

Editorial

The Path to Full Robotic Integration in Orthopaedic Surgery: A Binational Perspective

Umberto Vitale, MD^{1,2}^a, Federico D'Amario, MD^{3b}, Fabio Orozco, MD²

¹ Biomedical sciences, IRCCS Humanitas Research Hospital, ² Orozco Orthopaedics, ³ Orthopaedics and Traumatology, Casa di Cura Humanitas San Pio X

Keywords: robotic-assisted surgery, total joint arthroplasty, total knee arthroplasty, total hip arthroplasty, learning curve, outpatient arthroplasty, surgical innovation

<https://doi.org/10.60118/001c.145740>

Journal of Orthopaedic Experience & Innovation

Vol. 7, Issue 1, 2026

Robotic-assisted technology is transforming total joint arthroplasty (TJA), though surgeons often take very different paths to adoption. This binational perspective compares two high-volume practices. One, in the United States, has relied exclusively on a single robotic platform (Mako®) for more than 7,000 procedures, refining workflows to support same-day discharge and consistent outcomes. The other, in Italy, adopted a multi-platform strategy, achieving proficiency with ROSA®, CORI™, and Mako® systems and transitioning to 100% robotic utilisation within a year. Despite contrasting approaches, both models have delivered measurable gains in surgical accuracy, reproducibility, soft tissue preservation, and recovery speed compared with manual techniques. The robotic "learning curve" is reframed as a continuous process of technical and cognitive refinement. When supported by deliberate use, institutional commitment, and adaptability, diverse strategies can achieve full robotic integration and improve patient-specific care.

TWO PATHS, ONE ROBOTIC VISION

The introduction of robotic-assisted technology has significantly transformed the total joint arthroplasty (TJA) practice in the United States and the rest of the world (Khan et al. 2025; Inabathula et al. 2024). Robotic systems, which were once regarded as experimental or niche, are now fully integrated into academic and private institutions with broad utilization due to ample evidence of their impact on precision, consistency, and patient satisfaction (Hampp, Chughtai, et al. 2019; Emara et al. 2021).

This article synthesizes the insights of Dr. Fabio R. Orozco, an American orthopaedic surgeon proficient in outpatient joint replacement and robotic surgery, and Dr. Federico D'Amario, an Italian orthopaedic surgeon and specialist in the robotic minimally invasive knee arthroplasty. They aim to continue fostering innovation in robotic orthopaedic surgery, in which their distinct clinical experiences offer a cohesive transatlantic viewpoint.

Their professional career paths collectively illustrate two complementary approaches to adopting robotics in orthopaedic surgery. The American surgeon has maintained a single-robotic platform and implant system, performing over 7,000 robotic total knee arthroplasties (Grau et al.

a I am a final-year orthopedic surgery resident at the Humanitas University School of Specialization in Milan, Italy. I have completed an Observership in the United States and a Fellowship at St. MarteenKliniek. My professional interests focus on prosthetic surgery, particularly primary and robotic-assisted knee arthroplasty, as well as complex revision procedures.

[Connect with Umberto Vitale on LinkedIn](#)

[Conflicts of Interest Statement for Umberto Vitale](#)

b With over 25 years of experience and more than 5,000 prosthetic surgeries (including 540 robotic procedures), Dr. D'Amario is a leader in robotic hip and knee prosthetic surgery, focusing on complex revisions and sports medicine. 5000+ hip and knee prosthetic surgeries, 540 robotic surgeries (Mako, ROSA), 6000+ sports medicine and arthroscopy procedures, pioneer of the School of Robotics for international surgeon training. "Robotic surgery is not the future: it is the present standard. Millimetric precision for rapid recovery and custom prostheses." Affiliations: Humanitas San Pio X (Milan), GVM Rapallo, Habilita (AL/NO), FDA Salute (MI/CO). Contacts: Via Vincenzo Monti 79, Milan | Mon-Sat 9:00-20:00

[Visit Dr. D'Amario](#)

[Connect with Dr. D'Amario on LinkedIn](#)

[Conflicts of Interest Statement for Dr. D'Amario](#)

2019). This longitudinal focus has enabled procedural optimization, reproducibility, efficiency, and surgical accuracy and outcomes mastery (Mahoney et al. 2022; Sultan et al. 2019; Khlopas et al. 2020).

The Italian surgeon's experience contrasts this focus, illustrating the benefits of having broad cross-platform versatility and proficiency in three distinct robotic systems. This adaptability stems from a command of manual, free-hand arthroplasty, where practitioners need to understand anatomy to perform flexibly. This form of cross-platform experience supports emerging theories positing that exposure to multiple systems could enhance critical situational judgement and broaden a procedure's scope ("What We've Learned From 10,000 Robot-Assisted Total Joint Replacements," n.d.; Fan et al. 2025a).

Regardless of the approach, the common goal is to apply robotic technology to achieve better surgical precision, reduced variability, and improved clinical outcomes. The depth and breadth of our experiences highlight the broader capacity of robotics, and with that rigor and intent, orthopaedic care can be fully transformed.

The manuscript originates from the longstanding professional bond between Dr. D'Amario and Dr. Orozco, who aim to promote robotic-assisted orthopaedic surgery. Their collaboration seeks to provide practical insights for surgeons adopting robotic systems at different levels of experience, fostering a more nuanced understanding of robotics in arthroplasty.

ACROSS MULTIPLE PLATFORMS: THE EUROPEAN PERSPECTIVE WITH DR. FEDERICO D'AMARIO

The Italian experience stands out as uniquely progressive, multi-platform model of robotic integration grounded in versatility, systematic execution, and enduring institutional commitment (Ponna et al., n.d.). The initiative started in October 2020 with ROSA® Knee System (Zimmer Biomet Holdings, Inc., Warsaw, IN, USA) integration during the peak of the COVID-19 pandemic. Regardless of logistical and clinical constraints, robotic-assisted total knee arthroplasty (RA-TKA) was almost immediate, indicating the feasibility of full digital integration even in resource-limited settings (Kayani et al. 2019; Bosco et al. 2025).

By November 2021, our department had gained access to the ROSA® system. The surgical team transitioned to performing 100% of primary TKAs robotically within a year. It illustrates the value of standardized training pathways, protocol-driven workflows, and team-based collaboration covering the perioperative spectrum ("Introduction of ROSA Robotic-Arm System for Total Knee Arthroplasty Is Associated with a Minimal Learning Curve for Operative Time" 2025; Vanlommel et al. 2021).

In 2022, the center was designated an official ROSA Efficient Care Center for the EMEA region, emphasizing its robotic-assisted joint arthroplasty role. The use of adjunct digital health technologies, like the MyMobility® app and advanced analytics tools such as ZBEdge™, has enabled the capture of real-time perioperative and functional data, al-

lowing for evidence-based intraoperative decision-making and optimizing long-term outcomes (Kayani and Haddad 2019a; Lonner et al. 2023; Walgrave and Oussedik 2022a; Yocum, Redfern, and Yergler 2025).

In 2023, the robotic infrastructure continued to expand with the introduction of the CORI™ Surgical System (Smith & Nephew plc, Watford, Hertfordshire, United Kingdom) for medial and lateral unicompartamental knee arthroplasty. This system performs image-free navigation and robotic bone resurfacing, enhancing accuracy while improving soft tissue preservation (Adamska et al. 2023; Migliorini et al. 2023). At the same time, CORI™ Hip was launched for total hip arthroplasty (THA) and has carried out over 100 cases to date, supported by dedicated training partnerships (Fan et al. 2025b; "Smith+Nephew Expands Next-Generation, Handheld Robotic-Assisted CORI Surgical System, into Total Hip Arthroplasty with RI.HIP NAVIGATION," n.d.).

Simultaneously, the Mako® robotic system (Stryker Corporation, Kalamazoo, MI, USA) was integrated for both total and unicompartamental knee arthroplasty. The program completed 200 total knee replacements and 100 unicompartamental procedures, with the majority performed cementlessly. It is consistent with recent trends favoring biologic fixation in RA-TKA, which were made possible by the precision of robotic instrumentation and bone preservation offered (Helvie, Deckard, and Meneghini 2023; Hannon et al. 2023).

By June 2025, the multi-platform robotic arthroplasty program performed 2,200 total procedures, with over 900 cementless total knee replacements (TKRs). This volume is a significant institutional milestone, indicative not only of high adoption but also of procedural refinement and clinical maturity.

Advanced high-resolution 3D models improve patient-specific surgical planning by enabling proactive management of osseous deformities, bone defects, and implant positioning challenges (Kayani and Haddad 2019b; Ma et al. 2024). Intraoperatively, precision bone cuts and soft tissue balancing reduce the necessity for ligamentous releases, which is critical for the maintenance of soft tissue and joint stability. These factors are integral to joint stability and soft tissue preservation (A. C. Gordon, Conditt, and Verstraete 2021; Tsai et al. 2024; Armendariz et al. 2024).

Most patients can start ambulation in hours after surgery, with a return to baseline daily activities typically observed within two to three weeks. These outcomes represent a substantial acceleration compared to the time it takes to recover using traditional pathways, and align with enhanced recovery after surgery (ERAS) protocols (Archer et al. 2023; Weiner et al. 2023). Factors that enhance recovery include multimodal analgesia, robotic precision in surgical execution, and integration of digital rehabilitation tools (Bhowmik-Stoker et al. 2022; Bhimani et al. 2020; Gao et al. 2022; Lebleu et al. 2023).

Implementing a multi-platform robotic strategy emphasizes a critical focal point in surgical innovation. In the Italian experience, system selection depends largely on workflow integration and available support rather than a clear

superiority in clinical outcomes. While ROSA® emphasizes simplicity and quick intraoperative setup, other systems such as Mako® or CORI® offer more tactile or modular features. Surgeons should select platforms that align with their institutional needs and surgical philosophy.

In the United States, robotic systems typically obtain FDA 510(k) clearance within 9–12 months, whereas in Europe, the CE marking process under the MDR framework is generally slower and more variable, depending on the notified body's assessment. In Italy, additional steps such as regional procurement and post-market surveillance coordinated by the Ministry of Health can further extend timelines. As a result, European and Italian adoption tends to proceed more gradually, and comparison with the U.S. experience can offer useful perspective for anticipating later phases of implementation and software evolution.

The economic implications of robotic integration remain considerable. Although acquisition and maintenance costs are high, downstream efficiencies—such as reduced operative variability, optimized implant positioning, and lower revision rates—may help offset early investment. Cost-effectiveness analyses in robotic-assisted total knee arthroplasty (RA-TKA) indicate that, despite higher upfront costs, robotic surgery can achieve acceptable incremental cost-effectiveness ratios (ICERs) in high-volume centers owing to improved precision and fewer complications (Hua and Salcedo 2022). Systematic reviews across surgical specialties similarly report that, while robotic procedures remain more expensive overall, the cost gap narrows when accounting for long-term outcomes, shorter hospital stays, and lower revision risks (Sadri et al. 2023; Hoeffel et al. 2023). Cost-sharing models, cross-specialty use, and workflow standardization further support the financial sustainability of robotic programs within healthcare systems.

True mastery demands both technological versatility and cognitive integration across systems (Walgrave and Oussedik 2022b). Robotic proficiency does not come from simple mechanical repetition but involves tailoring each platform's strengths to individualized care ("Comparative Assessment of Current Robotic-Assisted Systems in Primary Total Knee Arthroplasty - PubMed," n.d.).

THE AMERICAN PERSPECTIVE: DR. FABIO OROZCO – A JOURNEY OF ROBOTIC LOYALTY AND SURGICAL INNOVATION

Dr. Fabio R. Orozco is an early adopter of robotic-assisted surgery due to its potential to improve precision and consistency in orthopaedic procedures. His use of robotic technology reflects a data-driven interest in surgical innovation and patient outcomes. While the broader adoption of robotics has progressed gradually within the orthopaedic community, Dr. Orozco's involvement is notable because it represents a commitment to investigate the potential of robotics in medicine.

His first engagement with robotics was with the Mako® robotic platform, developed by Stryker Corporation, Kalamazoo, MI, USA ("Mako SmartRobotics Overview," n.d.). His approach differs from many who worked with various

systems one at a time or switched between manual and robotic techniques. Dr. Orozco committed himself fully to this technology from its initial introduction. Through its evolutionary changes over the years, he remained loyal to the platform and its manufacturer, forging a long-standing, mutually beneficial collaboration.

Rather than viewing the robot simply as a tool, Dr. Orozco fostered a deep, symbiotic relationship with the Mako® system. He exercised his surgical skills with the evolution of the platform, actively contributing to its clinical development and optimization. He has mastered every nuance of the system due to the thousands of procedures he has done, using it to enhance precision, reproducibility, and patient outcomes. Today, he is among the most prolific users of Mako® systems globally, having performed more than 1,500 robotic joint replacements annually for almost 15 years.

However, Dr. Orozco's is not only known for his surgical precision. He was the first pioneer in advocating for same-day discharge protocols in joint arthroplasty, a concept that sparked controversy at the time. He dedicated himself to designing adaptable protocols that would allow patients to safely undergo total joint replacement and return home on the same day.

Through relentless research, clinical innovation, and multidisciplinary collaboration, Dr. Orozco could implement same-day discharge as a safe and effective option for certain patients. He has transformed perioperative care models, influenced national guidelines, and empowered other surgeons to practice same-day discharge. In many instances, his same-day discharge protocols would not have been feasible without the consistency, accuracy, and soft tissue preservation afforded by robotic assistance ("Just a Moment...", n.d.; Hampp, Sodhi, et al. 2019).

THE CONCEPT OF LEARNING CURVE

The learning curve concept, particularly in robotic surgery, is often oversimplified. It is usually defined as the amount of time it takes to perform a procedure with the same efficiency as before adopting a new technique or technology ("Systematic Review of Learning Curves in Robot-Assisted Surgery - PMC," n.d.). However, this definition is far too simple and does not capture the true essence of surgical adaptation.

A learning curve in robotic-assisted surgery goes beyond learning how to reduce time or improve procedural efficiency. While these quantifiable benchmarks are often used to gauge initial proficiency, they represent only the surface of a far more profound and intricate journey. The depth of the learning curve resonates with the surgeon's mindset, which involves a blend of cognitive flexibility, emotional intelligence, and an openness to re-evaluating ingrained surgical practices. Robotic surgical mastery is not a destination reached after a finite number of cases. It is an ongoing process characterized by humility, curiosity, and an unyielding commitment to continuous self-improvement.

This journey centers around adaptability, which is not confined to the early phases of robotic adoption, but applies

to all surgeons regardless of age, experience, or institutional reputation. The ability to learn does not decrease with age. Instead, it is determined by the willingness of the surgeon to engage in lifelong learning and harness the principles of neuroplasticity, which is the brain's remarkable ability to reorganize itself in response to new challenges.

Training curricula should emphasize manual skills and spatial understanding before exposure to robotic-assisted procedures. While fundamental surgical judgment remains essential, robotics can accelerate young surgeons' comprehension of knee biomechanics by providing real-time, data-driven feedback on alignment and soft-tissue balance. In recent years, dedicated robotic training opportunities ranging from webinars to hands-on workshops have expanded, and it is increasingly common for residents and fellows to perform supervised robotic procedures. In this sense, robotics now complements traditional teaching by enhancing biomechanical reasoning through objective visualization and by becoming progressively integrated into standard orthopedic education.

Moreover, structured training combining simulation and mentorship enhances understanding of intraoperative metrics and their relationship with soft-tissue tension. Over time, surgeons progressively recognize how each surgical maneuver influences the balancing parameters and vice versa, developing an anticipatory reasoning process. This cognitive evolution often leads to the creation of an individualized surgical decision-making algorithm that refines both efficiency and accuracy during robotic-assisted procedures.

This relationship cultivates a level of surgical mindfulness usually lacking in conventional procedures. Each case serves as a chance to reassess assumptions, refine techniques, and incorporate incremental innovations. Instead of trying to "conquer" the learning curve, the surgeon learns to embrace it as a continuous ascent, where every new challenge is viewed as an opportunity to grow.

From this perspective, the learning curve is not a hurdle to be cleared, but a pathway leading to higher levels of surgical excellence. It demands an emotional investment, patience in the face of early inefficiencies, resilience through moments of frustration, and an enduring sense of purpose centered on patient outcomes. It also necessitates a change within surgical teams and institutions, recognizing that robotic integration is not merely a technological upgrade, but a comprehensive transformation in surgical philosophy and daily workflow.

Most importantly, the end of the learning curve is not marked solely by reductions in operative time. It is possible that surgical time decreases or becomes neutral over time compared to manual techniques, but this does not necessarily indicate that the learning curve has concluded. The pivotal moment occurs when the surgeon begins to trust the system so deeply that even when intraoperative data appears counterintuitive, there is confidence in the system's accuracy and reliability. Achieving this level of trust signifies a profound shift in the learning curve, moving from mechanical execution to cognitive integration.

HOW TO BECOME A '100% ORTHOPAEDIC ROBOTIC SURGEON'

The transition to robotic-assisted TKA is not driven by dissatisfaction with conventional techniques, but by the pursuit of greater reproducibility and accuracy, supported by objective intraoperative metrics on alignment and ligament balancing. Embracing robotics therefore requires a profound and consistent commitment that reshapes the surgeon's mindset, workflows, and approach to patient care, as occasional or isolated use hinders the continuous learning and confidence needed to fully master the technology.

True proficiency in robotic surgery is not achieved by mastering isolated technical steps, but by fully integrating the technology into everyday practice so that each case reinforces fluency with the platform. Every procedure becomes an opportunity to deepen understanding of the interaction between robot, surgical technique, and patient-specific anatomy, using continuous feedback to refine a personal decision-making algorithm that improves both efficiency and accuracy over time.

Ultimately, mastery of robotic surgery is not a fixed destination. It is a dynamic journey marked by humility, the recognition that every case presents new lessons, perseverance, and the relentless drive to leverage technology to improve patient outcomes. Adopting this perspective allows one not to be a mere user of robotic technology but to become architects of a future where precision, consistency, and individualized care are elevated to unprecedented levels.

As of 2025, robotic platforms operate under a paradigm of complete surgeon autonomy (A. M. Gordon et al. 2025). Despite recent progress in sensor technologies, real-time data acquisition, and haptic feedback, the robotic components do not possess intelligence. The autonomy a robot may possess in judgment and execution remains firmly in the hands of the surgeon. Consequently, problems that may arise are intermittent and may be caused by the robot's mechanics. As with any high-performance instrument, whether it be a surgical robot, a scalpel, or a navigation system, the user's skills and acumen, especially in the clinical setting, are crucial in determining the results.

Robotics in surgery serves as a humbling reminder that technology alone cannot resolve the inherent complexities of orthopaedic procedures. Instead, it provides a structured platform for iterative improvement, challenging surgeons to elevate every aspect of their practice, from preoperative planning to intraoperative precision and postoperative care. In a world where approximately 20% of knee arthroplasty patients report dissatisfaction with their surgical outcomes, the precision and reproducibility afforded by robotic assistance compel us to scrutinize and enhance each step of our workflow. Robotic systems amplify the surgeon's capacity for excellence but simultaneously expose any lapses in planning, technique, or judgment (Smith et al. 2021; Gunaratne et al. 2017).

It is essential to resist the temptation to reduce robotic surgery to the role of a glorified digital caliper. The actual value of robotic technology lies in its ability to revolu-

tionize three-dimensional surgical planning, optimize deformity correction strategies, and facilitate meticulous implant positioning. For instance, contemporary robotic platforms can execute bone resections with an accuracy five times greater than manual techniques. These advancements represent fundamental shifts in our capacity to deliver predictable, patient-specific outcomes (“Robotic-Arm Assisted Total Knee Arthroplasty Demonstrated Greater Accuracy and Precision to Plan Compared with Manual Techniques - PubMed,” n.d.; Li et al. 2022).

Preoperative CT-based templating allows surgeons to visualize bone defects and optimize bone preservation (Pietrzak et al. 2018; Crutcher et al. 2023). Robotic workflows utilize fewer surgical trays, reduce inventory, and improve predictability, allowing the overall streamlining of the operating room environment (Lonner and Goh 2023; “Comparative Cost Analysis of Robotic-Assisted and Jig-Based Manual Primary Total Knee Arthroplasty” 2023).

Emerging robotic systems are evolving toward open, interoperable platforms with enhanced automation and artificial intelligence support. Autoregistration, image-based prediction, and integration with AR environments are expected to further reduce variability and expand indications, marking a shift toward ‘smart surgery’ rather than merely assisted surgery.

PRACTICAL IMPLICATIONS FOR AN ORTHOPEDIC SURGEON INTRODUCING ROBOTICS INTO DAILY PRACTICE

- Team training and workflow integration:

The introduction of robotics requires the entire operating room staff — including scrub technicians and surgical assistants — to be fully trained in the robotic workflow. This includes preoperative robot positioning, intraoperative movements, and procedures for managing logistical variations such as a change of operating room. A coordinated and well-informed team ensures safety and efficiency during robotic-assisted procedures.

- Attention to the registration phase:

The registration process represents a critical step in robotic surgery and demands exceptional accuracy and concentration. Any error at this stage may compromise the quality of the entire procedure. The surgeon must therefore allocate adequate time and attention to this phase, considering it as important as other key surgical steps.

- Collaboration with external technical personnel:

Robotic systems often require the assistance of a technical representative from the manufacturing company, who operates outside the sterile field. This necessitates the establishment of a clear, direct, and trust-based communication channel. The success of the intervention frequently depends on this professional relationship and on mutual understanding between the surgical and technical teams.

- Recognition of workflow differences from traditional surgery:

The robotic workflow includes steps — such as pin placement and anatomical registration — that differ from conventional orthopedic procedures. These must be treated with the same diligence and respect as other traditionally delicate moments of the surgery, as they significantly influence accuracy and outcomes.

- Preparedness for system-specific complications:

Adopting a robotic system implies accepting both its advantages and potential drawbacks. The surgeon must be prepared to manage complications such as pin loosening or issues with intra-articular checkpoints, developing predefined strategies to address them effectively.

- Integration between the robotic system and implant design:

When a surgeon commits to a specific robotic platform, they also effectively adopt the associated implant system. It is therefore crucial to develop a thorough understanding of the implant’s characteristics, design philosophy, and biomechanical nuances. Aligning the implant’s intrinsic properties with the technical capabilities of the robot is essential to achieving optimal clinical outcomes and ensuring that the robotic workflow fully complements the implant’s intended function.

- Cultural and professional adaptation:

Beyond its technological dimension, robotic surgery represents a cultural transformation in orthopedic practice. It requires continuous education, adaptability, and close interdisciplinary cooperation to fully integrate this technology into daily clinical routines.

CONCLUSION

In the end, robotic surgery is not about competing with technology but evolving alongside it. Integrating advanced technologies into surgical practice represents a natural progression in pursuing greater precision, consistency, and patient-centered outcomes. Innovation can be disruptive, while challenging established habits, workflows, and perceptions of surgical craftsmanship. However, resisting these advancements while preserving tradition may hinder clinical progress and patient benefit.

Surgeons are not being replaced by machines but are being empowered by tools that augment their capabilities, reduce variability, and allow for more personalized, data-driven decision-making. Mastery in the modern surgical era requires technical proficiency and cognitive adaptability to recognize when and how to leverage technological strengths to enhance patient care. By embracing and mastering these innovations, surgeons position themselves to lead this evolution rather than be passive observers, ensuring that the human element of surgery remains central, amplified by precision technology rather than overshadowed by it.

.....

CONFLICT OF INTEREST

Inc. MAKO® is a registered trademark of Mako Surgical Corp.

ROSA® is a registered trademark of Medtech S.A.

CORI® is a registered trademark of Smith & Nephew, Inc.

This material is intended for healthcare professional attendees. Distribution to any other recipient is prohibited.

Dr. D'Amario reports consultancy roles with Zimmer Biomet and Smith & Nephew, outside the submitted work. Dr.

Orozco reports consultancy with Stryker, outside the submitted work.

No other conflicts of interest are declared by the authors.

FUNDING STATEMENT

No external funding was received for the preparation of this manuscript.

Submitted: August 10, 2025 EDT. Accepted: October 08, 2025 EDT. Published: March 08, 2026 EDT.



This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY-NC-ND-4.0). View this license's legal deed at <https://creativecommons.org/licenses/by-nc-nd/4.0> and legal code at <https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode> for more information.

REFERENCES

- Adamska, O., K. Modzelewski, J. Szymczak, J. Świderek, B. Maciąg, P. Czuchaj, et al. 2023. "Robotic-Assisted Total Knee Arthroplasty Utilizing NAVIO, CORI Imageless Systems and Manual TKA Accurately Restore Femoral Rotational Alignment and Yield Satisfactory Clinical Outcomes: A Randomized Controlled Trial." *Medicina (Mex)* 59:236. <https://doi.org/10.3390/medicina59020236>.
- Archer, A., H. S. Salem, A. Coppolecchia, and M. A. Mont. 2023. "Lengths of Stay and Discharge Dispositions after Total Knee Arthroplasty: A Comparison of Robotic-Assisted and Manual Techniques." *J Knee Surg* 36:404–10. <https://doi.org/10.1055/s-0041-1735280>.
- Armendariz, M., B. J. Tadros, D. Collopy, and G. Clark. 2024. "No Evidence of Mid-Flexion Instability after Robotic-Assisted Total Knee Arthroplasty as Assessed by Intraoperative Pressure Sensors." *Arthroplasty* 6:32. <https://doi.org/10.1186/s42836-024-00253-3>.
- Bhimani, S. J., R. Bhimani, A. Smith, C. Eccles, L. Smith, and A. Malkani. 2020. "Robotic-Assisted Total Knee Arthroplasty Demonstrates Decreased Postoperative Pain and Opioid Usage Compared to Conventional Total Knee Arthroplasty." *Bone Jt Open* 1:8–12. <https://doi.org/10.1302/2633-1462.12.BJO-2019-0004.R1>.
- Bhowmik-Stoker, M., K.K. Mathew, Z. Chen, A.F. Chen, W.J. Hozack, O. Mahoney, et al. 2022. "Return to Work and Driving After Robotic Arm-Assisted Total Knee Arthroplasty." *Arthroplasty Today* 16:219–23. <https://doi.org/10.1016/j.artd.2022.06.002>.
- Bosco, F., G. Rovere, C. Burgio, G. Lo Bue, C. D. Cobisi, R. Giai Via, et al. 2025. "Accuracy and Learning Curve of Imageless Robotic-Assisted Total Knee Arthroplasty." *J Orthop* 66:77–83. <https://doi.org/10.1016/j.jor.2024.12.029>.
- "Comparative Assessment of Current Robotic-Assisted Systems in Primary Total Knee Arthroplasty - PubMed." n.d. Accessed August 2, 2025. <https://pubmed-ncbi-nlm-nih-gov.humanitas.idm.oclc.org/36602297/>.
- "Comparative Cost Analysis of Robotic-Assisted and Jig-Based Manual Primary Total Knee Arthroplasty." 2023. *ResearchGate*. <https://doi.org/10.1055/s-0040-1713895>.
- Crutcher, J. P., D. Hameed, J. Dubin, M. A. Mont, and M. Mont. 2023. "Comparison of Three-versus Two-Dimensional Pre-Operative Planning for Total Hip Arthroplasty." *J Orthop* 47:100–105. <https://doi.org/10.1016/j.jor.2023.11.001>.
- Emara, A.K., G. Zhou, A.K. Klika, S.M. Koroukian, N.K. Schiltz, V.E. Krebs, et al. 2021. "Robotic-Arm-Assisted Knee Arthroplasty Associated With Favorable In-Hospital Metrics and Exponentially Rising Adoption Compared With Manual Knee Arthroplasty." *J Am Acad Orthop Surg* 29:e1328–42. <https://doi.org/10.5435/JAAOS-D-21-00146>.
- Fan, X., Y. Wang, S. Zhang, Y. Xing, J. Li, X. Ma, et al. 2025a. "Orthopedic Surgical Robotic Systems in Knee Arthroplasty: A Comprehensive Review." *Front Bioeng Biotechnol* 13:1523631. <https://doi.org/10.3389/fbioe.2025.1523631>.
- . 2025b. "Orthopedic Surgical Robotic Systems in Knee Arthroplasty: A Comprehensive Review." *Front Bioeng Biotechnol* 13:1523631. <https://doi.org/10.3389/fbioe.2025.1523631>.
- Gao, C., T. Huang, K. Wu, W. Zhang, S. Wang, X. Chai, et al. 2022. "Multimodal Analgesia for Accelerated Rehabilitation after Total Knee Arthroplasty: A Randomized, Double-Blind, Controlled Trial on the Effect of the Co-Application of Local Infiltration Analgesia and Femoral Nerve Block Combined with Dexmedetomidine." *Brain Sci* 12:1652. <https://doi.org/10.3390/brainsci12121652>.
- Gordon, A. M., P. Nian, J. Baidya, and M. A. Mont. 2025. "Trends of Robotic Total Joint Arthroplasty Utilization in the United States from 2010 to 2022: A Nationwide Assessment." *J Robot Surg* 19:155. <https://doi.org/10.1007/s11701-025-02313-5>.
- Gordon, A.C., M.A. Conditt, and M.A. Verstraete. 2021. "Achieving a Balanced Knee in Robotic TKA." *Sensors* 21:535. <https://doi.org/10.3390/s21020535>.
- Grau, L., M. Lingamfelter, D. Ponzio, Z. Post, A. Ong, D. Le, et al. 2019. "Robotic Arm Assisted Total Knee Arthroplasty Workflow Optimization, Operative Times and Learning Curve." *Arthroplasty Today* 5:465–70. <https://doi.org/10.1016/j.artd.2019.04.007>.
- Gunaratne, R., D. N. Pratt, J. Banda, D. P. Fick, R. J. K. Khan, and B. W. Robertson. 2017. "Patient Dissatisfaction Following Total Knee Arthroplasty: A Systematic Review of the Literature." *J Arthroplasty* 32:3854–60. <https://doi.org/10.1016/j.arth.2017.07.021>.

- Hampp, E. L., M. Chughtai, L. Y. Scholl, N. Sodhi, M. Bhowmik-Stoker, D. J. Jacofsky, et al. 2019. "Robotic-Arm Assisted Total Knee Arthroplasty Demonstrated Greater Accuracy and Precision to Plan Compared with Manual Techniques." *J Knee Surg* 32:239–50. <https://doi.org/10.1055/s-0038-1641729>.
- Hampp, E. L., N. Sodhi, L. Scholl, M. E. Deren, Z. Yenna, G. Westrich, et al. 2019. "Less Iatrogenic Soft-Tissue Damage Utilizing Robotic-Assisted Total Knee Arthroplasty When Compared with a Manual Approach." *Bone Jt Res* 8:495–501. <https://doi.org/10.1302/2046-3758.810.BJR-2019-0129.R1>.
- Hannon, C. P., R. Salih, R. L. Barrack, and R. M. Nunley. 2023. "Cementless Versus Cemented Total Knee Arthroplasty: Concise Midterm Results of a Prospective Randomized Controlled Trial." *J Bone Joint Surg Am* 105:1430–34. <https://doi.org/10.2106/JBJS.23.00161>.
- Helvie, P. F., E. R. Deckard, and R. M. Meneghini. 2023. "Cementless Total Knee Arthroplasty Over the Past Decade: Excellent Survivorship in Contemporary Designs." *J Arthroplasty* 38:S145–50. <https://doi.org/10.1016/j.arth.2023.02.009>.
- Hoeffel, D., L. Goldstein, D. Intwala, L. Kaindl, A. Dineen, L. Patel, et al. 2023. "Systematic Review and Meta-Analysis of Economic and Healthcare Resource Utilization Outcomes for Robotic versus Manual Total Knee Arthroplasty." *J Robot Surg* 17:2899–2910. <https://doi.org/10.1007/s11701-023-01703-x>.
- Hua, Y., and J. Salcedo. 2022. "Cost-Effectiveness Analysis of Robotic-Arm Assisted Total Knee Arthroplasty." *PLOS ONE* 17:e0277980. <https://doi.org/10.1371/journal.pone.0277980>.
- Inabathula, A., D. I. Semerdzhiev, A. Srinivasan, F. Amirouche, L. Puri, and H. Piponov. 2024. "Robots on the Stage: A Snapshot of the American Robotic Total Knee Arthroplasty Market." *JB JS Open Access* 9:e24.00063. <https://doi.org/10.2106/JBJS.OA.24.00063>.
- "Introduction of ROSA Robotic-Arm System for Total Knee Arthroplasty Is Associated with a Minimal Learning Curve for Operative Time." 2025. *ResearchGate*. <https://doi.org/10.1186/s40634-022-00524-5>.
- "Just a Moment..." n.d. Accessed August 2, 2025. https://www.researchgate.net/publication/326101051_Robotic-arm_assisted_total_knee_arthroplasty_is_associated_with_improved_early_functional_recovery_and_reduced_time_to_hospital_discharge_compared_with_conventional_jig-based_total_knee_arthroplasty?utm_source=chatgpt.com.
- Kayani, B., and F. S. Haddad. 2019a. "Robotic Total Knee Arthroplasty." *Bone Jt Res* 8:438–42. <https://doi.org/10.1302/2046-3758.810.BJR-2019-0175>.
- . 2019b. "Robotic Total Knee Arthroplasty." *Bone Jt Res* 8:438–42. <https://doi.org/10.1302/2046-3758.810.BJR-2019-0175>.
- Kayani, B., S. Konan, S. S. Huq, J. Tahmassebi, and F. S. Haddad. 2019. "Robotic-Arm Assisted Total Knee Arthroplasty Has a Learning Curve of Seven Cases for Integration into the Surgical Workflow but No Learning Curve Effect for Accuracy of Implant Positioning." *Knee Surg Sports Traumatol Arthrosc Off J ESSKA* 27:1132–41. <https://doi.org/10.1007/s00167-018-5138-5>.
- Khan, S.T., A.K. Emara, G. Zhou, S.M. Koroukian, Cleveland Clinic Adult Reconstruction Research, N.S. Piuze, et al. 2025. "Robotic-Assisted Total Knee Arthroplasty in the USA: Nationwide Adoption Trends towards 70 % by 2030." *J Clin Orthop Trauma* 68:103069. <https://doi.org/10.1016/j.jcot.2025.103069>.
- Khlopas, A., N. Sodhi, W. J. Hozack, A. F. Chen, O. M. Mahoney, T. Kinsey, et al. 2020. "Patient-Reported Functional and Satisfaction Outcomes after Robotic-Arm-Assisted Total Knee Arthroplasty: Early Results of a Prospective Multicenter Investigation." *J Knee Surg* 33:685–90. <https://doi.org/10.1055/s-0039-1684014>.
- Lebleu, J., A. Pauwels, P. Anract, S. Parratte, P. Van Overschelde, and S. Van Onsem. 2023. "Digital Rehabilitation after Knee Arthroplasty: A Multi-Center Prospective Longitudinal Cohort Study." *J Pers Med* 13:824. <https://doi.org/10.3390/jpm13050824>.
- Li, C., Z. Zhang, G. Wang, C. Rong, W. Zhu, X. Lu, et al. 2022. "Accuracies of Bone Resection, Implant Position, and Limb Alignment in Robotic-Arm-Assisted Total Knee Arthroplasty: A Prospective Single-Centre Study." *J Orthop Surg* 17:61. <https://doi.org/10.1186/s13018-022-02957-1>.
- Lonner, J. H., M. B. Anderson, R. E. Redfern, D. Van Anel, J. C. Ballard, and S. Parratte. 2023. "An Orthopaedic Intelligence Application Successfully Integrates Data from a Smartphone-Based Care Management Platform and a Robotic Knee System Using a Commercial Database." *Int Orthop* 47:485–94. <https://doi.org/10.1007/s00264-022-05651-3>.
- Lonner, J. H., and G. S. Goh. 2023. "Moving beyond Radiographic Alignment: Applying the Wald Principles in the Adoption of Robotic Total Knee Arthroplasty." *Int Orthop* 47:365–73. <https://doi.org/10.1007/s00264-022-05411-3>.

- Ma, N., P. Sun, P. Xin, S. Zhong, J. Xie, and L. Xiao. 2024. "Comparison of the Efficacy and Safety of MAKO Robot-Assisted Total Knee Arthroplasty versus Conventional Manual Total Knee Arthroplasty in Uncomplicated Unilateral Total Knee Arthroplasty a Single-Centre Retrospective Analysis." *Int Orthop* 48:2351–58. <https://doi.org/10.1007/s00264-024-06234-0>.
- Mahoney, O., T. Kinsey, N. Sodhi, M. A. Mont, A. F. Chen, F. Orozco, et al. 2022. "Improved Component Placement Accuracy with Robotic-Arm Assisted Total Knee Arthroplasty." *J Knee Surg* 35:337–44. <https://doi.org/10.1055/s-0040-1715571>.
- "Mako SmartRobotics Overview." n.d. Accessed August 2, 2025. https://www.stryker.com/cl/en/joint-replacement/systems/Mako_SmartRobotics_Overview.html?utm_source=chatgpt.com.
- Migliorini, F., N. Maffulli, L. Schäfer, J. Schneider, A. M. Nobili, D. Kämmer, et al. 2023. "Robotic-Assisted Total Knee Arthroplasty in Clinical Practice: Protocol for a Randomised Controlled Trial." *J Orthop Surg* 18:623. <https://doi.org/10.1186/s13018-023-04101-z>.
- Pietrzak, J. R. T., F. E. Rowan, B. Kayani, M. J. Donaldson, S. S. Huq, and F. S. Haddad. 2018. "Preoperative CT-Based Three-Dimensional Templating in Robot-Assisted Total Knee Arthroplasty More Accurately Predicts Implant Sizes than Two-Dimensional Templating." *J Knee Surg* 32:642–48. <https://doi.org/10.1055/s-0038-1666829>.
- Ponna, A.K., A.M. Giakas, A.A. Khoudary, and A. Siddiqi. n.d. "Advancements in Robotic Orthopaedic Surgery: A Current Concept." *Surgicoll* 2025:3. <https://doi.org/10.58616/001c.132487>.
- "Robotic-Arm Assisted Total Knee Arthroplasty Demonstrated Greater Accuracy and Precision to Plan Compared with Manual Techniques - PubMed." n.d. Accessed August 2, 2025. <https://pubmed-ncbi-nlm-nih-gov.humanitas.idm.oclc.org/29715696/>.
- Sadri, H., M. Fung-Kee-Fung, B. Shayegan, P. Y. Garneau, and P. Pezeshki. 2023. "A Systematic Review of Full Economic Evaluations of Robotic-Assisted Surgery in Thoracic and Abdominopelvic Procedures." *J Robot Surg* 17:2671–85. <https://doi.org/10.1007/s11701-023-01731-7>.
- "Smith+Nephew Expands Next-Generation, Handheld Robotic-Assisted CORIO Surgical System, into Total Hip Arthroplasty with RI.HIP NAVIGATION." n.d. Accessed August 2, 2025. https://www.smith-nephew.com/en/news/2022/01/26/20220126-expands-next-generation-handheld-robotic-assisted-cori-surgical-system-into-total-hip?utm_source=chatgpt.com.
- Smith, A. F., C. J. Eccles, S. J. Bhimani, K. M. Denehy, R. B. Bhimani, L. S. Smith, et al. 2021. "Improved Patient Satisfaction Following Robotic-Assisted Total Knee Arthroplasty." *J Knee Surg* 34:730–38. <https://doi.org/10.1055/s-0039-1700837>.
- Sultan, A. A., L. T. Samuel, A. Khlopas, N. Sodhi, M. Bhowmik-Stoker, A. Chen, et al. 2019. "Robotic-Arm Assisted Total Knee Arthroplasty More Accurately Restored the Posterior Condylar Offset Ratio and the Insall-Salvati Index Compared to the Manual Technique; A Cohort-Matched Study." *Surg Technol Int* 34:409–13.
- "Systematic Review of Learning Curves in Robot-Assisted Surgery - PMC." n.d. Accessed August 2, 2025. https://pmc-ncbi-nlm-nih-gov.humanitas.idm.oclc.org/articles/PMC6996634/?utm_source=chatgpt.com.
- Tsai, H.-K., Z. Bao, D. Wu, J. Han, Q. Jiang, and Z. Xu. 2024. "A New Gap Balancing Technique with Functional Alignment in Total Knee Arthroplasty Using the MAKO Robotic Arm System: A Preliminary Study." *BMC Surg* 24:232. <https://doi.org/10.1186/s12893-024-02524-x>.
- Vanlommel, L., E. Neven, M. B. Anderson, L. Bruckers, and J. Truijen. 2021. "The Initial Learning Curve for the ROSA® Knee System Can Be Achieved in 6-11 Cases for Operative Time and Has Similar 90-Day Complication Rates with Improved Implant Alignment Compared to Manual Instrumentation in Total Knee Arthroplasty." *J Exp Orthop* 8:119. <https://doi.org/10.1186/s40634-021-00438-8>.
- Walgrave, S., and S. Oussedik. 2022a. "Comparative Assessment of Current Robotic-Assisted Systems in Primary Total Knee Arthroplasty." *Bone Jt Open* 4:13–18. <https://doi.org/10.1302/2633-1462.41.BJO-2022-0070.R1>.
- . 2022b. "Comparative Assessment of Current Robotic-Assisted Systems in Primary Total Knee Arthroplasty." *Bone Jt Open* 4:13–18. <https://doi.org/10.1302/2633-1462.41.BJO-2022-0070.R1>.
- Weiner, T. R., E. D. Ferreri, N. O. Sarpong, R. P. Shah, and H. J. Cooper. 2023. "Robotic Total Knee Arthroplasty Is Associated with Earlier Return of Postoperative Range of Motion." *Surg Technol Int* 43:197–201. <https://doi.org/10.52198/23.STI.43.OS1724>.
- "What We've Learned From 10,000 Robot-Assisted Total Joint Replacements." n.d. Cleveland Clin. Accessed August 2, 2025. <https://consultqd.clevelandclinic.org/what-weve-learned-from-10000-robot-assisted-total-joint-replacements>.

Yocum, D. S., R. E. Redfern, and J. D. Yergler. 2025.
“Integration of Data Across the Episode of Care via a
Robotic Knee System, Implanted Tibial Sensor, and
Smartphone-Based Care Management Platform: A
Case Study.” *J Orthop Exp Innov*, 6. [https://doi.org/
10.60118/001c.126156](https://doi.org/10.60118/001c.126156).