International Journal of Research in Orthopaedics
Mukartihal R et al. Int J Res Orthop. 2025 Nov;11(6):1480-1484
http://www.ijoro.org

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20253425

Original Research Article

Precision vs. tradition: evaluating alignment accuracy and functional outcomes in robotic vs. conventional total knee arthroplasty

Ravikumar Mukartihal*, Kamal Jain, Ameya Katariya, Tomin P. Zacarias, Kartik P. N., Sharan Patil

Department of Orthopaedics, Sparsh Hospital, Bengaluru, Karnataka, India

Received: 22 July 2025
Revised: 18 September 2025
Accepted: 14 October 2025

***Correspondence:**
Dr. Ravikumar Mukartihal,
E-mail: doctorcmravi@gmail.com

ABSTRACT

Background: Total knee arthroplasty (TKA) is the treatment of choice in severe osteoarthritis (OA) knee. Robot-assisted TKA (RA-TKA) promises superior precision and personalized bone resection and alignment, whereas conventional TKA (C-TKA) relies on manual alignment techniques. This randomized controlled trial compares alignment accuracy and short-term functional outcomes between the two modalities.
Methods: 100 patients with bilateral knee OA were randomized to RA-TKA (n=50) or C-TKA (n=50). Postoperative mechanical alignment (hip-knee-ankle (HKA) angle) and functional outcomes (new knee society score (NKSS) and forgotten joint score (FJS)) were assessed at 6 months.
Results: RA-TKA achieved significantly better alignment, with 82% of patients within±3° of the target HKA angle compared to 64% in C-TKA ($p<0.01$). However, functional outcomes were comparable: KSS (RA-TKA: 205.42±6.52 vs. C-TKA: 205.4±7.94, $p=0.989$) and FJS (RA-TKA: 88.6±4.07 vs. C-TKA: 88.92±4.16, $p=0.662$).
Conclusions: RA-TKA offers improved alignment accuracy over C-TKA but does not confer superior short-term functional outcomes. Despite achieving more precise mechanical alignment, no significant differences in key functional scores are observed within six months postoperatively. The potential long-term benefits of this improved alignment, such as increased implant longevity or reduced wear, remain unconfirmed and warrant further investigation in studies with extended follow-up.

Keywords: Total knee arthroplasty, Total knee, Arthroplasty, Robotic surgery, Mechanical alignment, Functional outcomes, Osteoarthritis

INTRODUCTION

Total knee arthroplasty (TKA) is a well-established surgical intervention designed to alleviate pain and restore functionality in patients with severe osteoarthritis (OA) of knee.[1-3] OA is a progressive degenerative joint disease that can lead to significant functional impairment and diminished quality of life.[4] While conventional TKA techniques have demonstrated efficacy in improving patient outcomes, they are often hampered by variability in the mechanical alignment of prosthetic components.[5] Such misalignment can result in complications, including joint instability, restricted range of motion, and premature wear or failure of the implant.[6-8]

Mechanical alignment has long been a cornerstone of successful TKA; however, achieving precise alignment during surgery can be challenging due to factors such as individual anatomical variations.[9] Robot-assisted TKA (RA-TKA) was introduced as a promising alternative, leveraging advanced robotic technology to improve the accuracy of bone preparation and component placement. By integrating real-time imaging and computer-assisted navigation, RA-TKA systems provide surgeons with

detailed insights into the patient's anatomy, allowing for more tailored surgical approaches. This technological advancement has the potential to reduce the variability associated with conventional TKA, leading to improved alignment of the prosthetic components.[10]

While RA-TKA demonstrates superior alignment accuracy in cadaveric and small cohort studies, its clinical relevance remains debated.[11-13] Recent meta-analyses report conflicting conclusions: some suggest RA-TKA improves early functional recovery, while others find no difference compared to C-TKA.[14-18] This ambiguity underscores the need for randomized trials evaluating both alignment and patient-reported outcomes.

The aim of our study was to compare RA-TKA and conventional TKA (C-TKA) in patients with bilateral knee osteoarthritis, hypothesizing that RA-TKA achieves superior alignment accuracy and improved short-term functional outcomes.

METHODS

Study design

A prospective randomized controlled trial was conducted at a single centre, enrolling 100 patients with bilateral knee OA. Patients were equally assigned to RA-TKA or C-TKA groups (50 per group). Institutional review board and ethics committee approvals were obtained. The study was conducted at Sparsh Hospital, Bengaluru, India, from March 2025 to June 2025.

Inclusion criteria

Diagnosis of bilateral knee OA (Kellgren-Lawrence grade ≥3); age ≥40 years; scheduled for primary bilateral TKA; willingness to complete six-month follow-up were included.

Exclusion criteria

Inflammatory arthritis (e.g., rheumatoid arthritis); prior knee surgery (e.g., osteotomy, fracture fixation); valgus deformity or pre-existing hip pathologies; varus deformity >20° or sagittal plane deformity >20°; neuromuscular disorders affecting gait; severe comorbidities (e.g., uncontrolled diabetes, cardiac disease) were excluded.

Randomization

Patients were randomized using a block randomization sequence (block size=4) [computer generated], stratified by preoperative hip-knee-ankle (HKA) alignment (±5°). Stratification was predefined in the study protocol to ensure balanced allocation across key subgroups. Post-randomization imbalances in baseline characteristics, if any, were addressed through statistical adjustments in the analysis.

Surgical techniques

C-TKA

Standard medial parapatellar arthrotomy; distal femur resection with intramedullary guide (valgus angle 5°–7°); tibial resection with extramedullary guide (7° posterior slope); soft tissue balancing as needed; cemented posterior-stabilized implants (DePuy synthes PFC sigma PS).

RA-TKA

Preoperative CT-based planning (256-slice GE Revolution) MAKO system (Stryker) for surgical navigation; optical trackers for registration robotic arm for guided bone resection with haptic feedback; cemented cruciate-retaining implants (Stryker Triathlon CR).

Both groups followed an identical rehabilitation protocol. On postoperative day 1, patients began weight-bearing with a walker and initiated active and passive range-of-motion (ROM) exercises. From weeks 1 to 4, outpatient physiotherapy focused on quadriceps strengthening and gait training. Between weeks 4 and 12, patients progressively returned to their daily activities.

Radiological and functional assessment

Radiological: HKA alignment measured on standing radiographs at six months

Functional: New knee society score (NKSS) (KSS, 0–240) and forgotten joint score (FJS, 0–100)

Complications: Infection, stiffness, and implant loosening (radiolucency or migration).

Statistical analysis

Statistical analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Baseline characteristics

Both groups were comparable in age, BMI, and preoperative HKA alignment (Table 1).

Table 1: Baseline demographic and radiographic characteristics of patients.

	C-TKA	RA-TKA	P value
Age (in years)	67.98±8.83	67.59±7.4	0.811
BMI	29.1±4.2	29.4±4.5	0.714
Pre-Op HKA	169.67±5.75	167.58±5.22	0.06

Radiological outcomes

RA-TKA achieved significantly fewer alignment outliers (Figure 1).

RA-TKA: 82% (41/50) within ±3° vs. C-TKA: 64% (32/50) (p<0.01).

Mean HKA deviation: RA-TKA (1.63°±1.22°) vs. C-TKA (3.36°±1.72°, p<0.001).

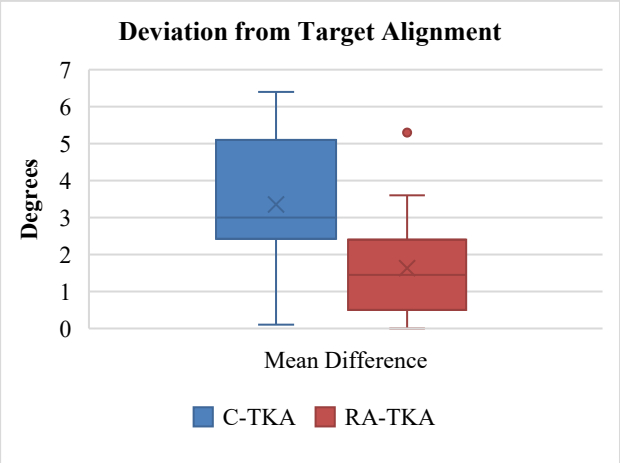

Figure 1: Postoperative HKA alignment deviation of the two groups.

Functional outcomes

No significant differences were observed at 6 months (Table 2). No major complications, such as infection, stiffness, or implant loosening, were reported in either group during the 6-month follow-up period.

Table 2: Functional outcomes at 6 months postoperatively.

	RA-TKA	C-TKA	P value
Oxford knee score	85.4±4.82	83.7±6.26	0.0544
Satisfaction and expectations	40.42±4.36	41±3.86	0.4829
Functional knee society score	79.6±7.20	80.7±7.14	0.4449
Knee society score (total)	205.42±6.52	205.4±7.94	0.989
FJS	88.6±4.07	88.92±4.16	0.6624

DISCUSSION

RA-TKA has emerged as a significant advancement in orthopedic surgery, primarily due to its ability to enhance the precision of implant alignment. In this study, RA-TKA achieved a notably higher proportion of patients within the optimal postoperative mechanical axis range (±3° of the target HKA angle) compared to C-TKA. Specifically, 82% of patients in the RA-TKA group were aligned within this threshold, while only 64% of C-TKA patients achieved similar accuracy (p<0.01). The mean deviation from the mechanical axis was also significantly lower in the RA-TKA group (1.63°±1.22°) compared to the C-TKA group (3.36°±1.72°, p<0.001).

These findings are consistent with recent literature, such as Richardson et al., who reported a mean postoperative HKA deviation of 2.0°±1.4° for RA-TKA versus 3.1°±3.2° for C-TKA, with a higher percentage of outliers in the conventional group. Similarly, Nam et al. observed a mean HKA deviation of 1.9°±1.6° in RA-TKA and 2.8°±1.5° in C-TKA, again highlighting the superior precision of robotic systems.

Functional outcomes: short-term comparison

Despite the clear advantage in alignment precision, the study found no significant difference in short-term functional outcomes between RA-TKA and C-TKA. At six months postoperatively, both groups demonstrated similar results in the New Knee Society Score (KSS: RA-TKA 205.4±6.5; C-TKA 205.4±7.9; p=0.989) and the FJS (RA-TKA 88.6±4.1; C-TKA 88.9±4.2; p=0.662).

This lack of short-term functional superiority for RA-TKA is echoed in other studies. Lee et al found no significant difference in patient-reported outcomes between the two techniques, even though robotic assistance led to better alignment metrics.[18] Jeon et al similarly reported that improved alignment did not translate into better functional results in the early postoperative period.[19]

Several factors may explain why enhanced alignment does not immediately yield improved function.

Soft-tissue management

Functional recovery is influenced by intraoperative soft-tissue handling, which may not differ substantially between the two techniques.

Patient-specific biomechanics

Individual differences in muscle strength, proprioception, and rehabilitation adherence can overshadow the impact of precise alignment.

Rehabilitation protocols

Both groups followed identical rehabilitation regimens, which may have equalized early functional outcomes.

Literature context and long-term implications

While short-term functional parity is observed, the potential long-term benefits of improved alignment remain

an area of ongoing research. Choi et al reported that RA-TKA patients had better patient-reported outcomes at two years, including higher satisfaction and function scores, compared to those who underwent conventional TKA.[20] However, these findings are not universal, and longer-term, high-quality randomized trials are needed to determine whether alignment precision translates into greater implant longevity or delayed onset of complications such as loosening or wear.

Limitations

Six-month follow-up may not capture long-term outcomes or implant durability. Different implant designs between groups may influence results. All surgeries performed by a single surgeon, limiting generalizability. Functional alignment in the robotic group versus mechanical alignment in the conventional group warrants further study.

CONCLUSION

RA-TKA enhances alignment accuracy but provides no demonstrable short-term functional advantage over C-TKA. Soft-tissue balance, rehabilitation, and patient-specific factors likely mediate early recovery more significantly than alignment precision alone. While valuable for complex cases requiring exact component positioning, routine RA-TKA use requires cost-benefit analysis and long-term durability data.

ACKNOWLEDGEMENTS

Authors would like to thank Dr. Soujanya K. Wilson, Group Head Clinical Research, Sparsh Group of Hospitals for the data mining and entire publication coordination.

Declaration

The authors used DeepSeek-V3, an AI-assisted writing tool, to improve clarity and structure. All content was thoroughly reviewed and finalized by the authors, who assume full responsibility for the manuscript.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. Laskin RS. The Genesis total knee prosthesis: a 10-year followup study. Clin Orthop Relat Res. 2001;(388):95-102.
2. Rodriguez JA, Bhende H, Ranawat CS. Total condylar knee replacement: a 20-year followup study. Clin Orthop Relat Res. 2001;388:10-7.
3. Scott WN, Rubinstein M, Scuderi G. Results after knee replacement with a posterior cruciate-substituting prosthesis. J Bone Joint Surg Am. 1988;70(8):1163-73.
4. Neogi T. The epidemiology and impact of pain in osteoarthritis. Osteoarthritis Cartilage. 2013;21(9):1145-53.
5. Chauhan SK, Clark GW, Lloyd S, Scott RG, Breidahl W, Sikorski JM. Computer-assisted total knee replacement. A controlled cadaver study using a multi-parameter quantitative CT assessment of alignment (the Perth CT Protocol). J Bone Joint Surg Br. 2004;86(6):818-23.
6. Ritter MA, Faris PM, Keating EM, Meding JB. Postoperative alignment of total knee replacement. Its effect on survival. Clin Orthop Relat Res. 1994;(299):153-6.
7. Piazza SJ, Delp SL, Stulberg SD, Stern SH. Posterior tilting of the tibial component decreases femoral rollback in posterior-substituting knee replacement: a computer simulation study. J Orthop Res. 1998;16(2):264-70.
8. Barrack RL, Schrader T, Bertot AJ, Wolfe MW, Myers L. Component rotation and anterior knee pain after total knee arthroplasty. Clin Orthop Relat Res. 2001;(392):46-55.
9. Nagamine R, Miura H, Bravo CV, Urabe K, Matsuda S, Miyanishi K, et al. Anatomic variations should be considered in total knee arthroplasty. J Orthop Sci. 2000;5(3):232-7.
10. Mostafa O, Malik M, Qayum M, Ishaq U, Khan A, Wasim A, et al. Robotic-assisted versus conventional total knee arthroplasty: a systematic review and meta-analysis of alignment accuracy and clinical outcomes. Ann Med Surg (Lond). 2025;87(2):867-79.
11. Lee HJ, Park KK, Park YB, Choi SW, Kim BO, Kim SH. Accuracy of Advanced Active Robot for Total Knee Arthroplasty: A Cadaveric Study. J Knee Surg. 2024;37(2):135-41.
12. Richardson MK, DiGiovanni RM, McCrae BK Jr, Cooperman WS, Ludington J, Heckmann ND, et al. Robotic-Assisted Total Knee Arthroplasty in Obese Patients. Arthroplast Today. 2024;26:101320.
13. Nam CH, Lee SC, Kim JH, Ahn HS, Baek JH. Robot-assisted total knee arthroplasty improves mechanical alignment and accuracy of component positioning compared to the conventional technique. J Exp Orthop. 2022;9(1):108.
14. Liow MHL, Goh GS, Wong MK, Chin PL, Tay DK, Yeo SJ. Robotic-assisted total knee arthroplasty may lead to improvement in quality-of-life measures: a 2-year follow-up of a prospective randomized trial. Knee Surg Sports Traumatol Arthrosc. 2017;25(9):2942-51.
15. Marchand RC, Sodhi N, Khlopas A, Sultan AA, Harwin SF, Malkani AL, et al. Patient Satisfaction Outcomes after Robotic Arm-Assisted Total Knee Arthroplasty: A Short-Term Evaluation. J Knee Surg. 2017;30(9):849-53.
16. Kayani B, Konan S, Tahmassebi J, Rowan FE, Haddad FS. An assessment of early functional

rehabilitation and hospital discharge in conventional versus robotic-arm assisted unicompartmental knee arthroplasty: a prospective cohort study. Bone Joint J. 2019;101-B(1):24-33.
17. Kim YH, Yoon SH, Park JW. Does Robotic-assisted TKA Result in Better Outcome Scores or Long-Term Survivorship Than Conventional TKA? A Randomized, Controlled Trial. Clin Orthop Relat Res. 2020;478(2):266-75.
18. Lee YM, Kim GW, Lee CY, Song EK, Seon JK. No Difference in Clinical Outcomes and Survivorship for Robotic, Navigational, and Conventional Primary Total Knee Arthroplasty with a Minimum Follow-up of 10 Years. Clin Orthop Surg. 2023;15(1):82-91.
19. Jeon SW, Kim KI, Song SJ. Robot-Assisted Total Knee Arthroplasty Does Not Improve Long-Term Clinical and Radiologic Outcomes. J Arthroplasty. 2019;34(8):1656-61.
20. Choi BS, Kim SE, Yang M, Ro DH, Han HS. Functional alignment with robotic arm assisted total knee arthroplasty demonstrated better patient-reported outcomes than mechanical alignment with manual total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2023;31(3):1072-80.

Cite this article as: Mukartihal R, Jain K, Katariya A, Zacarias TP, Kartik PN, Patil S. Precision vs. tradition: evaluating alignment accuracy and functional outcomes in robotic vs. conventional total knee arthroplasty. Int J Res Orthop 2025;11:1480-4.