Journal of Robotic Surgery (2026) 20:231
https://doi.org/10.1007/s11701-026-03149-3

RESEARCH

Robot-assisted versus manual total knee arthroplasty: precision without superiority in coronal alignment and patellar orientation

Carlos Peñaherrera-Carrillo[1,6] · Susana Cabrera-Ávila[2,6] · Francisco Endara Urresta[3] · Alejandro Barros Castro[4] · Eduardo Durán-Arce[1,6] · Alejandro Gallegos-Tejeda[1,6] · Carlos Javier Pineda Villaseñor[5] · Carlos Suarez-Ahedo[1,6]

Received: 5 December 2025 / Accepted: 3 January 2026
© The Author(s), under exclusive licence to Springer-Verlag London Ltd., part of Springer Nature 2026

Abstract Robot-assisted total knee arthroplasty (rTKA) has been proposed to improve precision in implant positioning and joint line restoration compared with manual TKA (mTKA). However, it remains unclear whether this increased accuracy results in superior functional or radiographic outcomes. This study aimed to compare mechanical alignment and patellofemoral restoration between robotic and manual techniques. A retrospective study including 600 consecutives primary TKAs performed from 2015 to 2024 was conducted. Patients were allocated into robotic ($n=300$) and manual ($n=300$) groups. All procedures were performed by the same arthroplasty team using a standardized surgical protocol and identical prosthesis model. Radiographic assessment included femorotibial mechanical axis and patellar orientation at a minimum of 12 months. Alignment was considered adequate when the absolute angular discrepancy was ≤2°. Statistical analyses included χ^2 tests, Student's t-tests, and equivalence testing with the Two One-Sided Tests (TOST) method. Baseline demographics were comparable between groups. All knees achieved alignment within the ≤2° tolerance (100% vs. 100%). Mean angular discrepancy showed no significant differences (manual 0.52° vs. robotic 0.48°; $p=0.37$). The robotic technique achieved a higher rate of exact matches (64% vs. 52%), while both remained within clinically accepted limits. Equivalence and non-inferiority analyses confirmed statistically and clinically equivalent outcomes between techniques. Robot-assisted TKA provides greater geometric precision; however, this advantage does not translate into measurable clinical or radiographic superiority when the manual technique is performed under a standardized protocol by experienced surgeons. Both methods demonstrated equivalent performance in restoring mechanical alignment and patellofemoral relationships.

Level of evidence III. Retrospective comparative study.

Keywords Arthroplasty, replacement, knee · Robotics · Knee joint · Patella · Radiographic image interpretation, computer-assisted

✉ Carlos Suarez-Ahedo
drsuarezahedo@gmail.com

Carlos Peñaherrera-Carrillo
carlospenaherrerac@gmail.com

Susana Cabrera-Ávila
sussieca@gmail.com

Francisco Endara Urresta
fren9123@hotmail.com

Alejandro Barros Castro
alejandroxbc27@gmail.com

Eduardo Durán-Arce
eduardo_duran2@hotmail.com

Alejandro Gallegos-Tejeda
alexgalle994@gmail.com

Carlos Javier Pineda Villaseñor
cpineda@inr.gob.mx

1 Adult Hip and Knee Reconstruction, National Rehabilitation Institute of Mexico, Mexico City, Mexico

2 Articular Surgery, National Rehabilitation Institute of Mexico, Mexico City, Mexico

3 Orthopedics and Traumatology, Arktros Clinic, Quito, Ecuador

4 Orthopedics and Traumatology, Metropolitan Hospital, International University of Ecuador, Quito, Ecuador

5 National Rehabilitation Institute of Mexico, Mexico City, Mexico

6 National Autonomous University of Mexico, Mexico City, Mexico

Abbreviations

SD	Standard deviation
BMI	Body mass index
PCL	Posterior cruciate ligament
CR	Cruciate retaining
CI	Confidence interval

Introduction

Knee osteoarthritis (KOA) is a common condition in older adults due to progressive wear and destruction of articular cartilage, and is a degenerative joint disease resulting from many factors. As a result of factors such as increased life expectancy and obesity, its prevalence continues to rise. Depending on the source, prevalence estimates range from 10% to 13%, with a 40% prevalence in patients entering their seventh decade [1]. It is estimated that KOA will affect 78.4 million Americans by 2040 [2]. The prevalence of symptomatic gonarthrosis is estimated at 44.7% [3]. According to the Mexican government, the prevalence rate is 10.5%, with females predominating (11.7%) and males (8.71%) [4]. A patient with KOA experiences pain, swelling, stiffness, and limitations in daily life [1].

Treatment is determined by the severity of symptoms and the degree of joint wear, classified according to Kellgren–Lawrence [5]. Among the nonsurgical and surgical options, total knee arthroplasty (TKA) is indicated in patients with severe degeneration and significant symptoms [6].

The number of TKAs performed in the United States has increased by 134% over 20 years [7]. Further studies predict that primary TKAs will increase by 139% by 2040 and by 469% by 2060 [7–9].

Despite being widely performed, well accepted, safe, and cost-effective, patient satisfaction rates remain between 82% and 89%. Dissatisfaction is caused by a variety of factors, including malalignment, incorrect prosthesis indication, soft-tissue imbalance, instability, high preoperative expectations, and altered joint line and patellar height (PH) [10–12].

After TKA, any change in the joint line affects the biomechanics [13]. This changes the center of rotation, the isometry of the medial collateral ligament (MCL), resulting in midflexion instability [14, 15].

Furthermore, JL elevation reduces posterior condylar offset, negatively affecting flexion angle and extensor mechanism force. A reported postoperative JL elevation after primary TKA ranges between 1.1 and 5.6 millimeters [16, 17].

Studies suggest functional impairments occur when JL elevation exceeds 3 to 5 millimeters compared with preoperative values [18].

While joint line elevation and patellar height have traditionally been assessed using linear measurements and validated ratios, these parameters represent isolated structural descriptors. An alternative and complementary perspective focuses on the global geometric coherence between limb alignment and patellofemoral orientation.

In this context, coronal angular concordance between the femorotibial mechanical axis and patellar orientation may serve as a surrogate marker of integrated alignment, independent of absolute linear displacement.

In response to dissatisfaction rates, robotic surgery has emerged as a potential solution [19]. Robotic knee arthroplasty (rTKA) has been shown to increase procedural precision. In comparison with conventional techniques, it achieves near-anatomical results in joint-line position and has been reported to yield better functional outcomes [20–24].

Because evidence remains limited, this investigation was undertaken to examine rTKA, its relationship with joint-line height and patellar position, and its impact on medium-term functional outcomes. Therefore, the present study does not aim to quantify joint line elevation or patellar height using linear indices, but rather to compare robotic and manual techniques in terms of coronal angular alignment and patellar orientation consistency.

Materials and methods

A retrospective study comparing robot-assisted (rTKA) and conventional manual knee arthroplasty techniques was performed. The study period was January 2015 to December 2024, at a single high-specialty hospital.

Population and inclusion criteria

Three hundred consecutive primary TKAs were included in each group (total = 600), all performed by the same surgical team. 300 patients in the robotic group and 300 patients in the manual group.

Inclusion criteria: patients with primary knee osteoarthritis (Kellgren–Lawrence grade III or IV), tricompartmental disease, elective TKA indication, and a minimum radiographic follow-up of 12 months. Exclusion criteria: prior peri-articular fracture, revision surgery, non-standard prosthesis, or deformities beyond 15°.

Ethical considerations

The protocol was approved by the local Ethics and Research Committee and followed the principles of the Declaration of Helsinki. All patients provided informed consent for the procedure and anonymous use of their clinical data.

Surgical technique

All surgeries followed a standardized protocol: regional anesthesia, medial parapatellar approach, distal femur and proximal tibia exposure, sequential soft tissue release, and extension/flexion gap balancing.

- In the robotic group, the ROSA™ (Zimmer Biomet, War-saw, Indiana, EE. UU.) robotic-assisted navigation system was used, incorporating intraoperative three-dimensional mapping, anatomic point registration, and guided bone cuts. The functional alignment method was employed.
- In the manual group, cutting was done with standard extramedullary and intramedullary mechanical guides. The mechanical alignment method was employed.

In both groups, the same cruciate-retaining (CR) VANGUARD™ (Zimmer Biomet, War-saw, Indiana, EE. UU.) prosthetic model was implanted, and the same cementing and postoperative rehabilitation protocols were applied.

Radiographic evaluation and measurements

Radiographs were obtained at 3, 6, and 12 months, and then annually, with a mean follow-up of 24 ± 6 months. Measurements were made by two independent observers blinded to the surgical technique, using weight-bearing anteroposterior and strict lateral radiographs. Interobserver reliability for angular measurements was assessed using the intraclass correlation coefficient (ICC).

The following were determined:

- Femoro-tibial mechanical axis (Line Axis, LA).
- Postoperative patellar position.
- Absolute angular discrepancy between the two parameters, classified as:
  - −0° (exact match),
  - −1° (mild deviation),
  - −2° (moderate discrepancy, clinically acceptable ≤ 2°).

Alignment was defined as adequate if the absolute discrepancy was ≤ 2°.

Definition of Patellar Orientation and Angular Measurement.

The angular relationship was assessed in the coronal plane using standardized weight-bearing long-leg anteroposterior radiographs.

The femorotibial mechanical axis was defined as the line connecting the center of the femoral head and the center of the ankle joint.

Patellar orientation was defined as the coronal orientation of the patella, represented by a line perpendicular to the transverse patellar axis, determined by the medial and lateral borders of the patellar component on the AP radiograph.

The angular discrepancy was calculated as the absolute angular difference between the femorotibial mechanical axis and the patellar coronal orientation line.

Measurements were performed digitally using calibrated radiographic software, and the mean of two independent blinded observers was used for analysis.

Statistical analysis

Data were analyzed using SPSS v.27 (IBM Corp., Armonk, NY). Continuous variables are presented as mean ± standard deviation (SD) or median [interquartile range], depending on distribution. Categorical variables were compared using χ^2 test or Fisher's exact test; continuous variables with Student's t-test or Mann–Whitney U test. Equivalence analyses used a predefined margin of ± 10% and bilateral non-inferiority testing (margin 5%), using the Two One-Sided Tests (TOST) approach. A p-value < 0.05 was considered statistically significant.

Results

Patient flow and baseline characteristics

Six hundred consecutive primary TKAs between January 2015 and December 2024 were analyzed, divided equally into robotic and manual groups ($n = 300$ each). Technique selection depended solely on robotic system availability, rather than on patient clinical characteristics, thereby avoiding indication bias. The same experienced arthroplasty team conducted all surgeries under a standardized protocol (medial parapatellar approach, distal femur/proximal tibia exposure, ligamentous release, gap balance, intra-operative femoral rotation verification using epicondyles and Whiteside's line, and final patellofemoral congruence check). The robotic group used intraoperative 3-D mapping and guided cuts; the manual group used traditional mechanical guides.

Baseline demographics and clinical features were comparable: mean age 67.8 ± 8.9 years in manual vs. 66.5 ± 9.2 years in robotic ($p = 0.21$); female proportion 62% vs. 59% ($p = 0.48$); mean BMI 28.6 ± 4.3 vs. 28.9 ± 4.1 kg/m²

Table 1 Baseline characteristics of the cohort

Variable	Manual ($n=300$)	Robotic ($n=300$)	P value
Age (years), mean±SD	67.8±8.9	66.5±9.2	0.21
Sex female, n (%)	186 (62.0)	177 (59.0)	0.48
BMI (kg/m²), mean±SD	28.6±4.3	28.9±4.1	0.63
Diabetes mellitus, n (%)	47 (15.7)	44 (14.7)	0.74
Hypertension, n (%)	179 (59.7)	182 (60.7)	0.82
Deformity>10°, n (%)	38 (12.7)	41 (13.7)	0.73
PCL retention (CR), n (%)	300 (100)	300 (100)	–
Patellar component, n (%)	262 (87.3)	258 (86.0)	0.67

($p=0.63$); prevalence of comorbidities (diabetes, hypertension, tricompartmental osteoarthritis, varus deformity > 10°) was similar ($p>0.05$). Minimum radiographic follow-up was 12 months, averaging 24±6 months, during which there were no prosthetic loosening, revisions, or major complications influencing postoperative alignment. No patients were lost to follow-up or excluded after surgery (Table 1).

Concordance between the femoro-tibial mechanical axis and post-operative patellar position

Evaluation of postoperative concordance between the femoro-tibial mechanical axis (LA) and patellar orientation showed comparable performance in both techniques. Defining adequate alignment as absolute discrepancy ≤2°, 100% of knees in both groups achieved this criterion ($p=1.000$, Fisher's exact test), demonstrating that robotic and manual surgeries attain clinically satisfactory patellofemoral alignment. This indicates that within the functionally accepted range (<2°), the probability of correct alignment is equivalent for both methods. From a clinical and biomechanical perspective, no significant superiority of robotic assistance over manual technique is evident when the exact alignment and balancing principles are followed.

Although the robotic group achieved a higher proportion of exact 0° matches, this increased geometric precision did not translate into a distinct alignment category outside the accepted functional envelope, nor into measurable clinical differentiation within the evaluated parameters.

Distribution of angular discrepancy

In the manual technique group, 52% of cases showed exact coincidence (0°), 44% a deviation of 1°, and 4% a discrepancy of 2°. In the robotic group, 64% had exact coincidence, 24% a 1° deviation, and 12% a 2° discrepancy (Fig. 1).

Although the χ^2 test identified differences in distribution shape ($p<0.001$), all measurements remained within the clinically accepted range for both groups. Mean angular values were similar: manual 0.52° vs. robotic 0.48° (difference = −0.04°; $p=0.37$). Medians were 0° in both groups,

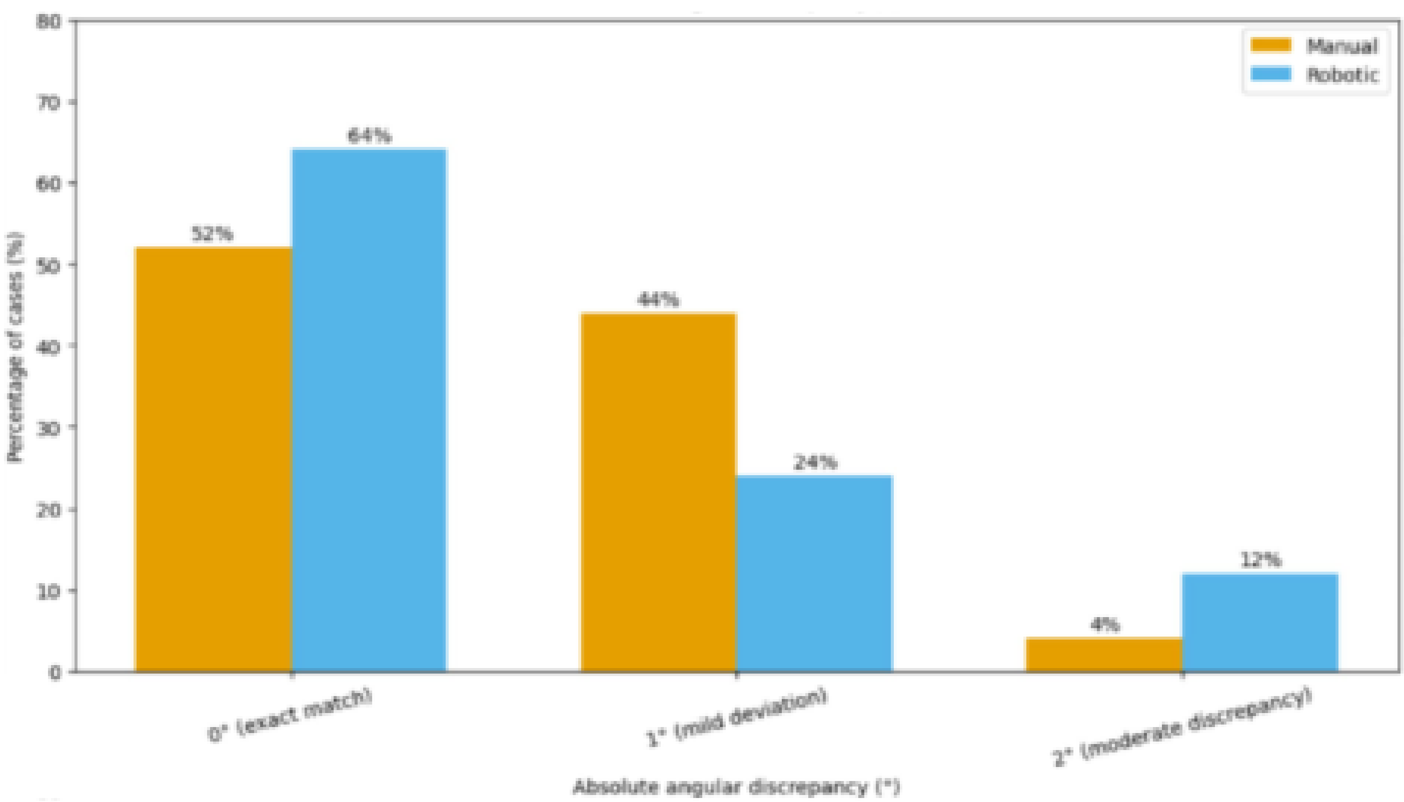

Fig. 1 Distribution of angular discrepancy between the femorotibial mechanical axis and patellar position according to the surgical technique. Although the distributions differ in shape, all values remain within the clinical tolerance (≤2°)

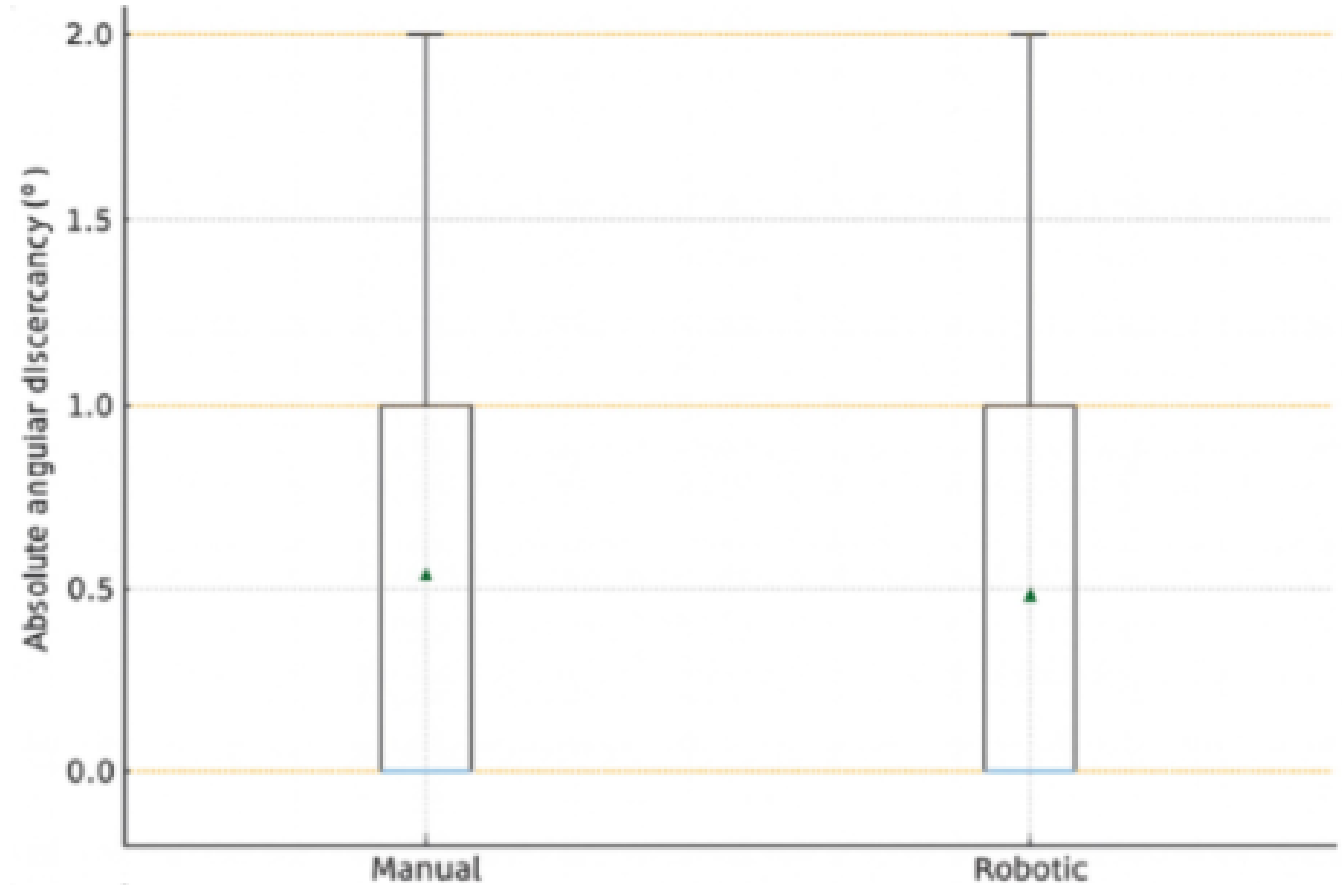

Fig. 2 Boxplots of absolute discrepancy. Both groups show overlapping medians and low dispersion, with no significant differences ($p > 0.05$)

Table 2 Postoperative angular outcomes

Variable	Manual ($n = 300$)	Robotic ($n = 300$)	Difference (IC 95%)	P value
Exact match (0°), n (%)	156 (52.0)	192 (64.0)	+12.0 (+0.8 a +22.9)	0.0029
Mild deviation (1°), n (%)	132 (44.0)	72 (24.0)	−20.0 (−29.5 a −10.6)	<0.001
Moderate discrepancy (2°), n (%)	12 (4.0)	36 (12.0)	+8.0 (+2.8 a +13.2)	0.001
Within tolerance (≤2°), n (%)	300 (100)	300 (100)	0.0 (−2.1 a +2.1)	1.000
Mean discrepancy (°) ± DE	0.52 ± 0.63	0.48 ± 0.71	−0.04 (−0.15 a +0.23)	0.37
Median [IQR] (°)	0 [0–1]	0 [0–1]	–	–

with identical IQRs (0–1°), confirming low and equivalent angular dispersion (Fig. 2).

Geometrically, the robotic technique showed a more 'polarized' pattern, a higher rate of exact matches, but a slight increase in 2° deviations. In contrast, the manual technique concentrated more cases at 1°, suggesting a centralized but equally controlled variability. None of these patterns implied behavior outside the optimal functional alignment range (Table 2).

Equivalence and non-inferiority analysis

An equivalence analysis with a ± 10% margin in the proportion of knees aligned within ±2° was performed. The 95% confidence interval (CI) for the difference in proportions (0.0%; 95% CI −2.1% to +2.1%) lay entirely within the predefined margin, demonstrating both clinical and statistical equivalence between the techniques (Fig. 3).

Additionally, a bilateral non-inferiority analysis (margin 5%) confirmed that neither method was inferior ($p < 0.001$ for both TOST contrasts), consolidating the conclusion of equivalent performance. Sensitivity analyses—excluding cases with deformities > 10°, BMI > 35 kg/m², or non-standard prostheses—maintained identical results (100% within ±2° in both cohorts) (Table 3).

Clinical interpretation

Overall, the results demonstrate that under standardized operative conditions and controlled execution, robot-assisted

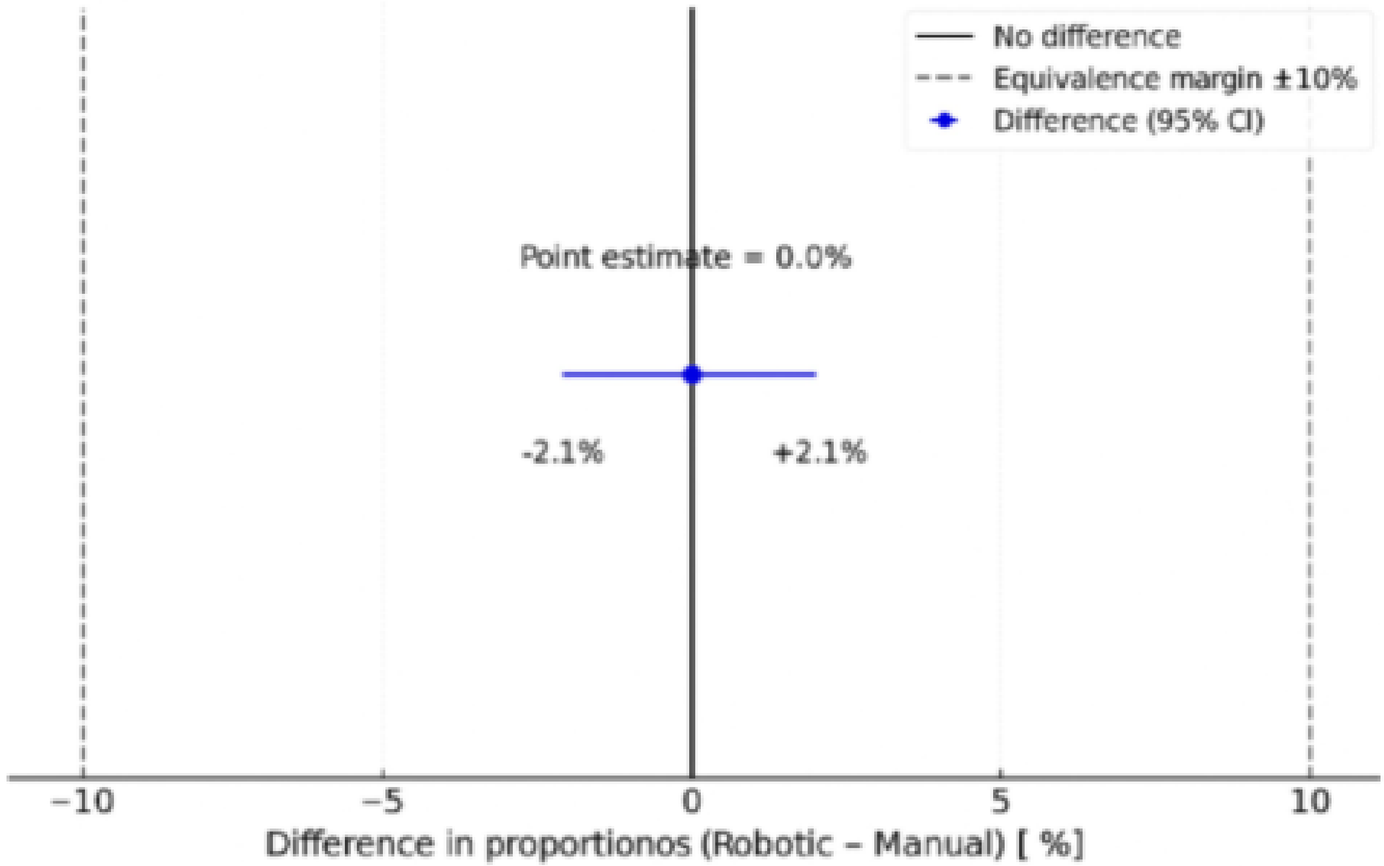

Fig. 3 Two-one-sided equivalence test (TOST) for the proportion of alignments within ±2°. The observed difference (0%) and its 95% CI (−2.1 to +2.1) lie entirely within the ±10% margin, confirming clinical equivalence between robotic and manual surgery

Table 3 Equivalence and non-inferiority analysis

Comparation	Observed difference (%)	Equivalence margin (%)	95% CI of the difference	Result
Proportion within ±2° (Robotic – Manual)	0.0	±10	[−2.1, + 2.1]	Equivalent
Idem (margin ±5%)	0.0	±5	[−2.1, + 2.1]	Equivalent
Two-sided non-inferiority test (5% margin)	0.0	5	[−2.1, + 2.1]	Non-inferiority demonstrated
Sensitivity analysis (excluding BMI > 35 or deformity > 10°)	0.0	±10	[−2.4, + 1.8]	Unchanged result

and conventional manual TKA achieve equivalent patellofemoral alignment. Every case in both cohorts fell within the clinically acceptable tolerance (<2°), without increased angular dispersion or a higher malalignment rate. Although the robotic technique achieved a greater proportion of exact 0° coincidences, this reflects increased mathematical precision rather than a tangible clinical benefit. The slight variability observed in the manual technique falls within the expected measurement precision of radiographic methods and has no functional consequences. Consequently, evidence suggests that in the hands of experienced surgeons following a reproducible surgical protocol, robot-assisted TKA does not offer significant clinical advantages over manual technique with respect to mechanical axis alignment or patellofemoral congruence. In summary, both approaches demonstrated equivalent biomechanical and functional behavior, with consistent, reproducible, and clinically satisfactory results, supporting the absence of a significant difference between the two surgical modalities. The evaluated angular discrepancy represents a static coronal radiographic parameter and does not assess dynamic patellar tracking.

Discussion

Robot-assisted total knee arthroplasty (rTKA) has emerged as a technological alternative to the conventional manual technique (mTKA) in advanced gonarthrosis. In our study, both groups achieved mechanical alignment and patellofemoral congruence within the clinically acceptable range, with no significant functional differences between techniques. This finding is consistent with a recent meta-analysis showing that although rTKA achieves better postoperative alignment, it does not translate into clear clinical or functional improvements in the short to mid-term [25–27].

The choice of a ± 2° margin was therefore not arbitrary but intentionally conservative, prioritizing clinical relevance over mathematical granularity. Although smaller angular differences (e.g., 0° versus 1°) can be detected radiographically, current evidence does not demonstrate consistent or clinically meaningful functional or biomechanical consequences associated with such minimal deviations.

Although previous studies have explored functional outcomes and patient satisfaction after robotic-assisted TKA, the present investigation was not designed to assess these domains, focusing instead on objective radiographic alignment.

From a biomechanical perspective, accuracy in implant positioning and restoration of the joint line are essential to prevent instability, ligament-muscular imbalance, or alterations in the extensor mechanism. Several studies indicate that rTKA reduces the rate of out-of-range cases in the mechanical axis (HKA) and other complementary implant-related angles [26, 28]. However, improvements in precision have not consistently translated into greater satisfaction or increased range of motion at one year postoperatively. This may be explained by the high proficiency achieved by experienced surgeons using the manual technique, or by the influence of other factors (such as soft-tissue balancing, rehabilitation protocols, or patient expectations), which may play a role as important as geometric accuracy.

An important methodological consideration in the present study is the potential presence of a ceiling effect, as both robotic and manual techniques achieved 100% alignment within the predefined ± 2° threshold. While this finding supports equivalence, it may theoretically limit the ability to detect subtle differences between techniques when overall performance is high.

However, the selected ± 2° threshold reflects a widely accepted clinical tolerance for coronal alignment in total knee arthroplasty, beyond which biomechanical alterations, increased polyethylene wear, and inferior survivorship have been reported. Deviations within this range are generally considered biomechanically neutral and clinically acceptable, particularly in the absence of component malposition or soft-tissue imbalance.

In the context of severe deformities, altered joint lines, or revision cases, rTKA may offer a more evident advantage. Recent studies support that the greater investment in technology is justified when anatomy presents major challenges or when a minimal margin of error is required [29, 30]. For primary procedures without added complexity, however, the equivalent clinical outcomes suggest that the manual technique remains a valid and efficient option.

Methodologically, the current trend in comparing surgical techniques is to use equivalence or non-inferiority designs rather than simply demonstrating superiority. Several studies have emphasized that reproducibility and standardization of the surgical protocol—rather than mere technological adoption—are key to optimizing outcomes [31]. This aligns with our findings: the experience of the surgical team, a standardized robotic assistance system, and appropriate patient selection can level the field between both techniques.

The relatively wide time frame of radiographic follow-up could be perceived as a potential source of variability. However, several factors reduce the likelihood that this aspect influenced the study results. First, all radiographic assessments were performed using a standardized protocol, with a minimum follow-up of 12 months and a mean follow-up of 24 ± 6 months, ensuring that measurements were obtained after completion of early postoperative remodeling. Second, no changes in surgical technique, implant design, robotic platform, or radiographic measurement methodology occurred throughout the study period. Third, the primary radiographic outcomes evaluated—mechanical axis alignment and patellar orientation—are static parameters once implant positioning is established and are not expected to vary over time in the absence of component migration, loosening, or revision surgery, none of which were observed in this cohort.

Patellar assessment was limited to a static coronal radiographic measurement, which does not capture dynamic patellar tracking or axial tilt. However, this approach was selected intentionally to ensure reproducibility and to isolate geometric alignment from soft-tissue–dependent variables.

This study did not include direct linear measurements of joint line elevation or patellar height ratios. Although these metrics are well validated, the present analysis intentionally focused on angular coronal parameters to enhance reproducibility and minimize projection-related variability.

The use of a binary threshold (≤2°) may introduce a ceiling effect in high-performing cohorts, potentially obscuring ultra-fine geometric differences. Nevertheless, the study was designed to detect **clinically meaningful misalignment**, rather than sub-degree variations of uncertain relevance.

An important limitation of the present study is the absence of clinical or patient-reported outcome measures (PROMs). Consequently, the findings are strictly limited to **radiographic alignment and geometric parameters**, and no direct conclusions can be drawn regarding patient satisfaction, functional recovery, or subjective outcomes after total knee arthroplasty.

All procedures were performed by a single, highly experienced arthroplasty team following a standardized surgical protocol. While this approach enhances internal validity and minimizes technical heterogeneity, it inherently limits **external generalizability**, as the results may not be directly extrapolable to settings with different levels of surgical experience or variability in technique.

One of the proposed advantages of robotic-assisted total knee arthroplasty is its potential to **reduce inter-surgeon variability** by standardizing bone cuts, alignment targets, and intraoperative decision-making. However, the present study design—focused on a single experienced surgical team—does not allow assessment of this potential benefit.

Therefore, the observed equivalence between robotic and manual techniques should be interpreted within the context of **expert-level execution**, and may not necessarily reflect outcomes in less experienced hands or in multicenter environments with greater surgeon-to-surgeon variability.

Finally, several limitations of our study must be acknowledged. First, the retrospective design reduces the ability to establish causality and may introduce selection bias, although both groups were comparable in baseline variables. Secondly, the follow-up period, although adequate to evaluate functional outcomes and mid-term alignment, does not allow conclusions regarding implant durability or long-term complications. Additionally, the study was conducted in a single center with a single surgical team, which enhances technical homogeneity but limits the generalizability of the findings to settings with different learning curves or technological resources. Cost-effectiveness, operative time, and the robotic learning curve were also not analyzed, despite being decisive factors in clinical implementation. In this sense, although the findings provide internal robustness, they should be interpreted with caution regarding their broader applicability.

Conclusions

Robot-assisted total knee arthroplasty provides increased geometric precision; however, when evaluated solely in terms of radiographic coronal alignment and patellar orientation, this advantage does not result in superiority over a standardized manual technique performed by experienced surgeons.

Both approaches demonstrated equivalent radiographic alignment within clinically accepted thresholds. The present findings should therefore be interpreted in radiographic terms only, without extrapolation to functional or patient-reported outcomes.

Author contributions Carlos Patricio Peñaherrera Carrillo, Contribution: conception of work, data curation, research, formal analysis, drafting work, critically revised work for intellectual content, final approval for publication, agreement of accountability. María Susana Cabrera Ávila, Contribution: conception of work, data curation, research, drafting work, final approval for publication, and agreement of accountability. Francisco Endara Urresta, Contribution: conception of work, research, drafting work, critically revised work for intellectual content, final approval for publication, and agreement of accountability. Alejandro Xavier Barros Castro, Contribution: conception of work, drafting work, critically revised work for intellectual content, final approval for publication, and agreement of accountability. Eduardo Durán-Arce, Contribution: conception of work, drafting work, critically revised work for intellectual content, final approval for publication, and agreement of accountability. Alejandro Guillermo Gallegos-Tejeda, Contribution: conception of work, drafting work, critically revised work for intellectual content, final approval for publication, and agreement of accountability. Carlos Enrique Suárez Ahedo, Contribution: conception of work, critically revised work for intellectual content, major revisions for intellectual content, final approval for publication, agreement of accountability. Carlos Javier Pineda Villaseñor, Contribution: conception of work, critically revised work for intellectual content, major revisions for intellectual content, final approval for publication, agreement of accountability.

Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

References

1. Hsu H, Siwiec RM, Knee O (2023) In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan. (**PMID: 29939661**)
2. Hootman JM, Helmick CG, Barbour KE et al (2016) Updated projected prevalence of self-reported doctor-diagnosed arthritis and arthritis-attributable activity limitation among US adults, 2015–2040. Arthritis Rheumatol Hoboken NJ 68:1582–1587
3. Murphy L, Schwartz TA, Helmick CG et al (2008) Lifetime risk of symptomatic knee osteoarthritis. Arthritis Rheum 59:1207–1213
4. Espinosa MR, Arce SCA, Cajigas MJC, Esquivel VJA, Gutiérrez GJJ, Martínez HJL et al (2013) Reunión multidisciplinaria de expertos En diagnóstico y Tratamiento de Pacientes Con osteoartritis. Actualización Basada En evidencias. Med Int Mex 29(1):67–92
5. Kellgren J, Lawrence J (1957) Radiological assessment of Osteo-Arthrosis. Ann Rheum Dis 16(4):494–502. https://doi.org/10.1136/ard.16.4.494
6. Aweid O, Haider Z, Saed A, Kalairajah Y (2018) Treatment modalities for hip and knee osteoarthritis: A systematic review of safety. J Orthop Surg (Hong Kong) 26(3):2309499018808669
7. Home | Agency for Healthcare Research and Quality. https://www.ahrq.gov/ (Accessed 20 Nov)
8. Shichman I, Roof M, Askew N, Nherera L, Rozell JC, Seyler TM, Schwarzkopf R (2023) Projections and Epidemiology of Primary Hip and Knee Arthroplasty in Medicare Patients to 2040–2060. JB JS Open Access. 8(1):e22.00112. https://doi.org/10.2106/JBJS.OA.22.00112. (**PMID: 36864906; PMCID: PMC9974080**)

9. Kahlenberg CA, Nwachukwu BU, McLawhorn AS, Cross MB, Cornell CN, Padgett DE (2018) Patient satisfaction after total knee replacement: a systematic review. HSS J 14:192–201
10. Bourne RB, Chesworth BM, Davis AM, Mahomed NN, Charron KDJ (2010) Patient satisfaction after total knee arthroplasty: who is satisfied and who is not? Clin Orthop Relat Res 468:57–63
11. Lording T, Lustig S, Neyret P (2017) Coronal alignment after total knee arthroplasty. EFORT Open Rev 1:12–17
12. Matsuda S, Kawahara S, Okazaki K, Tashiro Y, Iwamoto Y (2013) Postoperative alignment and ROM affect patient satisfaction after TKA. Clin Orthop Relat Res 471:127–133
13. van Lieshout KP, van Koen E-J, van Gino G (2018) The negative effect of joint line elevation after total knee arthroplasty on outcome. Knee Surgery, Sports Traumatology, Arthroscopy. 27(5):1477–86
14. Luyckx T, Vandenneucker H, Ing LS, Vereecke E, Ing AV, Victor J (2018) Raising the joint line in TKA is associated with Midflexion laxity: A study in cadaver knees. Clin Orthop Relat Res 476(3):601–611
15. Georg Matziolis, Brodt S, Windisch C, Roehner E (2017) Changes of posterior condylar offset results in midflexion instability in single-radius total knee arthroplasty. Arch Orthop Trauma Surg 137(5):713–717
16. Selvarajah E, Hooper G (2009) Restoration of the joint line in total knee arthroplasty. J Arthroplast 24(7):1099–1102
17. Snider MG, MacDonald SJ (2009) The influence of the posterior cruciate ligament and component design on joint line position after primary total knee arthroplasty. J Arthroplast 24(7):1093–1098
18. Koshire S, Mohanty SS, Keny SA, Rai AK, Rathod TN, Kamble P (2022) The influence of joint line restoration on functional outcome after primary total knee arthroplasty: A prospective study. J Clin Orthop Trauma 34:102023
19. St Mart JP, Goh EL (2021) The current state of robotics in total knee arthroplasty. EFORT Open Rev 6(4):270–279. https://doi.org/10.1302/2058-5241.6.200052 (PMID: 34040804; PMCID: PMC8142057)
20. Agrawal VO, Gadekar AP, Vaidya N. Does robotic technology successfully restore the joint line after total knee arthroplasty? A retrospective analysis. Arthroplasty. 2022 Jan 5;4(1):6. doi: 10.1186/s42836-021-00103-6. PMID: 35236508; PMCID: PMC8796510.
21. Gaillard R, Bankhead C, Budhiparama NC, Cécile Batailler E, Servien LS (2019) Influence of patella height on total knee arthroplasty: outcomes and survival. J Arthroplasty 34(3):469–477
22. Nakano N, Kuroda Y, Masanori Tsubosaka T, Kamenaga, Ishida K, Hayashi S et al (2023) The influence of patellar height on patellofemoral contact force during total knee arthroplasty. J Joint Surg Res 1(1):186–191
23. Jobe Shatrov M, Khasian, Lording T, Monk AP, Parker D, Lustig S (2024) Robotic assessment of patella tracking in total knee arthroplasty. J ISAKOS Joint Disorders Orthop Sports Med 9(5):100287–100287
24. Mayne AI, Harshadkumar Rajgor C, Munasinghe, Agrawal Y, Pagkalos J, Davis ET et al (2024) The ROSA robotic-arm system reliably restores joint line height, patella height and posterior condylar offset in total knee arthroplasty. Knee 48:1–7
25. Alrajeb R, Zarti M, Shuia Z, Alzobi O, Ahmed G, Elmhiregh A. Robotic-assisted versus conventional total knee arthroplasty: a systematic review and meta-analysis of randomized controlled trials. Eur J Orthop Surg Traumatol. 2024 Apr;34(3):1333-1343. doi: 10.1007/s00590-023-03798-2. Epub 2023 Dec 22. PMID: 38133653; PMCID: PMC10980635.
26. Riantho A, Christian J, Fidiasrianto K, Elson E, Irvan I, Handy H et al (2023) Radiographic outcomes of Robot-Assisted versus conventional total knee arthroplasty, vol 8. JB & JS Open Access, 2
27. Fu X, She Y, Jin G, Liu C, Liu Z, Li W, Jin R. Comparison of robotic-assisted total knee arthroplasty: an updated systematic review and meta-analysis. J Robot Surg. 2024 Jul 25;18(1):292. doi: 10.1007/s11701-024-02045-y. PMID: 39052153; PMCID: PMC11272701.
28. Sun C, Ma Q, Zhang X et al (2025) Improved alignment accuracy but similar early clinical outcomes with NAVIO imageless robotic-assisted vs. conventional total knee arthroplasty: a meta-analysis. J Orthop Surg Res 20:619. https://doi.org/10.1186/s13018-025-06013-6
29. Xing P, Qu J, Feng S et al (2024) Comparison of the efficacy of robot-assisted total knee arthroplasty in patients with knee osteoarthritis with varying severity deformity. J Orthop Surg Res 19:872. https://doi.org/10.1186/s13018-024-05372-w
30. Chen J, Loke RWK, Lim KKL et al (2025) Survivorship in robotic total knee arthroplasty compared with conventional total knee arthroplasty: A systematic review and meta-analysis. Arthroplasty 7:21. https://doi.org/10.1186/s42836-025-00304-3
31. Khasawneh Moh'dY, Ghandour M, Zuabi AA, Horst K, Hildebrand F et al (2025) Comparative efficacy and precision of Robot-Assisted vs. Conventional total knee arthroplasty: A systematic review and Meta-Analysis of randomized controlled trials. J Clin Med J Clin Med 14:3249. https://doi.org/10.3390/jcm14093249

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.