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Similar joint line convergence angle correction with mechanical and patient-specific alignment in robotic-assisted TKA

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ABSTRACT

Introduction: In total knee arthroplasty (TKA), positioning implants closer to the patient's constitutional alignment improves joint line obliquity (JLO), replicating normal biomechanics and gait patterns. As a result, the joint line convergence angle (JLCA) has gained recognition as a key parameter for assessing intra-articular deformity and lateral soft tissue laxity. This study aimed to evaluate JLCA changes following robotic-assisted TKA (RA-TKA) using two alignment strategies. We hypothesized that a patient-specific alignment (PSA) strategy would result in greater JLCA correction and improved outcomes.

Methods: A retrospective review of 98 patients (100 knees) undergoing RA-TKA was performed. Group I (50 knees) underwent mechanical alignment (MA), while Group II (50 knees) underwent PSA. JLCA was measured preoperatively and postoperatively by two independent observers. Demographic and functional data, including KOOS JR scores were collected, and statistical analyses were performed using STATA v.18.5.

Results: Both groups showed significant postoperative improvement in JLCA: from 2.34° to 0.35° in the MA group, and from 2.43° to 0.29° in the PSA group. However, the degree of JLCA correction did not differ significantly between groups ($p = 0.285$). KOOS JR scores improved similarly in both groups, with no significant differences at 1-year follow-up.

Conclusions: Robotic-assisted TKA significantly improved JLCA regardless of alignment strategy. Patient-specific and mechanical alignment approaches yielded comparable radiographic and functional outcomes.

Level of evidence: Level IV.

1. Introduction

Patient-reported satisfaction following total knee arthroplasty (TKA) varies widely, with average satisfaction rates around 80 %.[1–3] Several factors contribute to dissatisfaction after TKA, with malalignment and instability being among the most significant.[4] Malalignment, defined as more than 3° of deviation from the hip-knee-ankle (HKA) mechanical axis, has been observed in up to one-third of patients undergoing conventional total knee arthroplasty, potentially leading to pain and instability.[5] This is particularly concerning, as most experts recommend achieving limb alignment within ±3° to optimize surgical outcomes.

The concept of performing bone cuts at right angles—known as mechanical alignment (MA)—on both the femur and tibia, with the goal of creating parallel and equal flexion and extension spaces, was introduced in the early stages of TKA development.[6] However, MA introduces significant anatomical modifications for many individuals, potentially resulting in uneven bone resections. In the past, this led many surgeons to view TKA as a soft tissue surgery aimed at balancing bone cuts.[7] The need for soft tissue releases varies among surgeons and surgical techniques, releases are less frequently required in deformities under 15°.[8] Although multiple soft tissue release techniques have been proposed to balance joint spaces, studies have shown that these releases can be unpredictable and may lead to greater imbalance.[9] This imbalance can result in abnormal kinematics, loss of range of motion, implant loosening, increased wear, and early failure.[10]

On the other hand, it has been shown that restoring native soft tissue laxity in TKA is more easily achieved when implants are positioned closer to the prearthritic constitutional alignment.[11] For many surgeons,

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this has led to a philosophical shift in the approach to TKA, moving from mechanical alignment to a more patient-specific (PS) approach. This transition has been supported by new methods for classifying functional phenotypes of non-arthritic knees.[12]

Modern instrumentation and implants enhance the replication of native knee anatomy and biomechanics, but achieving precise alignment and balance intraoperatively remains challenging with traditional manual techniques. Robotic assistance, guided by 3D CT imaging, has proven highly effective, offering precision up to 0.05 mm.[13] The robotic arm-assisted system minimizes bone resection errors, the MAKO robot which is the current leader in robot market has error <1 mm, and provides real-time intraoperative guidance for optimal TKA component positioning before final implantation.

Restoring the limb's constitutional alignment and joint line obliquity (JLO) more accurately replicates physiological soft tissue laxities[14,10] and normal gait patterns.[15] Due to this paradigm shift, the joint line convergence angle (JLCA)—a key component of knee kinematics—has recently gained attention as a clinically relevant parameter. It is a well-recognized surrogate measure for estimating the degree of intra-articular deformity. The JLCA is influenced by intra-articular deformity and lateral soft tissue laxity.[16] For this reason, if JLCA is influenced by soft tissue laxity, performing RA-TKA should result in less disruption of soft tissues, thereby having a greater impact on JLCA. Furthermore, if a patient-specific alignment strategy is used—aiming to restore the pre-arthritic state while being less aggressive on soft tissues—the JLCA change should be even more pronounced.

This study aimed to evaluate changes in the joint line convergence angle following robotic-assisted TKA using two different alignment strategies. We hypothesized that both mechanical alignment and patient-specific alignment would achieve similar correction of JLCA within the normal physiological range (0–2°), with no significant differences between the two approaches.

2. Methods

A retrospective review was conducted on a cohort of patients who underwent RA-TKA (Mako, Stryker, Mahwah, NJ) between January 2023 and January 2024. Ethical review was undertaken by the Health and Disability Ethics Committee of our Center. Informed consent was obtained from all patients for use of clinical data. No funding was required for this study.

To account for the learning curve associated with RA-TKA, the first ten cases from each group were excluded. The indication for surgery was advanced knee osteoarthritis, classified as Kellgren-Lawrence stages 3 and 4, affecting at least two of the three knee compartments. Patients with coronal deformities greater than 15° on long-leg radiographs were excluded, as were those with prior ipsilateral knee surgeries or incomplete radiographic data.

A standard radiographic evaluation was performed using preoperative and postoperative weight-bearing X-rays, including anteroposterior, Rosenberg, lateral, axial patellar (skyline), and full-length lower limb radiographs. The joint line convergence angle was measured by two independent observers on both preoperative and postoperative radiographs. Postoperative JLCA was measured using tangents to the metallic surfaces of the femoral component (distal condyles) and tibial baseplate on standing AP radiographs. This technique aligns with the approach described by Mabrouk et al.[16] and has been used in prior studies evaluating postoperative JLCA.

2.1. RA-TKA operative technique

All patients underwent general anesthesia (combining inhalation and intravenous methods). A tourniquet was used to create a bloodless surgical field. The approach was via a medial parapatellar incision, with careful handling of soft tissue release. Special attention was given to the anteromedial tibial soft tissue release to avoid injuring the patellar tendon.

The robotic system (MAKO®, Stryker, MI, USA) was calibrated and configured following a standardized protocol before surgery. Preoperative computed tomography (CT) scans of the hip, knee, and ankle were obtained using the TKA application platform to create a patient-specific three-dimensional model. This data was uploaded to the robotic system to plan the implant sizes preoperatively.

Intraoperatively, guides for the robotic system's antennas were fixed on both the tibia and femur, and registration was performed by capturing 40 random points on the bony surface of each bone. During the registration of the 40 points on the bone surface, a precision level of less than 0.5 mm was required to proceed with the procedure. All measurements were performed intraoperatively using the robotic system's user interface, which has a resolution of 0.5 mm for distances and 0.1° for angles. All patients received a posterior-stabilized (PS) implant, necessitating the sacrifice of the posterior cruciate ligament (PCL) before any gap analyses to prevent interference with the flexion gap. The femoral and tibial component trials were positioned, and virtual planning was conducted according to each alignment technique. The goal was to balance the flexion and extension spaces based on either mechanical alignment or patient-specific alignment, depending on the assigned group. The tibial slope in both groups were standardized at 3°.

Patient rehabilitation was conducted by physical therapists at our center following a standardized protocol. This included immediate postoperative rehabilitation, starting with the use of a continuous passive motion machine from recovery, direct mobilization, and immediate full weight bearing with the aid of crutches. Under the supervision of the physical therapist, patients were encouraged to perform active flexion and extension exercises from day one. On average, patients stayed at our facility for two nights. After this, patients followed a rehabilitation program appropriate to the surgery.

The use of orthopedic canes was recommended for at least the first two weeks. All patients received routine prophylaxis with oral anticoagulation for three weeks following surgery. The first postoperative appointment at the outpatient clinic occurred at two weeks. Clinical follow-up was conducted at 2 weeks, 4 weeks, 2 months, 3 months, 6 months, and 1 year postoperatively.

2.2. Mechanical alignment (MA)

The MA technique aims to restore a neutral axis (0°) or, at a minimum, correct coronal deformity within a ±3° limit. The femoral resection is adjusted to preserve mild constitutional deformities and/or correct more severe deformities, while the tibial component is positioned in strict mechanical alignment. The tibial component was placed perpendicular (90°) to the tibial mechanical axis. Regarding flexion and extension spaces, both components were positioned to achieve 1–2 mm of residual laxity in both compartments. This approach ensures that the HKA angle remains within a safe range of 177–183°.

2.3. Patient-specific alignment (PSA)

In the PSA technique, the tibial component was positioned first by planning a resection of equal amounts of medial and lateral bone, accounting for bone wear. The goal was to restore the pre-arthritic medial proximal tibial angle (MPTA) within a safe range of 84° (varus) to 92° (valgus), which represents the knee's native alignment. The tibial slope was set to match the native medial tibial inclination. On the femoral side, the femoral component was positioned to restore the height of the medial joint line in both extension and flexion. Flexion and extension spaces were balanced by adjusting the distal lateral and posterior lateral femoral resection levels. Flexion space: The target was 1–2 mm of residual laxity in the medial compartment and 1–3 mm of residual laxity in the lateral compartment. Extension space: The goal was 1–2 mm of residual laxity in both compartments, ensuring the HKA angle remained within a safe range of 174–183°.

2.4. Bone resection

Tibial and femoral resections were performed according to the intraoperative plan defined by the surgeon using a robotic-assisted system with haptic feedback. Since a CT-based navigation tool was utilized, all planned resection thicknesses were measured as bone only, without accounting for cartilage. The robotic system enabled the surgeon to maneuver the oscillating saw within the predefined cutting plane while maintaining haptic boundaries, thereby protecting the soft tissues. The patella was routinely resurfaced using a conventional oscillating saw, with an asymmetric patellar implant placed.

2.5. Data extraction

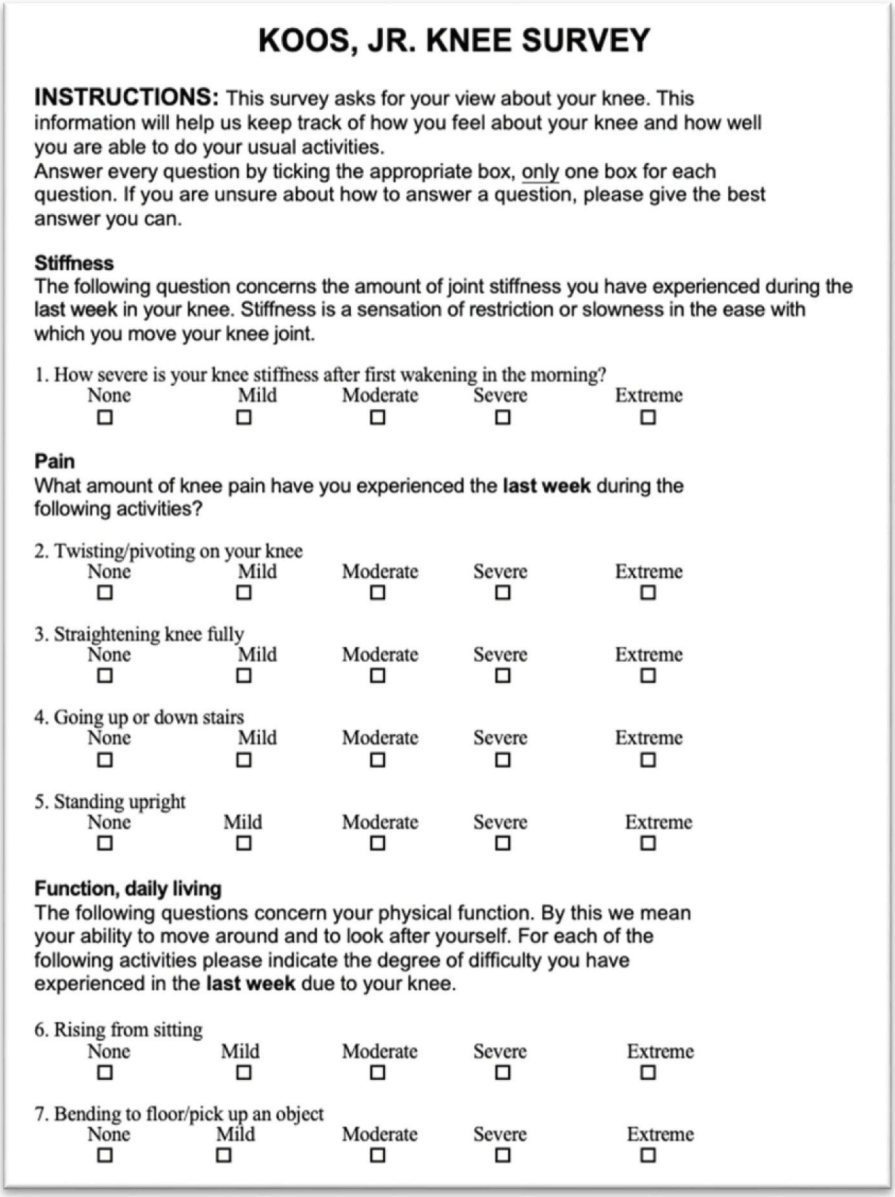
Demographic data and the Knee Injury and Osteoarthritis Outcome Score Junior (KOOS JR)[17] (see Fig. 1) were collected preoperatively and at 12 months postoperatively. Demographic data included age, sex, body mass index (BMI), and postoperative complications. Comorbidities assessed included hypertension, dyslipidemia, arthritis, cardiac diseases, respiratory conditions, depression, and anxiety.

2.6. KOOS JR

Clinical outcomes were evaluated using the Knee Injury and Osteoarthritis Outcomes Score for Joint Replacement (KOOS JR),[17] a shortened version of the KOOS[18] that assesses patient stiffness (1 item), pain (4 items), and daily living functions (2 items). Scores range from 0 to 100, where a score of 0 indicates total knee disability and 100 indicates perfect joint health. This is a joint-specific, patient-reported score designed to evaluate outcomes following total knee arthroplasty (Fig. 1).[19]

2.7. Data analysis

The JLCA was measured by two independent observers on both preoperative and postoperative radiographs. Statistical analysis was performed using Student's t-test, the chi-square test, and linear regression for multivariable analysis. The significance level was defined as P <



KOOS, JR. KNEE SURVEY

INSTRUCTIONS: This survey asks for your view about your knee. This information will help us keep track of how you feel about your knee and how well you are able to do your usual activities.
Answer every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can.

Stiffness
The following question concerns the amount of joint stiffness you have experienced during the last week in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your knee joint.

1. How severe is your knee stiffness after first wakening in the morning?
None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

Pain
What amount of knee pain have you experienced the **last week** during the following activities?

2. Twisting/pivoting on your knee
None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

3. Straightening knee fully
None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

4. Going up or down stairs
None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

5. Standing upright
None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

Function, daily living
The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

6. Rising from sitting
None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

7. Bending to floor/pick up an object
None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

Fig. 1. Knee injury and osteoarthritis outcomes score for joint replacement (KOOS JR).

0.05. All statistical analyses were performed using STATA version 18.5.

3. Results

A total of 110 patients underwent RA-TKA between January 2023 and January 2024. All patients were contacted between November 2024 and January 2025 for a review. At follow-up, 98 patients (100 knees) were available, giving a follow-up rate of 89 % at a minimun follow-up time of 12 months after surgery. Of these, 61.2 % (n = 60) were female, with a mean age of 70 years (SD: 8.2) and a BMI of 28.1 (SD: 4.2) (Table 1).

In Group I, the mean preoperative JLCA was 2.34° (SD 1.49), and the mean postoperative JLCA was 0.35° (SD 0.27). In Group II, the mean preoperative JLCA was 2.43° (SD 1.72), and the mean postoperative JLCA was 0.29° (SD 0.24). The mean difference between preoperative and postoperative JLCA was 2.34° (SD 1.48) in Group I and 2.43° (SD 1.72) in Group II. There was no statistically significant difference between the two groups regarding JLCA improvement (p = 0.285) (Table 2) (Fig. 2).

The mean preoperative KOOS JR score was 45.9 (SD: 10.7), while the postoperative KOOS JR score was 78.2 (SD: 12.1), with an average total improvement of 32.2 points (SD: 16.1) (Table 2). No significant differences were observed between the groups in terms of sex, age, body mass index (BMI), Kellgren-Lawrence classification (Table 3), preoperative range of motion, or hip-knee-ankle (HKA) angle measurement, preoperative KOOS JR or postoperative KOOS JR between the two groups at 1-year follow-up (Table 1).

No complications occurred during surgery. Knee stability and patellar tracking were assessed, with no need for soft tissue or lateral releases in either group. At the latest follow-up, none of the knees had undergone revision or were being considered for revision.

4. Discussion

The most important finding of our study is that both MA and PSA strategies—when optimized through robotic assistance—resulted in a similar and significant improvement in the postoperative JLCA, with values close to 0° in both groups. The PSA strategy did not result in greater JLCA correction compared to MA. This finding is clinically relevant, as it suggests that both alignment philosophies are capable of achieving satisfactory correction of intra-articular deformity and soft tissue balance when performed using robotic-assisted techniques.

The comparability between the two groups, with similar preoperative deformity and patient demographics, enhances the internal validity of our results. According to Mabrouk et al.,[16] JLCA is closely associated with the severity of intra-articular cartilage wear and soft tissue laxity. Achieving a postoperative JLCA between 0° and 2° may therefore reflect improved replication of native joint kinematics.

For decades, mechanical alignment has been considered the gold standard in prosthetic alignment, primarily aiming to distribute load evenly across the prosthetic joint, thereby reducing the risk of implant loosening. At the beginning of our robotic-assisted surgery experience, our group exclusively employed mechanical alignment in all joint replacement procedures, with few outliers. However, as we transitioned to a more patient-specific alignment approach, the boundaries of our planning expanded, leading us to consider implant positioning with varus angles of up to 5° or even 6° in certain patients. Interestingly, despite these variations, we observed that postoperative JLCA values remained largely unchanged, suggesting that individualized alignment strategies may still achieve comparable joint balance.

As studied by Macdessi et al.,[10] when ±3° limits are applied to the mechanical axis (HKA), the lateral distal femoral angle (LDFA), and the medial proximal tibial angle (MPTA), constitutional alignment and joint line obliquity (JLO) are restored in only 36.2 % of knees. Therefore, it is likely that more than 60 % of patients undergoing total knee arthroplasty (TKA) with this surgical approach will experience some degree of soft tissue imbalance, necessitating ligament releases to restore the native knee parameters. However, the percentage of patients in whom constitutional limb alignment is successfully restored increases significantly to 74 % when JLO restrictions are removed, while still maintaining the HKA limit within ±3°.

When orthopedic surgeons aim for mechanical alignment in the coronal plane, soft tissue releases may be necessary to achieve proper knee balance. In contrast, restoring the prearthritic constitutional alignment reduces the need for extensive soft tissue releases, allowing for better tissue balance without causing ligament damage or requiring major soft tissue releases.[12]

Regarding findings in the literature, Macdessi et al.[20] conducted a study on over 500 knees undergoing mechanical alignment TKA to determine whether restoring the preoperative JLCA and the native knee phenotype had any clinical impact. They found no significant differences between patients whose native phenotype was restored (approximately 18 %) and those who ended up with a different phenotype. Interestingly, despite advocating for a neutral mechanical alignment (HKA = 180°), more than 60 % of patients had an alignment outside the 178°–182° range. This highlights that planned bone cuts often do not translate perfectly into the achieved alignment, reinforcing the complexity of achieving precise mechanical alignment in TKA.

It is interesting to observe how our group has obtained similar results, demonstrating that certain mechanical alignment concepts are reproducible using the MAKO 2.0 software for more PSA philosophy. This system emphasizes prosthetic balance based on the ligamentous condition and the medial and lateral laxities throughout the entire range of flexion-extension. However, we believe it is important to highlight the safety margins we have identified as our robotic experience has evolved. These margins are closely related to the native condition of the knees we operate on. We consider JLCA a reliable and reproducible radiological indicator for evaluating coronal balance, especially when complemented by robotic precision.

This study has several limitations which should be acknowledged. First, this was a retrospective study with a short follow-up period, so longer-term outcomes beyond 12 months still need to be confirmed. Second, although deformities greater than 15° were excluded, we did not include preoperative MPTA or LDFA classification in the multivariate analysis due to the limited sample size. Additionally, no intraoperative sensor or dynamic balancing tool was used to correlate JLCA with soft tissue tension directly.

Despite these limitations, our study provides valuable insight into

Table 1
Univariate analysis (N = 100).

Characteristics	Mean (SD)
Female sex, %	60 (61.2)
Age	70.0 (8.2)
BMI	28.1 (4.2)
Preoperative KOOS	45.9 (10.7)
Postoperative KOOS	78.2 (12.1)

SD: Standard deviation, BMI: Body mass index.

Table 2
Statistical analysis: Group 1 versus group 2.

Group	Obs	Mean	Std. err.	Std. dev.	[95% conf. Interval]	
1	50	2.336	.2105728	1.48	1.91	2.75
2	50	2.428	.2437637	1.72	1.93	2.91
Combined	100	2.382	.1603114	1.60	2.06	2.70
diff			.3221205		0.73	0.54

Diff = mean (1) – mean (2)

t = -0.2856

Degrees of freedom = 98

Pr (T < t) = 0.3879 ; Pr (| T| > | t|) = 0.7758 ; Pr (T > t) = 0.6121

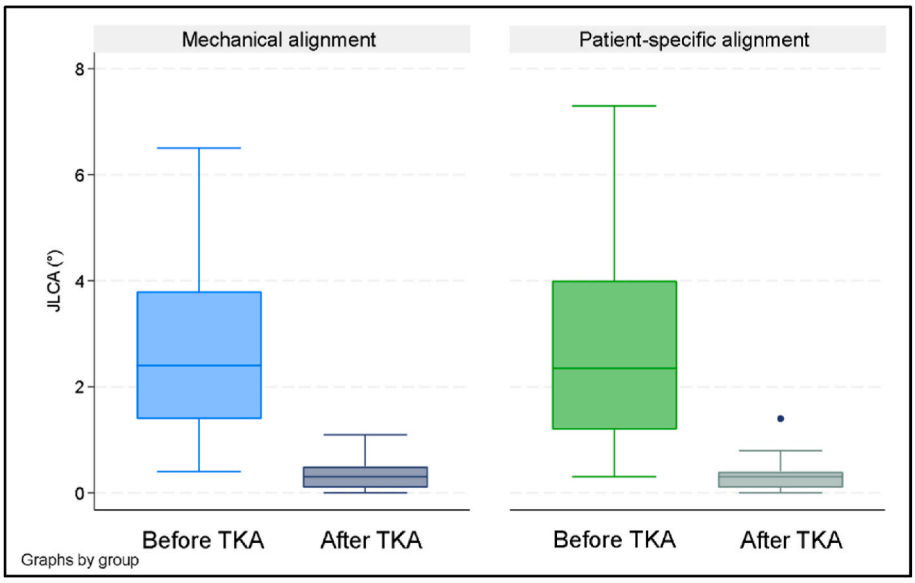


Fig. 2. Statistical results. Comparison between both groups of the preoperative versus postoperative JLCA change.

Table 3
Demographic table comparing Group 1 and Group 2.

Table 3. Demographic Characteristics	Group 1 (n = 50)	Group 2 (n = 50)	p-value
Patient Medical History			
Female	52 (58.4)	57 (67.9)	0.10
Age, years (SD)	71.7 (8.7)	72.0 (8.1)	0.97
Body mass index (IQR)	25.4 (24.1)	24.1 (22.3–26.4)	0.27
Surgical Characteristics			
Left laterality	37 (41.6)	41 (48.8)	0.57
Hospital stay, days (IQR)	3 (3,4)	3 (3,4)	0.43

SD: Standard deviation, IQR: Interquartile range.

how robotic-assisted TKA can standardize outcomes in different alignment philosophies, reinforcing the reproducibility and reliability of JLCA as a key radiographic parameter.

5. Conclusion

Postoperative joint line convergence angle improved in both mechanical and patient-specific alignment strategies following robot-assisted TKA, with no significant differences between the two approaches. Further studies with larger sample sizes, more long-term outcomes and the inclusion of more functional outcomes are needed to validate these findings.

Author contribution

All authors contributed equally to the development of this manuscript.

Conceptualization: All authors.
Methodology: All authors.
Investigation: All authors.
Data Curation: All authors.
Formal Analysis: All authors.
Writing – Original Draft: All authors.
Writing – Review & Editing: All authors.
Supervision: All authors.
Project Administration: All authors.

Patient or guardian consent

Ethical review was undertaken by the Health and Disability Ethics Committee of our Center. Informed consent was obtained from all patients for use of clinical data.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional.

Ethical review was undertaken by the Health and Disability Ethics Committee of Clinica Alemana Center. Informed consent was taken from all patients for use of data. No funding was required for this study.

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Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

1. Kahlenberg CA, Nwachukwu BU, McLawhorn AS, Cross MB, Cornell CN, Padgett DE. Patient satisfaction after total knee replacement: a systematic review. *HSS J.* 2018 Jul;14(2):192–201. https://doi.org/10.1007/s11420-018-9614-8. Epub 2018 Jun 5. PMID: 29983663; PMCID: PMC6031540.
2. Noble PC, Conditt MA, Cook KF, Mathis KB. The John Insall Award: patient expectations affect satisfaction with total knee arthroplasty. *Clin Orthop Relat Res.* 2006 Nov;452:35–43. https://doi.org/10.1097/01.blo.0000238825.63648.1e. PMID: 16967035.
3. Bourne RB, Chesworth BM, Davis AM, Mahomed NN, Charron KD. Patient satisfaction after total knee arthroplasty: who is satisfied and who is not? *Clin Orthop Relat Res.* 2010 Jan;468(1):57–63. https://doi.org/10.1007/s11999-009-1119-9. PMID: 19844772; PMCID: PMC2795819.
4. Gunaratne R, Pratt DN, Banda J, Fick DP, Khan RJK, Robertson BW. Patient dissatisfaction following total knee arthroplasty: a systematic review of the

literature. *J Arthroplast*. 2017 Dec;32(12):3854–3860. https://doi.org/10.1016/j.arth.2017.07.021. Epub 2017 Jul 21. PMID: 28844632.
5. Mason JB, Fehring TK, Estok R, Banel D, Fahrbach K. Meta-analysis of alignment outcomes in computer-assisted total knee arthroplasty surgery. *J Arthroplast*. 2007 Dec;22(8):1097–1106. https://doi.org/10.1016/j.arth.2007.08.001. PMID: 18078876.
6. Freeman MA, Swanson SA, Todd RC. Total replacement of the knee using the Freeman–Swanson knee prosthesis. *Clin Orthop Relat Res*. 1973;94:153–170.
7. Whiteside LA. Soft tissue balancing: the knee. *J Arthroplast*. 2002 Jun;17(4 Suppl 1):23–27. https://doi.org/10.1054/arth.2002.33264. PMID: 12068398.
8. McAulife MJ, Roe J, Garg G, Whitehouse SL, Crawford R. The varus osteoarthritic knee has no coronal contractures in 90 degrees of fexion. *J Knee Surg*. 2017;30:297–303.
9. Christensen CP, Stewart AH, Jacobs CA. Soft tissue releases afect the femoral component rotation necessary to create a balanced fexion gap during total knee arthroplasty. *J Arthroplast*. 2013;28:1528–1532.
10. MacDessi SJ, Griffiths-Jones W, Chen DB, et al. Restoring the constitutional alignment with a restrictive kinematic protocol improves quantitative soft-tissue balance in total knee arthroplasty: a randomized controlled trial. *Bone Joint Lett J*. 2020;102-B:117–124.
11. Blakeney W, Beaulieu Y, Puliero B, Kiss MO, Vendittoli PA. Bone resection for mechanically aligned total knee arthroplasty creates frequent gap modifications and imbalances. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(5):1532–1541. https://doi.org/10.1007/s00167-019-05562-8. Epub 2019 Jun 14. PMID: 31201441.
12. Hirschmann MT, Hess S, Behrend H, Amsler F, Leclercq V, Moser LB. Phenotyping of hip–knee–ankle angle in young non-osteoarthritic knees provides better understanding of native alignment variability. *Knee Surg Sports Traumatol Arthrosc*. 2019;27:1378–1384.
13. Hockstein NG, Gourin CG, Faust RA, Terris DJ. A history of robots: from science fiction to surgical robotics. *J Robot Surg*. 2007;1(2):113–118. https://doi.org/10.1007/s11701-007-0021-2. Epub 2007 Mar 17. PMID: 25484946; PMCID: PMC4247417.
14. Chang JS, Kayani B, Wallace C, Haddad FS. Functional alignment achieves soft tissue balance in total knee arthroplasty as measured with quantitative sensor-guided technology. *Bone Joint Lett J*. 2021.
15. Blakeney W, Clement J, Desmeules F, Hagemeister N, Riviere C, Vendittoli PA. Kinematic alignment in total knee arthroplasty better reproduces normal gait than mechanical alignment. *Knee Surg Sports Traumatol Arthrosc*. 2018.
16. Mabrouk A, An JS, Glauco L, et al. The joint line convergence angle (JLCA) correlates with intra-articular arthritis. *Knee Surg Sports Traumatol Arthrosc*. 2023 Dec;31(12):5673–5680. https://doi.org/10.1007/s00167-023-07616-4. Epub 2023 Oct 26. PMID: 37884727.
17. Noble PC, Scuderi GR, Brekke AC, et al. Development of a new Knee Society scoring system. *Clin Orthop Relat Res*. 2012 Jan;470(1):20–32. https://doi.org/10.1007/s11999-011-2152-z. PMID: 22065240; PMCID: PMC3237986.
18. Lyman S, Lee YY, Franklin PD, Li W, Cross MB, Padgett DE. Validation of the KOOS, JR: a short-Form knee arthroplasty outcomes survey. *Clin Orthop Relat Res*. 2016 Jun;474(6):1461–1471. https://doi.org/10.1007/s11999-016-4719-1. Epub 2016 Feb 29. PMID: 26926773; PMCID: PMC4868168.
19. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee injury and osteoarthritis outcome score (KOOS)–development of a self-administered outcome measure. *J Orthop Sports Phys Ther*. 1998 Aug;28(2):88–96. https://doi.org/10.2519/jospt.1998.28.2.88. PMID: 9699158.
20. MacDessi SJ, Allom RJ, Griffiths-Jones W, Chen DB, Wood JA, Bellemans J. The importance of joint line obliquity: a radiological analysis of restricted boundaries in normal knee phenotypes to inform surgical decision making in kinematically aligned total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc*. 2022 Sep;30(9):2931–2940. https://doi.org/10.1007/s00167-022-06872-0. Epub 2022 Jan 24. PMID: 35075509.