstrucción extrafisaria con el aporte biológico potencial de la preservación del remanente. En este reporte de un único caso, la técnica resultó ser una alternativa segura; no obstante, se requieren estudios de mayor nivel de evidencia para confirmar sus ventajas comparativas en términos de ligamentización y propiocepción.

Palabras clave: Ligamento cruzado anterior; pediatría; técnica de Micheli-Kocher; preservación del remanente; banda iliotibial.

Nivel de Evidencia: IV

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How to cite this article: Cucalón GR, Fernández-Staudacher G, Veloz Serrano D. Modification of the Micheli-Kocher Technique with Anterior Cruciate Ligament Remnant Preservation and Augmentation in Pediatric Patients: A Technical Note. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):503-509. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2315>

INTRODUCTION

Managing anterior cruciate ligament (ACL) tears in children requires a careful balance between restoring joint stability and protecting the physes. In prepubescent patients with substantial skeletal immaturity (Tanner stages I and II), traditional transphyseal techniques carry a documented risk of growth arrest and angular deformity.¹

To address this challenge, Kocher, Garg, and Micheli described a combined intra- and extra-articular, physeal-sparing reconstruction technique using an iliotibial band (ITB) autograft, deliberately avoiding bone tunnels that cross the femoral or tibial physes.¹ The technique has demonstrated long-term safety and effectiveness, with excellent rates of return to sport² and robust fixation owing to the versatility and strength of the ITB.³

However, the standard technique does not routinely preserve the ACL remnant, which has received increasing attention in the recent medical literature for its biological potential. Recent systematic reviews suggest that remnant preservation is superior to the standard technique in terms of revascularization and proprioceptive recovery⁴ and may provide better clinical and functional outcomes.⁵

Although several pediatric techniques have been described,⁶ no previous reports have specifically combined the Micheli–Kocher technique with remnant preservation. The indication for this technique was an anteromedial bundle tear with a mechanically stable posterolateral bundle remnant containing vascularized synovial fibers. Selective debridement of the intercondylar notch was performed to preserve this native tissue.

This technical note describes a surgical modification intended to combine the safety of an extraphyseal approach with the benefits of biological preservation.

MATERIALS AND METHODS

This study was approved by the Institutional Ethics Committee. Written informed consent was obtained from the patient's parents for the procedure and publication of the case report. Anonymity and protection of the patient's personal data were ensured in accordance with applicable regulations.

Positioning and approach

The patient is placed supine, and an examination under anesthesia is performed to confirm the degree of instability. A longitudinal lateral incision approximately 8 cm long is made over the distal ITB and lateral femoral epicondyle, following the principles described for surgical exposure of the ITB.³

Graft harvest and preparation

Dissection proceeds through the tissue layers to expose the fascia lata. Two parallel incisions, 15–20 mm apart, are made in the distal ITB and extended proximally beneath the skin to obtain a graft of sufficient length, generally 16–18 cm (Figure 1). It is essential to preserve the distal ITB insertion at Gerdy's tubercle to maintain its native anatomical attachment. The proximal end of the graft is released, delivered through the wound, and tubularized using high-strength sutures in a Krackow configuration.

Arthroscopic phase and remnant management

Standard arthroscopic portals are established. In the original technique described by Kocher and Micheli, the intercondylar notch is debrided to clearly visualize the “over-the-top” position.¹ In this modification, debridement is selective. The ACL remnant is preserved, particularly when it retains a robust tibial attachment and vascularized synovial fibers.

Graft passage and integration with the remnant

The “over-the-top” passage is prepared by carefully dissecting the posterior capsule and periosteum along the posterior aspect of the lateral femoral condyle, taking care to avoid injury to the perichondral ring. The tubularized graft is passed deep to the lateral collateral ligament and introduced into the joint using the “over-the-top” technique (Figure 2).



Figure 1. Graft harvest and preparation. The lateral incision and isolated central strip of the iliotibial band are shown, with the distal attachment at Gerdy's tubercle preserved. The proximal end of the graft has been tubularized.



Figure 2. Arthroscopic view of the modified technique. The tubularized iliotibial band graft (white arrow) enters the joint through the "over-the-top" route and lies in close contact with the preserved native anterior cruciate ligament remnant (yellow arrow).

The key step, once the ITB graft is inside the joint, is to pass it through or adjacent to the preserved remnant. An arthroscopic shaver is used to create an oblique opening approximately 7 mm in diameter in the superolateral corner of the ACL remnant, following the orientation of its fibers and preserving as much viable tissue as possible. The ITB graft is then passed through this opening from posterior to anterior. If a size mismatch prevents smooth passage, the opening is gradually enlarged to match the graft diameter as closely as possible, while avoiding excessive resection of the remnant. The native tissue thus envelops the graft, providing biological and mechanical support that guides the orientation of the reconstructed ligament and maximizes tissue-graft contact for revascularization. No additional sutures are needed to secure the remnant to the graft.

Tibial fixation

The graft is pulled distally toward the tibia. Extraepiphyseal tibial fixation is achieved by passing the graft beneath the intermeniscal ligament and suturing it to the medial tibial periosteum (Figure 3). Fixation may be reinforced with staples or bone anchors placed distal to the anterior tibial physis, with appropriate tension maintained at 20°–30° of knee flexion.

Finally, full knee extension is checked clinically and arthroscopically to rule out graft impingement or interposition of the remnant within the intercondylar notch.



Figure 3. Tibial fixation. The graft is passed distally between the tibial surface and the intermeniscal ligament, then secured to the proximal tibia with extraepiphyseal fixation, avoiding the growth plate.

RESULTS

We present the case of an 8-year-old boy, a competitive motocross rider, who was skeletally immature (Tanner stage I). He sustained a knee injury, and an ACL tear was confirmed by magnetic resonance imaging (MRI) (Figure 4) and physical examination. Intraoperative assessment confirmed an anteromedial bundle tear with an intact posterolateral bundle and a viable tibial remnant.



Figure 4. Preoperative parasagittal MRI of the knee showing the anterior cruciate ligament tear.

The modified Micheli–Kocher technique with remnant preservation described above was performed. The post-operative protocol included immobilization in a long-leg splint for 6 weeks and progressive weight bearing as tolerated. At the 12-month follow-up, the knee was clinically stable, with negative Lachman and pivot-shift tests and a full range of motion. The patient had returned to his previous competitive level without pain or limitations. Follow-up radiographs showed no limb length discrepancy or angular deformity of the lower limbs. MRI showed a correctly positioned and oriented reconstructed ligament, without a horizontal course (Figure 5).

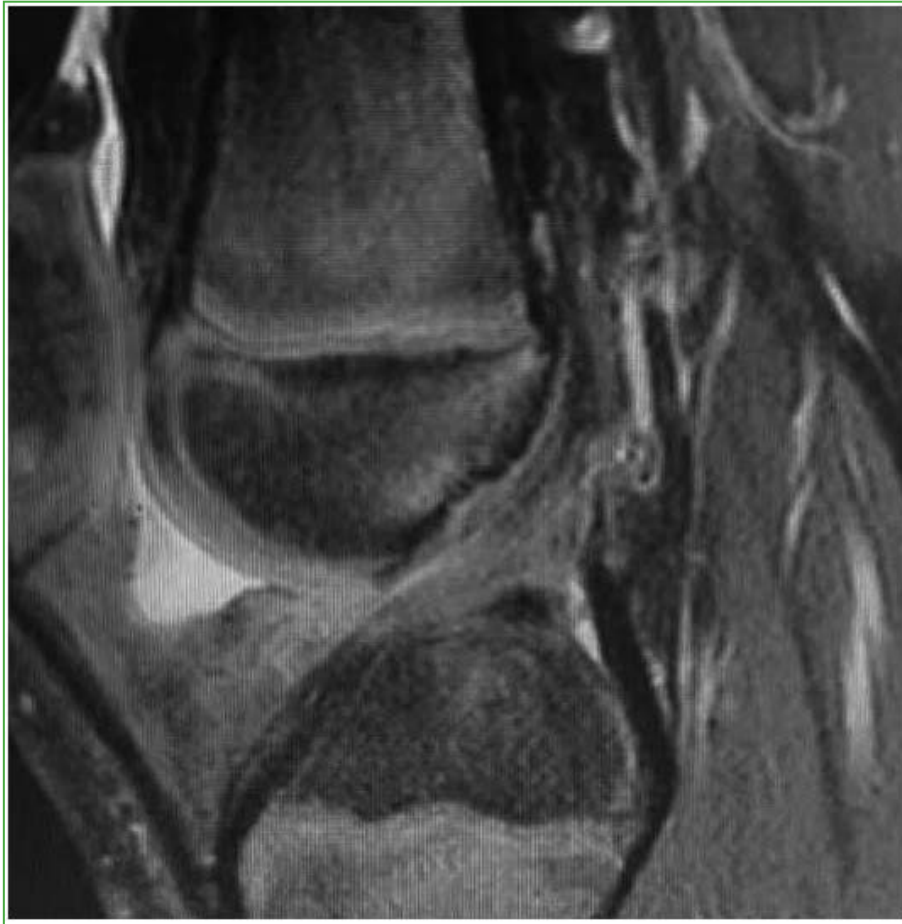


Figure 5. Postoperative parasagittal MRI of the knee showing the reconstructed ligament in the correct position and orientation, without a horizontal course.

DISCUSSION

ACL reconstruction in skeletally immature patients, generally aged 6–13 years, presents unique challenges. The Micheli–Kocher technique remains the procedure of choice because it fully spares the physes.^{1,2} Our modification aims to add a meaningful biological benefit to this mechanically established procedure.

The main rationale for preserving the remnant lies in the biology of “ligamentization.” The current medical literature suggests that remnant preservation may accelerate cellular repopulation and improve vascularization. Available evidence indicates that it may promote cellular repopulation, revascularization, and biomechanical graft integration.⁴ In our case, the successful return to motocross indicates good functional recovery. However, the potential benefits in proprioceptive reinnervation and the quality of ligamentization remain hypothetical and were not assessed objectively. In children, whose biological response is greater, maximizing this potential is a logical step. Preserving the tibial remnant may also offer important rehabilitation benefits, as the loss of mechanoreceptors is a major concern in reconstruction and the remnant serves as a source of proprioceptive reinnervation.⁵

From a biomechanical perspective, although current trends favor anatomical reconstruction,⁷ the Micheli–Kocher technique prioritizes physeal safety over precise restoration of femoral anatomy. Creating the opening in the superolateral corner gives the remnant an even greater role: it acts as a hammock or natural scaffold, helping the reconstructed ligament follow an orientation closer to that of the native tissue and preventing a horizontal

course. This makes soft tissue integration even more critical. The proposed synergy extends beyond biology, as remnant preservation also helps control rotation more effectively than reconstruction alone.⁵ However, these theoretical benefits must be distinguished from the observed clinical outcomes, which are limited to mechanical stability and range of motion.

This technique requires careful patient selection. As Pascual-Leone et al. emphasize, pediatric surgical techniques must be tailored to each patient's individual characteristics.⁶ Not all patients are suitable candidates. Attempting to preserve a fibrotic or insufficient remnant, or one that obstructs visualization, may lead to complications such as cyclops syndrome or extension deficits. As Colombet cautions, surgeons must always weigh the intraoperative risks and benefits of augmentation to avoid compromising joint mechanics.⁸

In conclusion, this modification of the Micheli–Kocher technique maintains the established safety of extraphyseal reconstruction while preserving the remnant's biological potential by passing the graft through a superolateral opening. In this single case report, the technique was feasible and safe, although prospective studies with larger samples are needed to determine whether it offers clinical advantages over the conventional technique.

This study has the limitations inherent to a single case report (level V evidence), which prevent generalization of the findings or statistical comparison with the standard technique. The absence of validated functional scores and objective proprioception testing also limits assessment of the actual biological benefit of the technique described.

Conflicts of interest: The authors declare no conflicts of interest.

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Hip Growth Disturbances in Childhood

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ABSTRACT

Growth disturbances of the proximal femur, described in the medical literature as avascular necrosis, osteochondritis, or post-reduction epiphysitis, are associated almost exclusively with the treatment of developmental dysplasia of the hip. Some of these disturbances can lead to later joint degeneration, with clinical, functional, and social implications. Various treatment-related factors have been identified. However, preexisting idiosyncratic, morphological, and vascular factors also determine specific risk profiles. This study aims to analyze the natural history of these disturbances and identify possible strategies to prevent them or reduce their sequelae. Understanding hip growth, development, and vascular supply is essential to understanding their pathogenesis. Diagnosis and treatment of developmental dysplasia of the hip during the neonatal period remain the gold standard, given the extremely low rates of treatment failure and residual abnormalities.

Keywords: Developmental dysplasia of the hip; femoral growth disturbance; natural history; children.

Level of Evidence: V

Alteraciones del crecimiento de la cadera en la infancia

RESUMEN

Las alteraciones del crecimiento del fémur proximal, referidas en la literatura médica como necrosis avascular, osteocondritis o epifisitis posreduccional, se relacionan casi exclusivamente con la terapéutica empleada en la displasia del desarrollo de la cadera. Algunas de ellas condicionan la ulterior degeneración articular con sus implicancias clínicas, funcionales y sociales. Se han individualizado una diversidad de factores relacionados con el tratamiento. Sin embargo, otras variables preexistentes idiosincrásicas, morfológicas y vasculares configuran perfiles de riesgo específicos. El objetivo de esta investigación es analizar la historia natural de estas alteraciones y establecer posibles formas de prevención o reducir sus secuelas. Una síntesis del crecimiento, el desarrollo y la vascularización de la cadera es imprescindible para la comprensión de la patogenia. El diagnóstico y el tratamiento de la displasia del desarrollo en el período neonatal siguen siendo el método de referencia, dado las ínfimas tasas de fracaso terapéutico y anomalías residuales.

Palabras clave: Displasia del desarrollo de la cadera; alteración del crecimiento femoral; historia natural; niños.

Nivel de Evidencia: V

INTRODUCTION

Proximal femoral growth disturbances (PFGDs) in childhood are morphological abnormalities involving the epiphysis, physis, femoral neck, or a combination of these structures. Although PFGDs are predominantly associated with the treatment of developmental dysplasia of the hip (DDH), they have also been observed in the contralateral, nondysplastic hip after immobilization.¹ The untreated hip may also show signs of dysplasia at skeletal maturity in 13%–40% of cases, consistent with the term “developmental dysplasia.”^{2,3} PFGDs may be transient and reversible or permanent and irreversible, with various deformities and joint degeneration that remain clinically silent for years, reflecting a discrepancy between radiographic and clinical findings.

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How to cite this article: Miranda MG, Fernández CA. Hip Growth Disturbances in Childhood. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):510-518. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2411>

This study aims to analyze the natural history of PFGDs and identify ways to prevent or reduce their sequelae. In DDH, the primary driver of deformity lies in the acetabulum, whereas in PFGDs, the initial changes occur in the proximal femur and acetabular involvement is secondary. The terms avascular necrosis, post-reduction osteochondritis, and epiphysitis are used synonymously in the scientific literature. Histological uncertainty has led many investigators to favor the euphemism “proximal femoral growth disturbance.”^{1,4-6} Proposed etiopathogenic mechanisms include mechanical factors (excessive joint pressure) and ischemia, hypotheses supported by experimental studies in pigs.⁷ These mechanisms may also interact (Figure 1).⁸

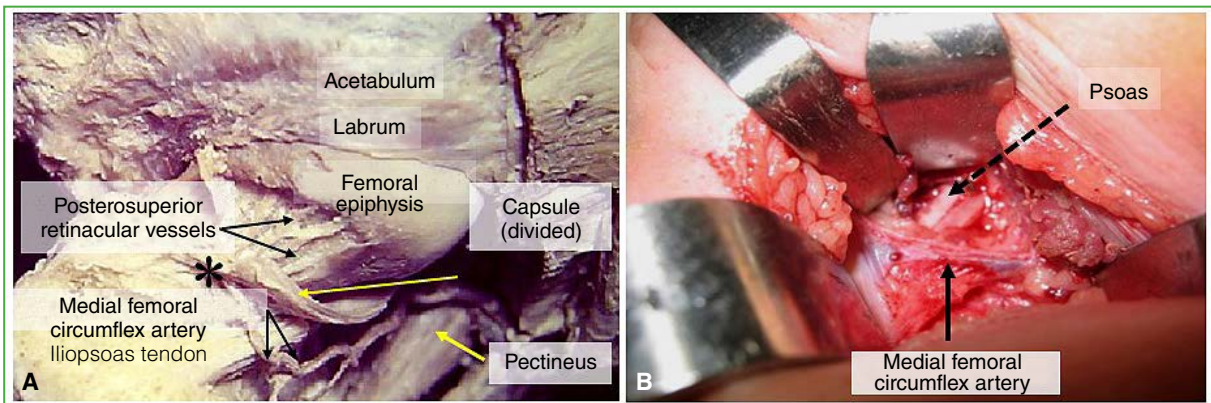


Figure 1. **A.** Dissection of the right hip in the inguinal region (cadaveric specimen). Note the relationship of the pectineus muscle and iliopsoas tendon to the medial circumflex femoral artery and its entry into the retrotrochanteric fossa (black asterisk). (Dissection by Prof. Rodolfo Cosentino, MD.) **B.** Corresponding intraoperative photograph showing the course of the medial circumflex femoral artery (solid arrow) and its relationship to the iliopsoas tendon (dashed arrow). The Farabeuf retractors at the apex are positioned anterior to the femoral epiphysis. Arterial compression may occur between the iliopsoas tendon and the pectineus muscle. In young children, the underdeveloped femoral neck makes the retinacular vessels more susceptible to compression by the labrum during extreme abduction and internal rotation.

The reported prevalence of PFGDs varies widely, from 0% to 73%, possibly reflecting differences in diagnostic rigor and follow-up duration. Numerous predisposing factors have been described: age >6 months at reduction, an unossified femoral head nucleus, greater cartilage volume, high dislocations, an inverted labrum, soft tissue interposition, nonconcentric reduction, preoperative traction, all surgical modalities, forceful reduction, immobilization in $\geq 60^\circ$ of abduction combined with internal rotation, prolonged immobilization, and surgery after failed treatment.^{1,9-11} In a prospective multicenter study of dysplastic hip dislocations, 20% of children already had epiphyseal abnormalities and femoral neck widening before treatment. During follow-up, 42% met the criteria for PFGDs, demonstrating that these abnormalities *are not iatrogenic* but pre-existing.⁶ Similarly, a *pretreatment* MRI study revealed *impaired perfusion and an immature microcirculatory pattern*.¹² Comparable findings have been reported with real-time contrast-enhanced ultrasound (CEUS; Optison®).¹³ The prevalence of PFGDs with devices such as the Pavlik harness, von Rosen splint, and Frejka pillow is *exceptionally low*, at 0%–1%. However, delaying treatment by several weeks or persisting with treatment after failed reduction raises the risk above 25%.^{2,11,12,14} Rates of PFGDs following closed reduction under general anesthesia and various surgical procedures range from 20% to 60%.^{3-6,8,11,14-16} Even without PFGDs, joint quality may deteriorate over time, as dysplasia cannot be regarded solely as a mechanical fetal disorder. Regardless of treatment, the risk of PFGDs is related to the high position of the proximal femur, underscoring the importance of classification systems with excellent intra- and interobserver reliability (Figures 2 and 3).¹⁷⁻²⁰

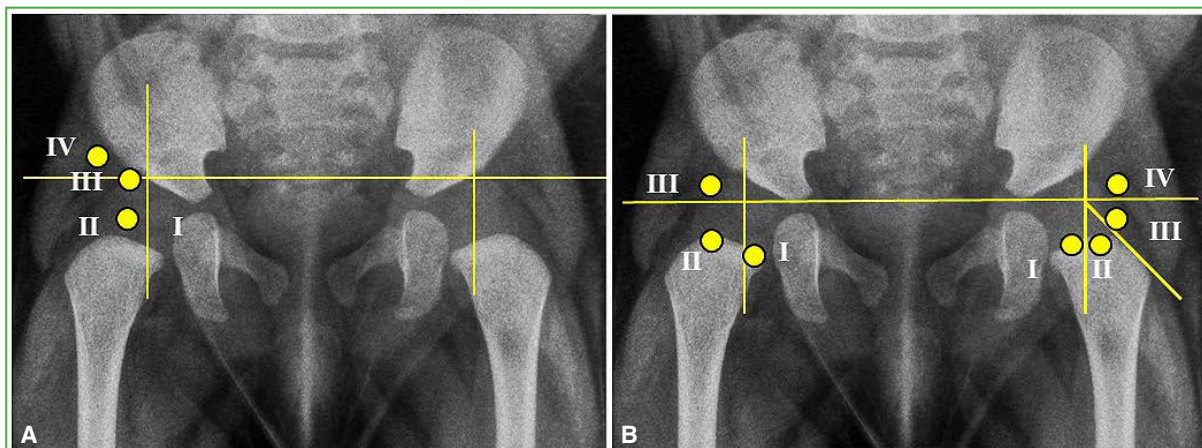


Figure 2. Topographic classifications of the unossified femoral epiphysis based on anteroposterior radiographs of both hips. In all three systems, grade I is normal, indicating that at least one-third of the femoral metaphysis lies medial to Perkins' line. **A.** Tönnis classification: a horizontal line through the acetabular roofs and the vertical Perkins' line. **B.** Right hip: Terjesen parameters, using the vertical Perkins' lines and the horizontal Hilgenreiner's line through the triradiate cartilages. The medial metaphyseal point indicates the epiphyseal position. Left hip: *International Hip Dysplasia Institute* (IHDI) method, using the resultant vector between the lines described in B. A midpoint on the metaphysis provides an objective reference for the epiphyseal position and, consequently, the level of dislocation.

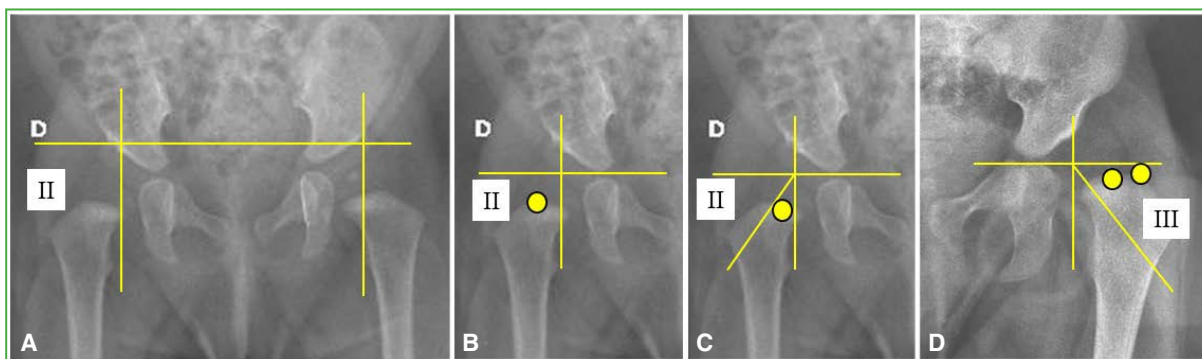


Figure 3. Anteroposterior hip radiographs of a 5-month-old girl showing grade II right hip dislocation according to all three classification systems. **A.** Tönnis. **B.** Terjesen. **C.** International Hip Dysplasia Institute (IHDI). Note the metaphyseal reference point in the latter two systems. **D.** Anteroposterior hip radiograph of a 7-month-old girl showing grade III dislocation according to the Terjesen and IHDI classifications.

HIP GROWTH AND DEVELOPMENT

The proximal femur and acetabulum arise from the same embryonic mesenchyme. During the eleventh week of intrauterine life, the fully formed hip begins to differentiate into cartilage, following the pattern of endochondral ossification, supplemented after birth by periosteal bone apposition. In the newborn, both joint components consist of hyaline cartilage (Figure 4).¹

The femoral epiphysis and greater trochanteric apophysis are *spherical chondroepiphyses*. Their growth is *centripetal*, driven by the metabolic activity of peripheral epiphyseal chondrocytes, whereas ossification is *centrifugal and radial*, proceeding from the center toward the periphery. The proximal femoral growth plate is *linear* and resembles an inverted L with three segments: the physeal or discoid segment, perpendicular to the femoral neck axis; the cervicotrochanteric segment; and the isthmus, which connects the other two and contributes to femoral neck thickness.¹ The calcification front of this configuration may occasionally be visible on radiographs as Harris lines. Interruption or distortion of these lines is considered *predictive* of PFGDs (O'Brien's sign) (Figure 5).¹

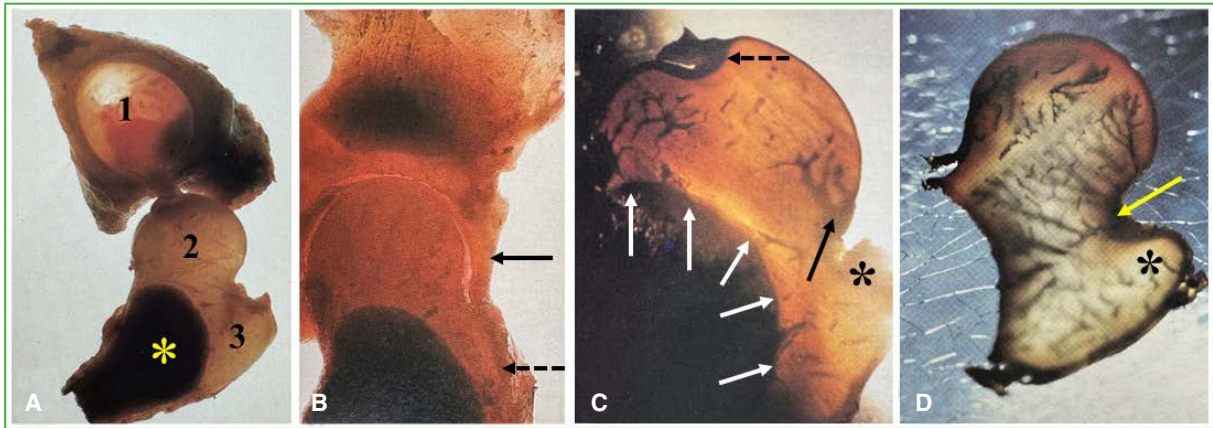


Figure 4. A-C. Transillumination images of the hip of a neonatal cadaveric specimen at 38 weeks' gestation, showing the fibro-hyaline composition of both joint components. **A.** Disarticulated specimen: 1. Acetabulum. 2. Femoral chondroepiphysis. 3. Greater trochanteric chondroepiphysis. 4. Osseous femoral metaphysis (yellow asterisk). **B.** Hip in situ. Capsule and labrum (black arrow), underdeveloped femoral neck, and trochanteric region at the entry site of the posterosuperior retinacular vessels (dotted arrow). **C.** Enlarged view of B. White arrows indicate the physis. From left to right: discoid cartilage, isthmus, and femoral neck. Greater trochanter and retrotrochanteric fossa (black asterisk), entry of the posterosuperior retinacular arteries (black arrow), and artery of the ligamentum teres (dotted arrow). **D.** Apical view of the femoral epiphysis and neck of a 25-week fetus. Greater trochanter (black asterisk) and the previously described retinacular vessels forming a rich branching network (yellow arrow). (Reproduced from: Teot L, Deschamps F. *Atlas d'Échographie de la hanche dans la première année de la vie*, 1987. With permission from Sauramps Medical.)

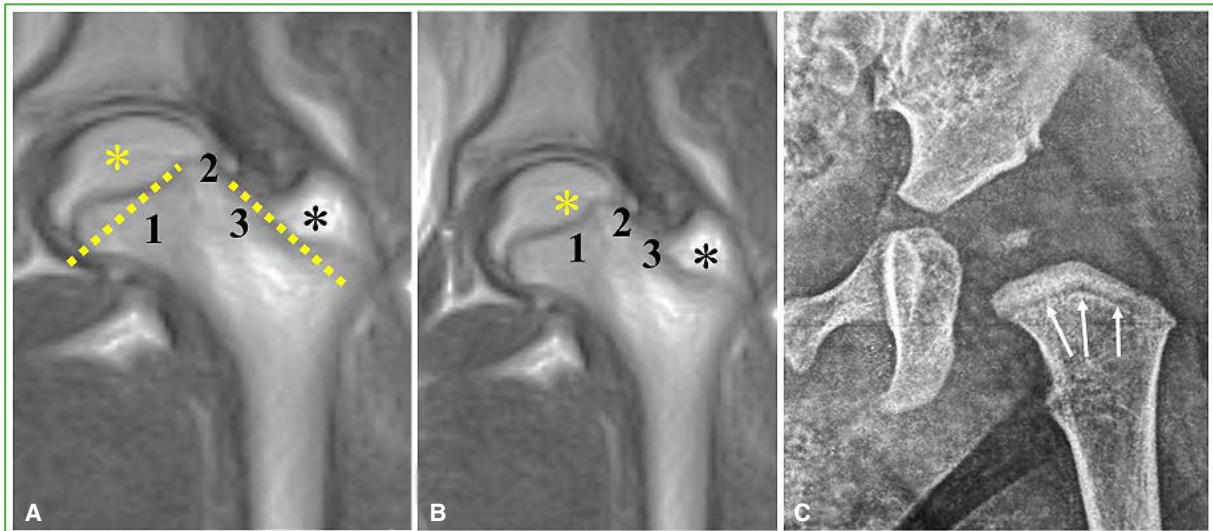


Figure 5. A and B. Coronal T1-weighted MRI of the hip of a 4-year-old child. Yellow asterisk: femoral chondroepiphysis; black asterisk: greater trochanter. The proximal femoral physis forms an inverted L with three continuous segments: 1. Femoral discoid cartilage. 2. Isthmus. 3. Femoral neck. **C.** Anteroposterior radiograph of the left hip of a 4-month-old child in slight internal rotation. Arrows indicate Harris lines that mirror the morphology of the physis.

Physiological physeal closure begins in the *lateral, superior, and slightly posterior* regions of the physis and then progresses in all directions.^{21,22} The blood supply comes from an extracapsular vascular network at the base of the femoral neck, supplied by the circumflex arteries. The medial circumflex artery passes between the iliopsoas muscle, enters the joint through the retrotrochanteric fossa, and gives rise to the retinacular vessels, particularly the posterosuperior vessels, which provide 80% of the blood supply to the epiphysis, isthmus, and much of the femoral metaphysis. The anterior retinacular branches arising from the lateral circumflex artery provide a supplementary

supply. This vascular network forms a *bipartite* system: the retinacular vessels perfuse the epiphyseal ossification center and physis for the synthesis of ground substance and osteoid, while the metaphyseal system contributes to substrate mineralization and bone resorption according to the Hueter–Volkmann law. *This vascular network does not follow a fixed pattern; it shows substantial anatomical variation according to sex, ethnicity, the number and diameter of the arteries, and the variable presence of intra-articular vascular rings.*

Classification and characterization of PFGDs

Several authors have proposed classifications of PFGDs. In chronological order, these include: Salter and Kostuk,⁷ Bucholtz and Ogden,² Kalamchi and MacEwen,²³ and Kruczynski²⁴ (Figure 6). All have moderate interobserver reliability.⁶ Given their similarity and widespread use in the specialized literature, the Kalamchi–MacEwen and Bucholtz–Ogden classifications will be considered together in this analysis. Type I is characterized by *delayed ossification and an appearance of epiphyseal fragmentation*. Although reversible, these changes may precede lesions with a poorer prognosis (Figure 7).

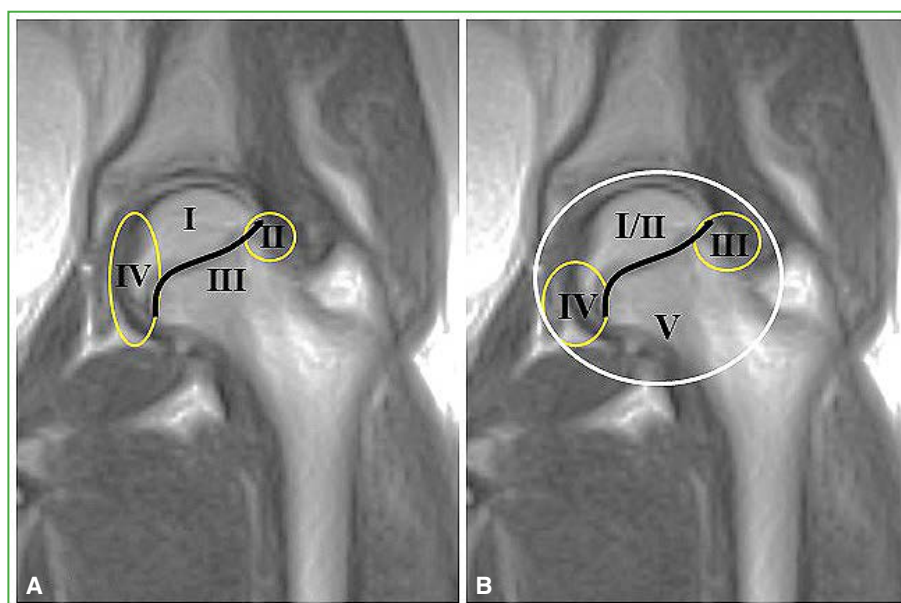


Figure 6. Coronal T1-weighted MRI of the hip of a 4-year-old child illustrating the classifications. **A.** Bucholtz and Ogden (combined with Kalamchi and MacEwen). I. Femoral epiphyseal fragmentation. II. Isthmic epiphysiodesis. III. Severe physeal damage. IV. Medial lesion. **B.** Kruczynski. The difference lies in the numerical assignments. Type V represents global damage, indicated by the white circle.

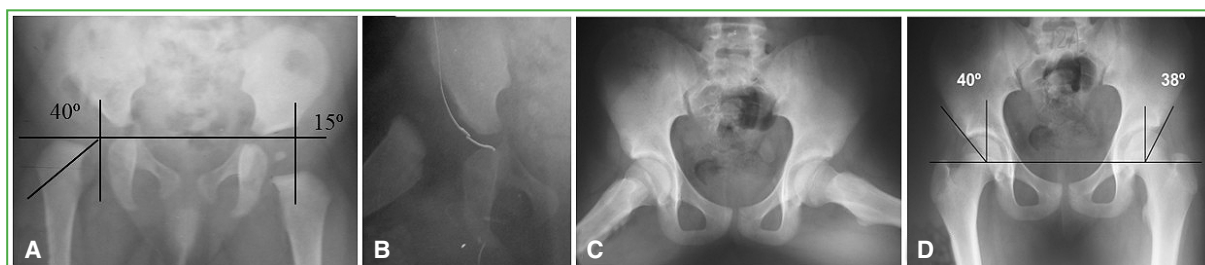


Figure 7. Anteroposterior and lateral hip radiographs. **A and B.** A 9-month-old girl with grade III right hip dislocation according to the Terjesen and International Hip Dysplasia Institute (IHDI) classifications and an uncalcified epiphyseal ossification center. Previous treatment consisted of an unsuccessful trial of a Pavlik harness, followed by unsuccessful closed reduction and hip spica casting under general anesthesia. Hilgenreiner’s angle (alpha): 40°. **C and D.** Anteroposterior and lateral hip radiographs at 13 years of age, showing the outcome of open reduction through a medial approach using the Weinstein–Ponseti technique. Severin grade IA. Absence or fragmentation of the femoral epiphysis may be transient and reversible.

The type II pattern has a prevalence of 25% and is defined by *epiphysiodesis or a lateral physeal bar*, which causes valgus tilt of the epiphysis relative to the femoral neck and may lead to secondary subluxation (Figure 8A). One study evaluated 58 hips in 48 patients with type II PFGDs treated by closed reduction ($n = 36$) or surgery through an inguinal approach ($n = 22$), with a follow-up of 21 years (range, 10–55). The abnormality became radiographically apparent at 10 years of age (range, 4–14). Outcomes were classified as Severin groups I/II in 59% of hips; the remainder had unsatisfactory outcomes (Table).^{4,24}

Table. Severin radiographic classification

I. Normal hip	a. CEA $>19^\circ$ at ages 6–13 years
	CEA $>25^\circ$ from age 14 years onward
	b. CEA 15° – 19° at ages 6–13 years
	CEA 20° – 25° from age 14 years onward
II. Moderate deformity	a and b. Same CEA values as in group I
III. Dysplasia without subluxation	CEA $<15^\circ$ at ages 6–13 years and $<20^\circ$ at ages >14 years
IV. Subluxation	Moderate: CEA positive or zero
	Severe: CEA negative
V. Dislocation	Femoral head articulating with the upper part of the original acetabulum
VI. Redislocation	Femoral head in a neoacetabulum

CEA = cervicoepiphyseal angle.²⁵

Another study included 155 dislocated hips treated by closed reduction at a mean age of 15 months. Type II PFGDs were present in 23% and were detected at a mean age of 8.9 years (range, 3–12). Sixty-six percent were classified as Severin grades I/II, while the remainder had suboptimal outcomes (Figures 8A and 9).²⁵

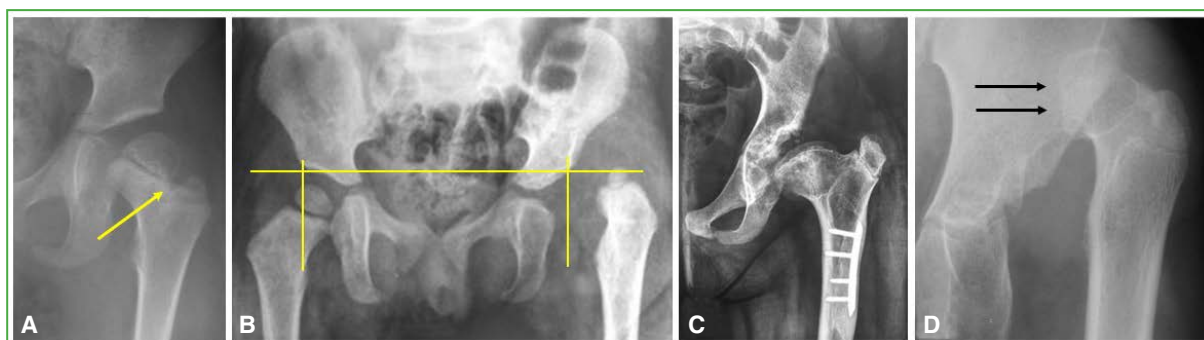


Figure 8. Anteroposterior radiographs. **A.** A 6-year-old boy with a lesion of the physeal isthmus following joint infection (yellow arrow), resulting in valgus tilt of the epiphysis. Type II proximal femoral growth disturbance. **B.** A 20-month-old girl with a previously undiagnosed Tönnis grade III left hip dislocation. Treatment consisted of open reduction through a Smith–Petersen approach, adductor longus tenotomy, Salter osteotomy, and femoral derotation and shortening osteotomies. **C.** Type III proximal femoral growth disturbance with evident dysplasia, coxa vara, and relative elevation of the greater trochanter. **D.** Preoperative radiograph of a previously untreated 7-year-old girl showing a type IV proximal femoral growth disturbance.



Figure 9. A girl aged 10 years and 10 months presenting with a limp, a positive Trendelenburg sign, and thigh pain. Coronal images of both hips. **A.** Radiograph showing valgus tilt of both epiphyses and isthmus epiphysiodesis of both femoral necks, defining a type II proximal femoral growth disturbance according to Bucholz and Ogden/Kalamchi and MacEwen, or type III according to Kruczynski (black arrows). Reimers' migration percentage is 20%. Alsberg's angle, which describes the angular relationship between the physis and femoral shaft, is 90° (reference value, 65°). Note the crossover sign of the acetabular lines, suggesting retroversion (yellow arrows). **B.** Corresponding CT and MRI findings showing the eccentric physal bridge at the isthmus (yellow arrows).

This phenomenon appears to reproduce physiological proximal femoral physal closure *prematurely*.²²

Type III PFGDs have a prevalence of 14%–30% and are the most damaging deformities, causing progressive joint and functional deterioration. They involve *severe epiphyseal and physal damage*, leading to reduced femoral neck growth and varus deformity, lower limb shortening, relative elevation of the greater trochanter with gluteus medius dysfunction, and coxa magna. Severe ischemia is the presumed cause (Figures 8B and C, 10A-C).²

In a study that followed 29 hips in 22 patients over four decades, the abnormality became radiographically visible a mean of 10 months (range, 5–19) after closed reduction or surgery through an inguinal approach. High dislocations (Tönnis grade IV) had an odds ratio of 3.43 for joint deterioration compared with grades II and III. At skeletal maturity, 90% of hips were classified as Severin grades III/IV. By 39 years of age, 32% of patients had undergone total hip replacement (Table).^{5,24}

In light of these findings, some surgeons opted for an anterolateral approach combined with femoral and pelvic osteotomies. The results were also disappointing, however, as 32% developed type II/III PFGDs (Figure 7B and C).¹⁵ Thus, type III PFGD represents the worst treatment outcome, regardless of the method used. Type IV is a medial epiphyseal–metaphyseal defect characteristic of longstanding dislocations or subluxations and is observed *before* any treatment (Figure 8D). Finally, 25% of cases show unclassifiable or mixed patterns (Figure 10D and E).

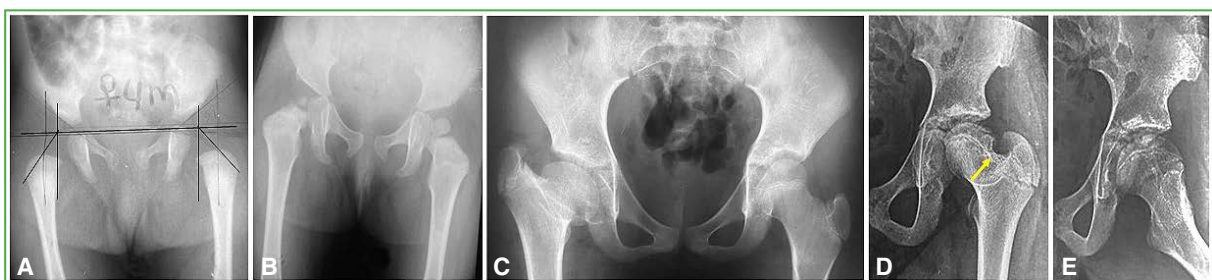


Figure 10. AP and lateral radiographs of both hips. **A.** A 4-month-old girl with bilateral grade II dysplasia according to the Terjesen and *International Hip Dysplasia Institute* (IHDI) classifications, treated with closed reduction and immobilization. **B.** Follow-up at 10 months showing epiphyseal hypoplasia and an apparently underdeveloped femoral neck. **C.** At 30 years of age, coxa vara with relative elevation of the greater trochanter and reversal of its relationship to the joint. These are classic sequelae of a type III proximal femoral growth disturbance according to Bucholz and Ogden/Kalamchi and MacEwen. **D.** A 13-year-old girl with a history of Tönnis grade IV left hip dislocation. After unsuccessful treatment with a Pavlik harness, open reduction was performed at 5 months of age through a Smith–Petersen approach. Mixed proximal femoral growth disturbance. The anteroposterior radiograph clearly shows a type II lesion (yellow arrow indicating epiphysiodesis), while the lateral view shows a shortened, widened femoral neck and evident coxa magna, consistent with type III according to Bucholz and Ogden/Kalamchi and MacEwen.

CONCLUSIONS

The gold standard for preventing PFGDs or mitigating their sequelae is neonatal or perinatal diagnosis and treatment of DDH. Beyond the epidemiological and treatment-related variables associated with DDH, *individual anatomical characteristics* (both morphological and vascular) also predispose patients to PFGDs, as demonstrated by advances in imaging technology and recent clinical research. Following children throughout growth is essential for a definitive and accurate assessment of the outcome.

Conflicts of interest: The authors declare no conflicts of interest.

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Case Resolution

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Case Presentation on page 408.

Synovial Chondromatosis of the Knee

ABSTRACT

Imaging studies showed intra-articular loose bodies, suggesting synovial chondromatosis. This rare, benign condition is characterized by the formation of cartilaginous loose bodies within the joint as a result of metaplasia of the synovial membrane.

Keywords: Chondromatosis; synovial tissue; cartilage.

Level of Evidence: IV

Condromatosis sinovial de rodilla

RESUMEN

Los estudios por imágenes mostraron cuerpos libres intrarticulares, esto sugiere condromatosis sinovial. Se trata de un cuadro raro y benigno caracterizado por la formación de cuerpos libres cartilaginosos intrarticulares, producto de una metaplasia de la membrana sinovial.

Palabras clave: Condromatosis, tejido sinovial, cartílago.

Nivel de Evidencia: IV

DIAGNOSIS: Synovial chondromatosis of the knee.

DISCUSSION

Coronal fat-suppressed proton density (PD)-weighted MRI of the knee showed magnetic susceptibility artifacts related to the ACL reconstruction. The graft had normal signal intensity and morphology. Well-defined low-signal lesions were visible, including a rounded 6-mm lesion anterior to the proximal third of the graft and another rounded 9-mm lesion posterior to its proximal third (Figure 2).

Axial images showed well-defined intra-articular low-signal lesions posterior to the patella and along the intercondylar line, together with increased joint fluid (Figure 3). Sagittal images showed an intact posterior cruciate ligament with normal orientation and an anterior intra-articular low-signal lesion (Figure 4).

Coronal fat-suppressed T2-weighted MRI showed a well-defined intra-articular low-signal lesion, joint effusion, and apparently intact collateral ligaments (Figure 5).

Nine loose bodies were removed arthroscopically and submitted for histopathological examination. The report stated: "Synovium with a villous configuration, increased vascularity, areas of edema and vascular congestion, and active fibroblasts. No significant inflammatory infiltrate is seen. Mature cartilage with foci of mineralization. Diagnosis: synovium with reactive changes and morphological findings consistent with an intra-articular loose body."

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How to cite this article: Caruso F, Promizio N, Korol D. Postgraduate Orthopedic Instruction – Imaging. Case Resolution. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):519-523. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2428>

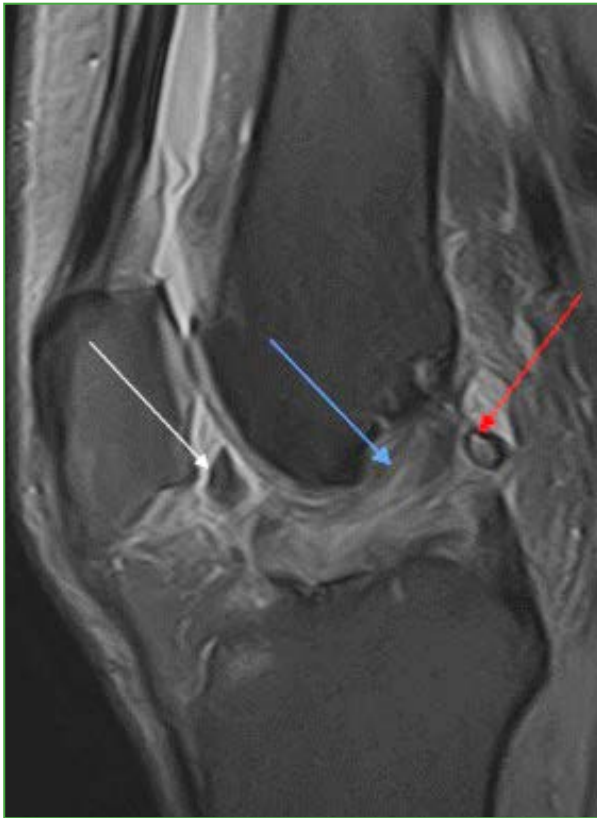


Figure 2. Sagittal fat-suppressed proton density-weighted MRI of the knee showing magnetic susceptibility artifacts related to the anterior cruciate ligament reconstruction. The graft has normal signal intensity and morphology (blue arrow). Well-defined low-signal lesions include a rounded 6-mm lesion anterior to the proximal third of the graft (white arrow) and a rounded 9-mm lesion posterior to its proximal third (red arrow).



Figure 3. Axial fat-suppressed proton density-weighted MRI of the knee showing well-defined intra-articular low-signal lesions posterior to the patella and along the intercondylar line (white arrows), together with increased joint fluid (red arrow).



Figure 4. Sagittal fat-suppressed proton density-weighted MRI of the knee showing an intact posterior cruciate ligament with normal orientation (red arrow) and an anterior intra-articular low-signal lesion (white arrow).



Figure 5. Coronal fat-suppressed T2-weighted MRI of the knee showing well-defined intra-articular low-signal lesions (blue arrows), joint effusion, and apparently intact collateral ligaments (red arrow).

The patient returned to physical activity without complications, with full knee range of motion and no limitations or locking.

Vasudevan et al. describe synovial chondromatosis as a rare, benign condition characterized by metaplastic transformation of the synovial membrane, resulting in multiple intra-articular cartilaginous bodies.¹

The condition predominantly affects men aged 20–50 years and has a prevalence of 1 in 100,000 people.¹ Although considered nonaggressive and self-limiting, synovial chondromatosis can cause substantial joint damage if not adequately treated.¹ According to Yin-Tsi Palma and Gómez, MRI can identify complications associated with ACL repair and distinguish between complete and partial tears in cases of graft failure, helping guide treatment decisions.² It is also the imaging modality of choice for identifying anterior arthrofibrosis and helps rule out intra-articular collections and soft tissue infection after surgery.² Alvarez-Lopez et al. note that the many advantages of arthroscopy make it the most effective surgical approach for diagnosing and treating patients with intra-articular loose bodies.³ Diagnosis rests on clinical, imaging, and arthroscopic findings, and treatment involves several successive stages.³ Diagnosing synovial chondromatosis of the knee requires a thorough clinical assessment and diagnostic imaging.⁴ Plain radiographs may reveal intra-articular calcifications, although these are not always visible in the early stages.⁴ MRI is useful for detecting intra-articular loose bodies, assessing cartilage condition, and determining the extent of synovial involvement.⁴

Treatment of synovial osteochondromatosis is surgical and involves excision of the nodules, with or without total synovectomy. An open or arthroscopic approach is chosen according to fragment size, location, and the surgeon's experience. Surgery should be performed early when the condition is clinically suspected to prevent progressive joint deterioration and even malignant transformation into chondrosarcoma.⁵ MRI findings vary with the degree of mineralization. The most common pattern, present in 77% of cases, consists of low-to-intermediate signal intensity on T1-weighted images and very high signal intensity on T2-weighted images, with low-signal calcifications.⁶ These MRI signal characteristics and the low attenuation of nonmineralized regions on CT reflect the high water content of cartilaginous lesions.⁶ In the early stages, bone scintigraphy is positive, while CT and MRI may help locate loose bodies.⁷

Synovial chondromatosis is characterized by the formation of metaplastic chondroid nodules in the subsynovial connective tissue of the synovial membrane lining joints, tendon sheaths, and bursae.⁸ These nodules often protrude into the joint cavity, become pedunculated, and detach to form loose bodies.⁸ They may continue to grow within the synovial fluid, which supplies their nutrients. The knee is the most frequently affected joint.⁸ Radiographically, the condition is characterized by calcified bodies associated with the joint cavity. Pathological examination shows characteristic gross findings: areas of synovial membrane with sessile or pedunculated nodules of varying sizes and loose bodies ranging from 1 mm to several centimeters in diameter.⁸ Comba et al. evaluated 10 patients who underwent hip arthroscopy between 2007 and 2011. None had other relevant medical history or disease at another site.⁹ Six were athletes, including three engaged in high-demand sports: two cyclists and one marathon runner. Diagnosis followed a protocol of clinical examination, radiographs, and MRI and was confirmed in all cases by subsequent histological examination. MRI showed findings characteristic of synovial chondromatosis in every case.⁹ MRI is also recommended for detecting synovial abnormalities, including nodules or thickening that may suggest the diagnosis.¹⁰ Nevertheless, the most effective diagnostic method is histopathological examination of a synovial biopsy, which reveals nodules of mature hyaline cartilage in the subsynovial layer of the synovial membrane, as well as mature cartilage nodules with central ossification and osteoblastic rimming.¹⁰

In our case, the patient's history and clinical presentation prompted MRI to establish the diagnosis and guide management, as described by Yin-Tsi Palma and Gómez. Following the approach described by Alvarez-Lopez et al., we proceeded with surgical exploration and removal of nine small loose bodies of synovial origin (1 cm x 0.6 cm and 0.9 cm), which were submitted to the pathology department. The patient continued rehabilitation and returned to his usual activities without complications.

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Case Resolution

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Synovial Chondromatosis of the Knee

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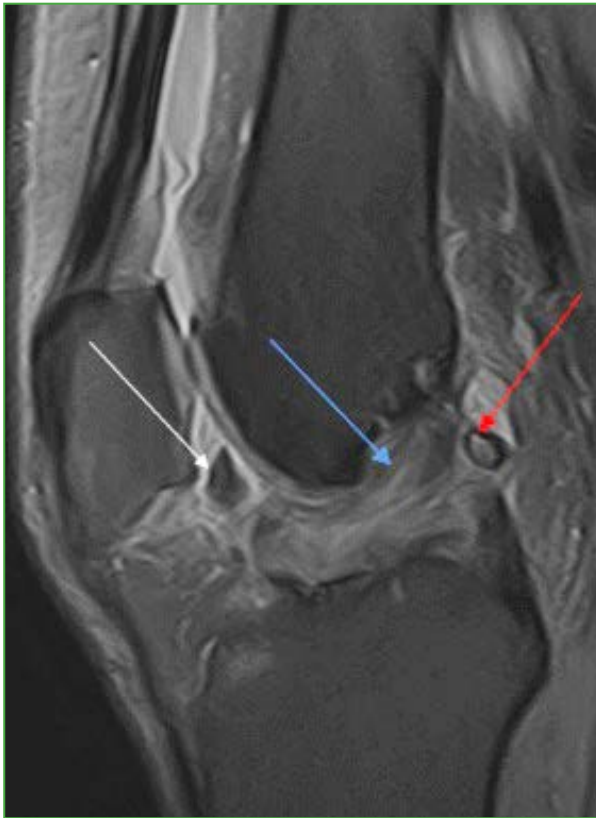


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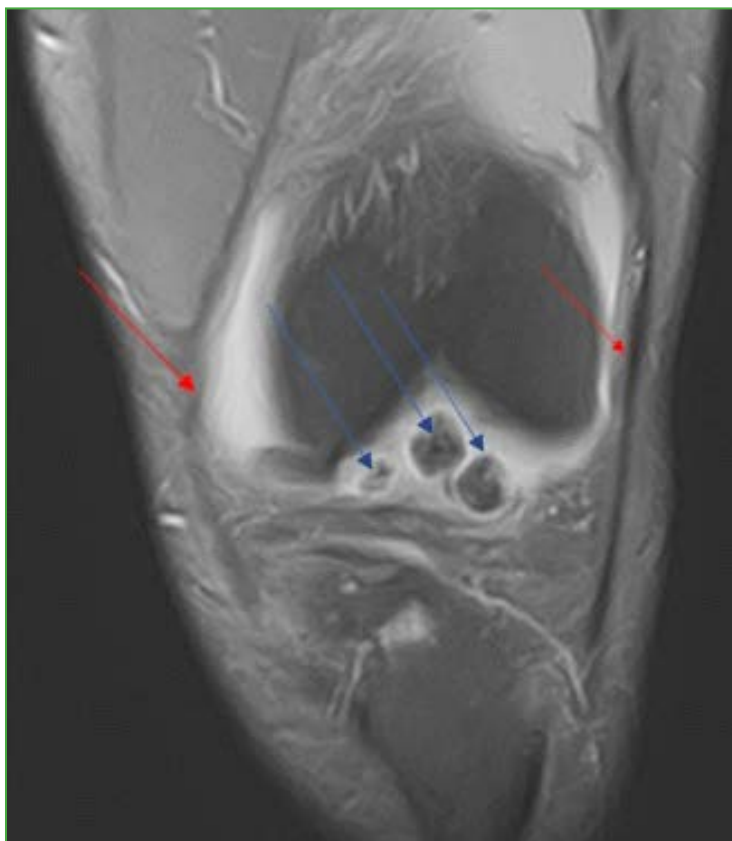


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