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Original Research Article

TECHNICAL ERRORS, INTRAOPERATIVE GLITCHES AND TROUBLESHOOTING DURING THE INITIAL 100 VELYS ROBOTIC-ASSISTED TOTAL KNEE ARTHROPLASTIES

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ABSTRACT

Background: Robotic-assisted total knee arthroplasty (RA-TKA) introduces additional technical requirements related to registration, optical tracking, fixation, planning, system communication and robot-assisted bone preparation. Specific intraoperative technical problems and their practical troubleshooting strategies remain less well characterized than alignment accuracy and operative-time learning curves.

Materials and Methods: We retrospectively evaluated the first 100 consecutive VELYS robotic-assisted TKAs performed at a tertiary care teaching hospital between November 2024 and August 2026. Technical errors and workflow-related events, troubleshooting measures, operative duration and conversion to conventional instrumentation were recorded. Transient line-of-sight interruptions corrected immediately were analyzed separately. Temporal changes were assessed across four consecutive 25-case groups.

Results: Mean age was 68.5 ± 7.0 years and mean operative duration was 128.43 ± 8.07 minutes. Failed anterior femoral cortex registration was the most frequent substantive technical event (50%), followed by excessive cutting resistance/bone-chip accumulation (31%), inability of the camera to visualize trackers (16%) and operating-table attachment problems (13%). Anterior cortex registration failure decreased from 84% in cases 1–25 to 0% in cases 76–100 (χ^2=37.92, P=0.00000003), whereas bone-chip/cutting-resistance events remained present throughout the series (16%, 20%, 40% and 48% across quartiles; χ^2=8.37, P=0.039). Chronological case number was not associated with operative duration (Spearman ρ=-0.018, P=0.858), but increasing substantive technical-event burden was weakly associated with longer operative time (ρ=0.214, P=0.033). System freeze/communication errors occurred in three cases and were associated with prolonged operative duration in exploratory analysis. One procedure (1%) required conversion to conventional instrumentation. No complications attributable to the robotic system or recorded technical events were identified.

Conclusion: Technical and workflow-related problems during early VELYS robotic-assisted TKA were predominantly manageable using systematic troubleshooting, with conventional conversion required in 1% of cases. Registration-related difficulties demonstrated a marked learning-dependent reduction, whereas cutting-related events persisted. Individual technical-event analysis may characterize robotic proficiency more meaningfully than operative time alone.

Keywords: Robotic Surgical Procedures; Arthroplasty, Replacement, Knee; Learning Curve; Equipment Failure; Intraoperative Care.

INTRODUCTION

Total knee arthroplasty (TKA) is an established treatment for end-stage degenerative and inflammatory knee arthritis. Accurate bone resection, component positioning, restoration of limb alignment and appropriate soft-tissue balance are important technical objectives. Robotic-assisted TKA has increasingly been adopted to improve the reproducibility and precision of these intraoperative steps.

The VELYS Robotic-Assisted Solution is an imageless platform using bone-mounted arrays, optical tracking, intraoperative registration and a bed-mounted robotic arm with an attached saw. Cadaveric evaluation has demonstrated improved accuracy for several resection and implant-alignment parameters compared with conventional instrumentation.[1] A prospective multicentre adoption-phase study subsequently demonstrated non-inferior hip-knee-ankle alignment and improved accuracy of several femoral and tibial component-positioning parameters without an increased complication risk.[2]

Introduction of robotic technology, however, creates additional workflow requirements. Accurate registration, stable tracker fixation, uninterrupted optical communication, appropriate robotic positioning, reliable system communication, correct interpretation of the operative plan and satisfactory robot-assisted bone resection must all be maintained. Successful adoption therefore depends on both surgeon familiarity and coordinated operating-room workflow.

Published VELYS studies have predominantly emphasized alignment, early outcomes and operative efficiency. Pagan et al. identified an operative-time learning phase during the first nine cases, followed by a competence phase and later optimization.[3] Daxini and Mahajan reported accurate coronal correction in an initial 101-case Indian series and a reduction in tourniquet time with experience.[4] A later Indian series of more than 1000 VELYS-assisted TKAs reported safe and consistent adoption with low complication rates, including a single robot-hardware failure requiring conventional conversion.[5]

Operative time alone, however, does not describe the nature of technical learning. Registration failure, loss of optical tracking, tracker or pin instability, system errors, planning discrepancies and cutting difficulties represent distinct problems requiring different corrective strategies. Detailed case-level descriptions of such problems and their troubleshooting remain comparatively limited.

The primary aim of this study was to identify and characterize technical errors, intraoperative glitches and workflow-related problems encountered during the first 100 consecutive VELYS robotic-assisted TKAs and to describe the troubleshooting strategies used. Secondary aims were to evaluate temporal patterns across successive 25-case groups, identify events that diminished or persisted with experience, assess the relationship between technical-event burden and operative duration, and determine the frequency of conversion to conventional instrumentation.

MATERIALS AND METHODS

Study design and setting

This retrospective observational study evaluated the first 100 consecutive VELYS robotic-assisted TKAs performed between November 2024 and August 2026 at Malla Reddy Narayana Multispeciality Hospital, Malla Reddy Medical College for Women, Malla Reddy Vishwavidyapeeth, Hyderabad, India.

Patient population and variables

For each procedure, age, sex, diagnosis, side, operative duration, technical errors or intraoperative glitches, troubleshooting/corrective measures, repeat registration or recut where applicable, conversion to conventional instrumentation and complications attributable to the robotic workflow were recorded. Tourniquet time was excluded because it was fixed at 35 minutes in the operative workflow and therefore did not provide independent analytical information. Registration/planning time was excluded because reliable case-level measurements were not available. Operative duration was defined as skin-to-skin time (from initial skin incision to final wound dressing placement).

Classification of technical events

Technical events were grouped conceptually into registration-related, optical tracking/camera-related, tracker/fixation-related, system/setup/team-related, planning/balancing-related and bone-cutting-related events. Repeat registration, recut and conversion were interpreted primarily as corrective actions or consequences rather than independent primary technical failures.

Line-of-sight interruptions

Transient loss of optical tracking caused by obstruction from the surgeon, assistant, drapes or suction tubing was recorded separately. Because these interruptions were corrected immediately by removing the obstruction, they were excluded from the composite analysis of substantive time-consuming technical events.

Troubleshooting protocol

Difficult anterior femoral cortex registration was managed by clearing interfering soft tissue over the lateral/anterior cortical crest, beginning registration more proximally and repeating acquisition until satisfactory. In affected cases, two to 25 attempts were reported. Camera-related problems were managed by repositioning the infrared optical camera and/or the patient's limb. Tracker movement or fixation problems were addressed by readjustment, tightening or refixation, replacement of damaged trackers when required, and verification of tracker stability before bone cuts. Bone-chip accumulation within saw-blade gullets/serrations was managed by

clearing debris or replacing the blade. Unsatisfactory resections were assessed clinically and visually and recut when required; a conventional oscillating saw could be used when satisfactory robotic completion was not possible. Planning discrepancies were reassessed using clinical judgment, alignment, balance and planned resection information.

Temporal analysis

The chronological series was divided into four groups of 25 cases (1–25, 26–50, 51–75 and 76–100) to evaluate whether specific technical-event patterns changed with increasing procedural experience.

Preventive registration-point preparation: Before bony landmark registration, osteophytes overlying or adjacent to the intended femoral and tibial registration points were cleared to permit direct and consistent contact with the native bony surface. This was routinely performed by the surgical team to minimize registration inaccuracy that could subsequently affect bone-resection planning and soft-tissue balance assessment.

Statistical analysis

All statistical analyses were performed using Python 3.13 with the SciPy statistical computing library.

Continuous variables were summarized using mean and standard deviation and median/range where appropriate; categorical variables were summarized as frequency and percentage. Operative duration between cases with and without substantive technical events was compared using the Mann–Whitney U test. Spearman rank correlation was used to assess relationships between case number or technical-event burden and operative duration. Technical-event frequencies across quartiles were compared using chi-square testing. Event-specific analyses with small cell counts were considered exploratory. A two-sided $P<0.05$ was considered statistically significant.

Ethics statement: The study was reviewed and approved by the Malla Reddy Medical College for Women Institutional Ethics Committee (MRMCWIEC), Project No. MRMCWIEC/AP/627/2026. The IEC reviewed the study protocol, data collection proforma, and patient information sheet/informed consent form submitted with the protocol. The approval letter was dated 11 September 2026 and records that the study was approved in its present form. The approval is valid for the study period specified in the protocol.

Patient characteristics

The study included 100 procedures. Mean age was 68.5 ± 7.0 years (range, 54–86 years); 55 patients were male and 45 female. Osteoarthritis was the primary diagnosis in 91% and rheumatoid arthritis in 9%. Fifty right and fifty left knees were included.

Technical events

At least one substantive non-line-of-sight technical event occurred in 89/100 procedures. The most frequent event was failed anterior femoral cortex registration (50%), followed by excessive cutting resistance/bone-chip accumulation (31%), inability of the camera to visualize trackers (16%), and robotic attachment problems at the operating table (13%). Less frequent events included inaccurate landmark registration (6%), reflective-sphere detachment (6%), loose fixation pins (4%), system freeze/communication errors requiring troubleshooting or restart (3%), saw-blade bending (3%), tracker movement after fixation (2%), and loosening of the high-speed infrared stereoscopic camera hinge (2%). The camera-hinge events occurred in cases 76 and 91 and were corrected by the technician by tightening the hinge screw with an Allen (hex) key, restoring camera stability.

Temporal pattern

Anterior femoral cortex registration failure occurred in 21/25 (84%), 15/25 (60%), 14/25 (56%) and 0/25 (0%) cases across successive quartiles ($\chi^2=37.92$, $P=0.00000003$). Cutting resistance associated with bone-chip accumulation occurred in 4/25 (16%), 5/25 (20%), 10/25 (40%) and 12/25 (48%), respectively ($\chi^2=8.37$, $P=0.039$). The latter pattern was interpreted cautiously because retrospective recognition/documentation and unmeasured case or equipment factors could contribute. Both camera-hinge loosening events occurred in the final quartile (cases 76–100; 2/25, 8%) and were treated descriptively because of the small event count. The temporal distribution is illustrated in Figure 1.

Operative time

Mean operative duration was 128.43 ± 8.07 minutes (median 126; range 121–187). Mean operative durations across successive quartiles were 128.88, 126.36, 128.60, and 129.88 minutes, respectively. There was no significant relationship between chronological case number and operative duration (Spearman $\rho=-0.018$, $P=0.858$).

Conversion and complications

One procedure (1%) required conversion to conventional instrumentation. No complications attributable to the robotic system or recorded technical events were identified in the series.

RESULTS

Table 1: Patient characteristics

Characteristic	Value
Number of procedures	100
Age, years	68.5 ± 7.0 (range 54–86)
Male	55 (55%)
Female	45 (45%)
Osteoarthritis	91 (91%)
Rheumatoid arthritis	9 (9%)

Right knee	50 (50%)
Left knee	50 (50%)

Representative intraoperative setup views are shown in Figures 2 and 3.

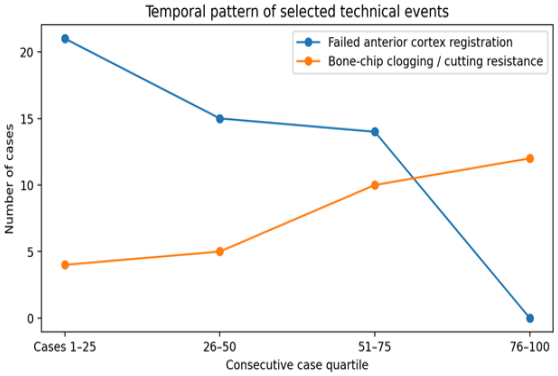


Figure 1: Temporal distribution of failed anterior femoral cortex registration and bone-chip/cutting-resistance events across consecutive 25-case groups



Figure 2: Intraoperative operating-theatre setup of the VELYS™ Robotic-Assisted Solution viewed from the optical-camera side, demonstrating the operative field and tracker configuration



Figure 3: Intraoperative operating-theatre setup of the VELYS™ Robotic-Assisted Solution viewed from the robotic-arm side, demonstrating the robotic system, display and operative field

Table 2: Principal technical events and troubleshooting

Technical event	n (%)	Troubleshooting / corrective action
Failed anterior femoral cortex registration	50 (50%)	Clear interfering soft tissue at the lateral/anterior cortical crest; start registration more proximally; repeat until satisfactory.
Excessive cutting force / bone-chip clogging	31 (31%)	Clear bone chips from blade gullets/serrations; replace blade if cutting performance remains unsatisfactory.
Camera unable to visualize trackers	16 (16%)	Readjust infrared optical camera and/or patient leg position.
OT-table attachment issue	13 (13%)	Detach and securely reattach robot to the operating table.
Inaccurate landmark registration	6 (6%)	Repeat landmark registration until satisfactory.
Reflective sphere detachment	6 (6%)	Reseat and reassess near completion; replace affected tracker early in the procedure when necessary.
Loose fixation pins	4 (4%)	Refix and secure pins; recheck stability/checkpoints before proceeding.
System freeze / communication error	3 (3%)	Troubleshoot and restart/reboot if persistent; consider conventional completion if reliable robotic continuation is not possible.

High-speed infrared stereoscopic camera hinge loosening	2 (2%)	Technician tightened the hinge screw using an Allen (hex) key and confirmed restoration of camera stability.
Saw-blade bending	3 (3%)	Assess cut clinically/visually; recut as required; use conventional oscillating saw if necessary.
Tracker movement after fixation	2 (2%)	Readjust tracker, tighten clamps, replace if damaged, and reverify stability before bone cuts.
Team unfamiliarity	2 (2%)	Educate staff and maintain a consistent core robotic arthroplasty team.
Conversion to conventional instrumentation	1 (1%)	Stop unreliable robotic progression and complete with conventional instrumentation when required.

This study describes the spectrum, temporal distribution and management of technical errors and intraoperative workflow problems encountered during the first 100 consecutive VELYS robotic-assisted TKAs. The principal findings were that technical events were common during early adoption but predominantly manageable without abandoning the robotic workflow; individual technical problems demonstrated different temporal patterns; anterior femoral cortex registration difficulty showed a marked reduction with experience, whereas cutting-related problems persisted; and conversion to conventional instrumentation was required in only one case.

The most frequent substantive event was failed anterior femoral cortex registration. Its reduction from 84% in the first quartile to 0% in the final quartile is consistent with a workflow-specific learning effect. In our experience, clearing interfering soft tissue, initiating registration more proximally and repeating acquisition were effective practical responses. Published VELYS literature has focused more heavily on operative efficiency and alignment than on granular troubleshooting.[2-5] Our findings therefore complement existing learning-curve work by identifying a specific technical process that improved even though total operative duration did not.

Pagan et al. reported a nine-case initial operative-time learning phase and optimized performance after approximately case 52,[3] while a more recent multicentre/surgeon study also reported short surgeon-specific learning curves based on skin-to-skin time.[6] In contrast, chronological case number in the present series was not associated with operative duration. This difference may reflect variation in definitions of operative time, institutional workflow, team composition and closure practices. More importantly, it suggests that total operative time may be an incomplete surrogate for technical proficiency: individual workflow-specific errors can improve substantially even when overall duration remains stable. A 2025 systematic review and meta-analysis of 31 learning-curve studies reported a median proficiency threshold of 17 cases, while emphasizing that operative time remains the dominant learning-curve metric.[7]

Cutting resistance associated with bone-chip accumulation behaved differently. It remained evident throughout the series and was recorded more frequently in later quartiles. This should not be interpreted as evidence that experience caused the problem to increase. Blade condition, bone quality, cutting technique, case mix and improved recognition or documentation are plausible contributors. The contrasting temporal behavior of registration and cutting problems supports separating learning-dependent workflow errors from persistent equipment- or execution-related technical events.

System freeze or communication errors were uncommon but carried the greatest observed operative-time burden. Because only three such cases occurred, this association should be regarded as exploratory. Nevertheless, the finding is clinically relevant: rare system-level interruptions may have a disproportionate effect on workflow. Maintaining readiness to complete the operation conventionally remains important. The large Indian VELYS series similarly reported a robot-hardware failure requiring conventional conversion among more than 1000 procedures.[5]

Optical tracking interruptions also require careful classification. Brief obstruction of the camera–tracker line of sight by the surgeon, assistant, drapes or suction tubing was immediately corrected and was therefore separated from substantive technical events. Camera inability to visualize trackers, by contrast, required active repositioning of the camera and/or limb. In two later cases (76 and 91), mechanical loosening of the hinge at the top of the high-speed infrared stereoscopic camera was identified; the technician tightened the hinge screw using an Allen (hex) key, after which camera stability was restored. These events were distinct from transient line-of-sight obstruction because they represented a mechanical camera-assembly issue requiring technician intervention. Their occurrence only in the final quartile and the very small number of events do not support inference of a learning-curve relationship. This classification prevents trivial momentary interruptions from being weighted equivalently to registration failure, tracker instability, system restart, recut, or a mechanical camera problem.

The series also emphasizes that robotic adoption is a team learning process. Assistants, scrub nurses and technical personnel influence tracker visibility, draping, equipment setup and troubleshooting.

Education and maintenance of a consistent core team became part of the local troubleshooting strategy. This practical dimension is not captured by alignment accuracy alone.

Broader systematic reviews indicate that robotic TKA generally improves the precision of alignment compared with conventional instrumentation, but consistent superiority in clinical outcomes has not been established.[8,9] These findings support evaluating each robotic platform and each clinically relevant technical outcome separately rather than extrapolating generic conclusions across systems.

Meticulous preparation of bony registration points was also considered an important preventive workflow step. Osteophytes at femoral or tibial landmark-registration sites were routinely removed before registration. No registration or subsequent bone-cutting error in this series was attributed to failure to remove osteophytes. This observation is presented as a description of the team's preventive practice rather than evidence of a causal protective effect.

No complications attributable to the robotic system or recorded technical events were identified, and 99% of procedures were completed robotically. This is consistent with prospective adoption-phase evidence suggesting that VELYS can be introduced without compromising alignment or increasing complication risk.[2] However, broader reviews highlight that technical errors and system-specific pitfalls remain underreported risks during robotic adoption.[10]

This study was not powered to establish safety equivalence, and absence of observed robot-related complications should not be interpreted as proof that such complications cannot occur.

Robotic and navigation-assisted knee arthroplasty also introduce tracker-pin-specific risks that are distinct from conventional instrumentation. A systematic review of 7,336 non-case-report procedures found an overall pin-related complication rate of 1.4%, with pin dislodgement and superficial pin-site infection each reported at 0.6%.[11] Another systematic review identified pin-site fractures as uncommon but clinically important complications and highlighted factors such as diaphyseal placement, larger pin diameter and multiple drilling attempts.[12] Although no pin-related fracture or infection was identified in the present series, four episodes of loose fixation pins reinforce the importance of secure fixation and verification of tracker stability before bone resection. Recent evidence syntheses further support platform-specific assessment of robotic TKA safety, complications and learning-curve characteristics.[13-15]

Strengths and limitations

A strength of this study is the detailed characterization of specific technical events together with the corrective actions used across a consecutive 100-case implementation series. The analysis also distinguishes transient line-of-sight interruptions from substantive events and examines temporal behavior of individual error types rather than relying only on operative time.

Limitations include the retrospective single-centre design, absence of a conventional-TKA control group, small numbers in several event categories, and potential changes in recognition or documentation of events over time. Registration attempts were not prospectively timed, and registration/planning time was therefore excluded. The analysis cannot determine whether individual events arose primarily from the robotic system, surgical technique, patient characteristics, instrumentation or interactions among these factors. Postoperative clinical and radiographic outcomes were not the primary focus. Finally, inferential analyses of rare event categories should be considered exploratory.

Technical and workflow-related events were frequently encountered during early adoption of VELYS robotic-assisted TKA but were predominantly manageable through systematic troubleshooting, with conventional conversion required in only 1% of cases. Registration-related difficulties demonstrated a marked learning-dependent reduction and disappeared during the final 25 procedures, whereas cutting-related problems persisted throughout the series. These findings suggest that technical challenges during robotic TKA are heterogeneous: some improve substantially with procedural experience, while others require continued equipment- and workflow-specific vigilance. Individual technical-event analysis may characterize robotic proficiency more meaningfully than operative time alone.

Reporting guideline: The study was prepared with reference to the STROBE recommendations for observational studies.

CONCLUSION

Technical and workflow-related problems during early VELYS robotic-assisted TKA were predominantly manageable using systematic troubleshooting, with conventional conversion required in 1% of cases. Registration-related difficulties demonstrated a marked learning-dependent reduction, whereas cutting-related events persisted. Individual technical-event analysis may characterize robotic proficiency more meaningfully than operative time alone.

Declarations

Ethics approval: Approved by the Malla Reddy Medical College for Women Institutional Ethics Committee (MRMCWIEC), Project No. MRMCWIEC/AP/627/2026; IEC meeting 9 September 2026; approval letter dated 11 September 2026. IEC Registration No. EC/NEW/INST/2023/TE/0221.

Consent: The IEC approval letter confirms review of the patient information sheet and informed consent form submitted with the protocol. Because the approval letter does not explicitly state a waiver of

informed consent, no waiver is claimed in this manuscript.

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

Author contributions: Dr Kommireddy Pavan Kumar: conceptualization, methodology, investigation, data curation, formal analysis, and writing—original draft. Dr Anjani Kumar R: supervision, validation, and critical review of the manuscript. Dr Anchuri Prasanth: investigation, data curation, and critical review of the manuscript. All authors approved the final manuscript.

Data availability: The de-identified analytical dataset is maintained by the investigators. Data may be made available on reasonable request, subject to institutional and ethics requirements.

REFERENCES

1. Doan GW, Courtis RP, Wyss JG, Green EW, Clary CW. Image-Free Robotic-Assisted Total Knee Arthroplasty Improves Implant Alignment Accuracy: A Cadaveric Study. J Arthroplasty. 2022;37(4):795-801. doi:10.1016/j.arth.2021.12.035.
2. Alton TB, Severson EP, Ford MC, et al. VELYS robotic-assisted total knee arthroplasty: Enhanced accuracy and comparable early outcomes versus manual instrumentation during adoption. J Exp Orthop. 2025;12:e70163. doi:10.1002/jeo2.70163.
3. Pagan CA, Karasavvidis T, Siljander B, Debbi EM, DeCook CA, Vigdorchik J. Operative Time Learning Curve for an Image-Free Robotic Arm Assisted Total Knee Arthroplasty: A Cumulative Sum Analysis. Arthroplast Today. 2025;31:101588. doi:10.1016/j.artd.2024.101588.
4. Daxini A, Mahajan U. Initial Experience With VELYS Robot-Assisted Total Knee Replacement: Coronal Plane Accuracy and Effect of Robotic Training on Outcomes. Cureus. 2024;16(12):e76323. doi:10.7759/cureus.76323.
5. Mahajan UM, Wakefield SM, Daxini AH, Jafri SS, Rodham PL, Pandit HG. Early Indian experience with the VELYS robotic system: A consecutive series of first 1000 Total Knee Arthroplasty cases. J Orthop Rep. 2025:100794. doi:10.1016/j.jorep.2025.100794.
6. Le Guen A, Mouton A, Auberger G, Le Strat V, Marmor S, Aubert T. Short learning curve associated with robotic total knee arthroplasty: A retrospective study. J Exp Orthop. 2025;12(3):e70401. doi:10.1002/jeo2.70401.
7. Abdel Khalik H, Abesteh J, Aldawodi M, Khanna V, Adili A. The learning curve of robotic-assisted total knee arthroplasty: a systematic review and meta-analysis. J Robot Surg. 2025;19(1):456. doi:10.1007/s11701-025-02576-y.
8. Daoub A, Qayum K, Patel R, Selim A, Banerjee R. Robotic assisted versus conventional total knee arthroplasty: a systematic review and meta-analysis of randomised controlled trials. J Robot Surg. 2024;18(1):364. doi:10.1007/s11701-024-02048-9.
9. Vermue H, Batailler C, Monk P, Haddad F, Luyckx T, Lustig S. The evolution of robotic systems for total knee arthroplasty, each system must be assessed for its own value: a systematic review of clinical evidence and meta-analysis. Arch Orthop Trauma Surg. 2023;143(6):3369-3381. doi:10.1007/s00402-022-04632-w.
10. Nogalo C, Meena A, Abermann E, Fink C. Complications and downsides of the robotic total knee arthroplasty: a systematic review. Knee Surg Sports Traumatol Arthrosc. 2023;31(3):736-750. doi:10.1007/s00167-022-07031-1.
11. Thomas TL, Goh GS, Nguyen MK, Lonner JH. Pin-Related Complications in Computer Navigated and Robotic-Assisted Knee Arthroplasty: A Systematic Review. J Arthroplasty. 2022;37(11):2291-2307.e2. doi:10.1016/j.arth.2022.05.012.
12. Smith TJ, Siddiqi A, Forte SA, Judice A, Sculco PK, Vigdorchik JM, Schwarzkopf R, Springer BD. Periprosthetic Fractures Through Tracking Pin Sites Following Computer Navigated and Robotic Total and Unicompartmental Knee Arthroplasty: A Systematic Review. JBJS Rev. 2021;9(1):e20.00091. doi:10.2106/JBJS.RVW.20.00091.
13. Yong J, Li H, Wu Z, Cao Z. Safety and efficacy of robot-assisted total knee arthroplasty: a network meta-analysis and systematic review. J Orthop Surg Res. 2026;21:377. doi:10.1186/s13018-026-06889-y.
14. Peñaherrera-Carrillo C, Cabrera-Ávila MS, Quintero-Quintero M, Carranza Aranda V, Pineda Villaseñor CJ, Suarez-Ahedo C. Periprosthetic fractures associated with pin placement in robot- or navigation-assisted total knee arthroplasty: a systematic review and meta-analysis. J Robot Surg. 2026;20(1):455. doi:10.1007/s11701-026-03346-0.
15. Szymczak J, Łapiński M, Stolarczyk A, Balawender K. Robotic-assisted total knee arthroplasty: accuracy, clinical outcomes, complications, learning curve and cost-effectiveness: a critical clinical review. J Robot Surg. 2026;20(1):922. doi:10.1007/s11701-026-03854-z.