

Assessment of Functional Outcome of Robotic-Assisted Knee Arthroplasty Versus Conventional Knee Arthroplasty

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DOI: <https://doi.org/10.5281/zenodo.22825408>

Received: 21 August 2026, Revised: 06 September, Accepted: 16 September 2026, Online First: 18 September 2026

ABSTRACT

Background: Total knee arthroplasty (TKA) is the standard treatment for advanced knee osteoarthritis (OA). Robotic-assisted TKA (RA-TKA) has been introduced to improve implant positioning, alignment, and soft tissue balancing; however, its clinical benefits over conventional TKA (C-TKA) remain under evaluation. **Methods:** This hospital-based cross-sectional analytical study included 60 patients with primary knee OA undergoing TKA at a tertiary care center. Thirty patients underwent RA-TKA and 30 underwent C-TKA. Functional outcomes were assessed using the Oxford Knee Score (OKS) preoperatively and at 2 weeks, 1 month, 3 months, and 6 months postoperatively. Postoperative complications were also compared between the two groups. Statistical significance was considered at $p < 0.05$. **Results:** Baseline demographic and clinical characteristics were comparable between the groups. Preoperative OKS did not differ significantly (21.4 ± 4.8 vs. 22.1 ± 5.2 ; $p = 0.59$). However, the RA-TKA group demonstrated significantly higher OKS at 2 weeks (30.6 ± 5.1 vs. 26.9 ± 5.8 ; $p = 0.01$), 1 month (36.8 ± 4.9 vs. 30.7 ± 5.4), 3 months (42.3 ± 3.8 vs. 35.9 ± 4.6), and 6 months (45.1 ± 2.9 vs. 40.8 ± 3.7) (all $p < 0.001$). Arthrofibrosis, persistent postoperative pain, and surgical site infection were less frequent in the RA-TKA group, while no cases of deep vein thrombosis, implant loosening, or periprosthetic fracture were observed in either group. **Conclusion:** Robotic-assisted TKA demonstrated superior early functional recovery and fewer postoperative complications compared with conventional TKA. These findings suggest that RA-TKA is a safe and effective option for managing advanced knee osteoarthritis, although larger randomized studies with longer follow-up are required to confirm long-term benefits.

Keywords: Robotic-assisted total knee arthroplasty; Conventional total knee arthroplasty; Knee osteoarthritis; Oxford Knee Score; Functional outcome.

INTRODUCTION

The knee joint is one of the most complex and heavily loaded joints in the human body, playing a fundamental role in weight bearing, stability, and locomotion. Because of its intricate anatomy and continuous exposure to mechanical stress, it is highly susceptible to degenerative changes, traumatic injuries, and age-related deterioration. These pathological conditions commonly lead to chronic pain, stiffness, reduced range of motion, functional disability, and impaired quality of life, particularly among the elderly population. When conservative treatment options such as pharmacological therapy, physiotherapy, weight reduction, and intra-articular injections fail to provide adequate symptom relief, total knee arthroplasty (TKA) remains the treatment of choice for relieving

pain, restoring joint function, and improving patient quality of life.^[1-4]

Osteoarthritis (OA) is the most common indication for TKA and is among the leading causes of disability worldwide. Approximately 22.9% of older adults are affected by symptomatic knee OA, while nearly one-fifth of individuals over 45 years of age experience the disease globally. The increasing burden of OA has resulted in a rapid rise in knee replacement surgeries, with projections estimating more than 3.5 million TKA procedures annually in the United States by 2030.^[5-8]

Conventional TKA using mechanical alignment guides has demonstrated excellent long-term survivorship and substantial improvement in pain and function. However, nearly one-fifth of patients continue to report dissatisfaction due to persistent pain, stiffness,

instability, soft tissue imbalance, malalignment, or limited functional recovery. Even minor errors in implant positioning may adversely affect implant longevity and postoperative outcomes.^[9-13]

Robotic-assisted total knee arthroplasty (RA-TKA) has emerged as an innovative approach that combines three-dimensional preoperative planning with real-time intraoperative robotic guidance to improve surgical precision. Robotic systems facilitate accurate bone preparation, optimal implant positioning, restoration of mechanical alignment, and precise soft tissue balancing, thereby reducing alignment errors and enhancing surgical reproducibility. Although several studies have reported superior radiological accuracy and improved early functional outcomes with robotic-assisted TKA, concerns regarding increased operative time, higher costs, and uncertain long-term clinical benefits remain.^[14-17] Therefore, the present study was undertaken to compare the functional outcomes and postoperative complications of robotic-assisted and conventional TKA using the Oxford Knee Score, thereby providing evidence regarding the clinical effectiveness of robotic-assisted knee arthroplasty.

MATERIALS AND METHODS

This hospital-based cross-sectional analytical study was conducted in the Department of Orthopaedics, Sri Aurobindo Medical College and Post Graduate Institute, Indore, Madhya Pradesh, India. The study was carried out over a period of 18 months, from June 1, 2024, to November 30, 2025, after obtaining approval from the Institutional Ethics Committee. A total of 60 patients with primary knee osteoarthritis undergoing total knee arthroplasty (TKA) were enrolled. Thirty patients underwent robotic-assisted total knee arthroplasty (CUVIS ROBOTIC SYSTEM) (RA-TKA), while thirty underwent conventional total knee arthroplasty (C-TKA). Eligible patients were selected using an alternate (odd-even) allocation method after providing written informed consent.

Inclusion Criteria

Patients were eligible if they fulfilled the following criteria:

- Age greater than 35 years.
- Primary osteoarthritis of the knee with Kellgren-Lawrence Grade III or Grade IV disease.
- Planned for primary total knee arthroplasty.
- Provided written informed consent.

Exclusion Criteria

Patients with any of the following conditions were excluded:

- Active local or systemic infection.
- Revision total knee arthroplasty.
- Periprosthetic fracture.
- Inflammatory arthritis.
- Refusal to participate in the study.

Methodology

All procedures were performed by experienced orthopedic surgeons using standardized perioperative protocols.

- **Conventional Total Knee Arthroplasty:** A standard anterior midline incision with medial parapatellar arthrotomy was used to expose the knee joint. Bone preparation was performed using conventional instrumentation with a tibia-first gap-balancing technique. The proximal tibial cut was made using an extramedullary alignment guide perpendicular to the mechanical axis while maintaining approximately 7° posterior tibial slope. Femoral preparation was performed using a 5° valgus intramedullary alignment guide. Ligament balancing was achieved through selective soft tissue release whenever required to obtain balanced flexion and extension gaps before implantation of the final prosthesis.
- **Robotic-Assisted Total Knee Arthroplasty:** After standard surgical exposure, femoral and tibial arrays were secured, and anatomical landmarks were registered using the robotic navigation platform. A patient-specific three-dimensional surgical plan was generated to determine implant size, alignment, and bone resections. Robotic assistance was used to execute the planned resections with real-time intraoperative feedback. Distal femoral and proximal tibial cuts were performed perpendicular to the mechanical axis while maintaining approximately 7° posterior tibial slope. Femoral and tibial rotational alignment was optimized using the robotic system to achieve appropriate soft tissue balance and implant positioning before definitive implantation.

Outcome Measures

The primary outcome was postoperative functional outcome assessed using the Oxford Knee Score (OKS). The OKS is a validated 12-item patient-reported outcome measure with scores ranging from 0 to 48, where higher scores indicate better knee function. Secondary outcomes included operative duration, length of hospital stay, and postoperative complications such as wound infection, stiffness, instability, thromboembolic events, periprosthetic fracture, and revision surgery.

Data Collection

Demographic characteristics including age, sex, body mass index, affected side, and Kellgren-Lawrence grade were recorded preoperatively. Operative details, postoperative complications, and Oxford Knee Scores were documented using a standardized case record form.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean $\pm$ standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. Comparisons between the two groups were performed using the independent Student's *t*-test for normally distributed continuous variables and the Mann-Whitney *U* test for non-normally distributed data. Categorical variables were compared using the Chi-square test or Fisher's exact test, as appropriate. Changes in Oxford Knee Score during follow-up were analyzed using repeated-measures analysis of variance (ANOVA) or the Friedman test depending on data distribution. Correlations between quantitative variables were assessed using Pearson's or Spearman's correlation coefficients. A two-tailed *p*-value of <0.05 was considered statistically significant.

RESULTS

A total of 60 patients undergoing primary total knee arthroplasty were included in the study. Of these, 30 patients (50%) underwent robotic-assisted total knee arthroplasty (RA-TKA) and 30 patients (50%) underwent conventional total knee arthroplasty (C-TKA), providing equal representation of both treatment groups for comparison. Baseline demographic and clinical characteristics were comparable between the two groups. [Table 1]

The majority of patients in both groups belonged to the 66–75 years age category. The mean age was 64.0 ± 12.27 years in the robotic-assisted group and 65.0 ± 11.77 years in the conventional group. Females constituted the majority of the study population (76.7% vs. 73.3%). Right-sided arthroplasty was performed slightly more frequently than left-sided surgery in both groups. Most patients had symptoms for more than two years before surgery (66.7% in the robotic group and 56.7% in the conventional group). Diabetes mellitus was the most common associated comorbidity, followed by hypertension and combined diabetes mellitus with hypertension. [Table 1]

Table 1. Baseline Characteristics of Patients Undergoing Robotic-Assisted and Conventional Total Knee Arthroplasty (N = 60)

Parameter	Category	Robotic TKA (n=30)	Conventional TKA (n=30)
Age Group (years)	35–45	3 (10.0%)	2 (6.7%)
	46–55	4 (13.3%)	4 (13.3%)
	56–65	7 (23.3%)	8 (26.7%)
	66–75	10 (33.3%)	9 (30.0%)
	>75	6 (20.0%)	7 (23.3%)
Mean Age (years)	Mean $\pm$ SD	64.0 ± 12.27	65.0 ± 11.77
Gender	Male	7 (23.3%)	8 (26.7%)
	Female	23 (76.7%)	22 (73.3%)
Operative Side	Right	17 (56.7%)	16 (53.3%)
	Left	13 (43.3%)	14 (46.7%)
Duration of Disease	<1 year	2 (6.7%)	3 (10.0%)
	1–2 years	8 (26.7%)	10 (33.3%)
	>2 years	20 (66.7%)	17 (56.7%)
Comorbidities	Diabetes mellitus	8 (26.7%)	9 (30.0%)
	Hypertension	6 (20.0%)	4 (13.3%)
	Diabetes mellitus + Hypertension	6 (20.0%)	4 (13.3%)
	None	10 (33.3%)	13 (43.3%)

Functional outcome assessed using the Oxford Knee Score (OKS) improved progressively in both groups throughout the follow-up period. The preoperative OKS was comparable between the robotic-assisted and conventional TKA groups (21.4 ± 4.8 vs. 22.1 ± 5.2 , $p = 0.59$). At 2 weeks postoperatively, the robotic-assisted group demonstrated significantly better functional outcomes with a mean OKS of 30.6 ± 5.1 , compared with 26.9 ± 5.8 in the conventional group ($p = 0.01$). This difference became more pronounced at subsequent follow-up visits. At 1 month, the mean OKS was 36.8 ± 4.9 in the robotic group versus 30.7 ± 5.4 in the conventional group ($p < 0.001$). Similarly, at 3 months, the robotic-assisted group achieved a significantly higher score (42.3 ± 3.8) compared to the conventional group (35.9 ± 4.6 , $p < 0.001$). At the 6-month follow-up, patients who underwent robotic-assisted TKA attained the highest functional scores (45.1 ± 2.9) compared with 40.8 ± 3.7 in the conventional TKA group ($p < 0.001$), indicating superior postoperative recovery and knee function following robotic-assisted arthroplasty. [Table 2, Figure 1]

Table 2. Comparison of Functional Outcome Between Robotic-Assisted and Conventional Total Knee Arthroplasty Using Oxford Knee Score

Time Interval	Robotic TKA (Mean $\pm$ SD)	Conventional TKA (Mean $\pm$ SD)	p-value
Preoperative	21.4 $\pm$ 4.8	22.1 $\pm$ 5.2	0.59
Postoperative (2 weeks)	30.6 $\pm$ 5.1	26.9 $\pm$ 5.8	0.01*
Postoperative (1 month)	36.8 $\pm$ 4.9	30.7 $\pm$ 5.4	<0.001*
Postoperative (3 months)	42.3 $\pm$ 3.8	35.9 $\pm$ 4.6	<0.001*
Postoperative (6 months)	45.1 $\pm$ 2.9	40.8 $\pm$ 3.7	<0.001*

Statistically significant at $p < 0.05$.

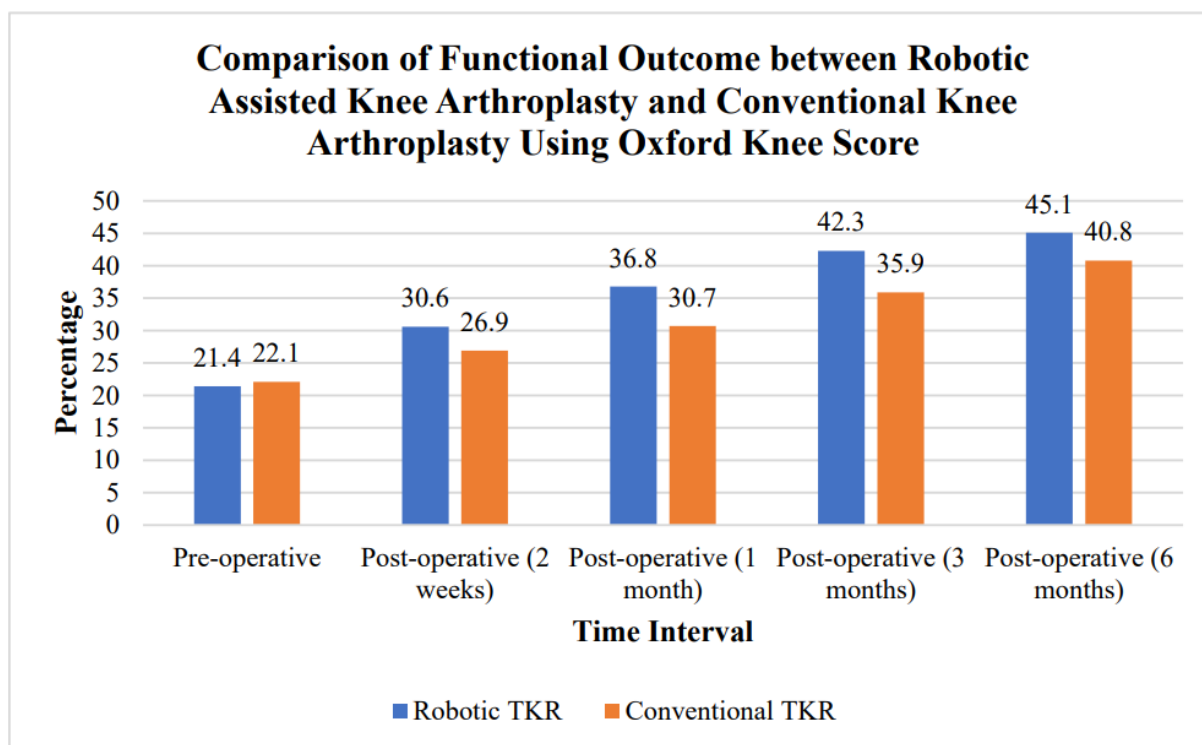


Figure 1: Comparison of Functional Outcome between Robotic Assisted Knee Arthroplasty and Conventional Knee Arthroplasty Using Oxford Knee Score

Postoperative complications occurred less frequently following robotic-assisted TKA than conventional TKA. Knee stiffness (arthrofibrosis) was the most common complication, occurring in 16.7% of patients in the robotic-assisted group compared with 33.3% in the conventional group. Persistent postoperative pain was reported in 6.7% of robotic-assisted cases and 20.0% of conventional TKA cases. Surgical site infection occurred in 3.3% of patients undergoing robotic-assisted TKA compared with 10.0% in the conventional group. No patients in either group developed deep vein thrombosis, pulmonary embolism, implant loosening, joint instability, periprosthetic fracture, or allergic reactions. Overall, the robotic-assisted TKA group demonstrated a lower incidence of postoperative complications than the conventional TKA group. [Table 3, Figure 2]

Table 3. Comparison of Postoperative Complications Between Robotic-Assisted and Conventional Total Knee Arthroplasty

Complication	Robotic TKA (n=30)	Conventional TKA (n=30)
Deep vein thrombosis/Pulmonary embolism	0 (0%)	0 (0%)
Surgical site infection	1 (3.3%)	3 (10.0%)
Nerve or vascular injury	0 (0%)	0 (0%)
Knee stiffness (Arthrofibrosis)	2 (6.7%)	4 (33.3%)
Persistent postoperative pain	2 (6.7%)	6 (20.0%)
Implant loosening	0 (0%)	0 (0%)
Joint instability	0 (0%)	0 (0%)
Periprosthetic fracture	0 (0%)	0 (0%)
Allergic reaction	0 (0%)	0 (0%)

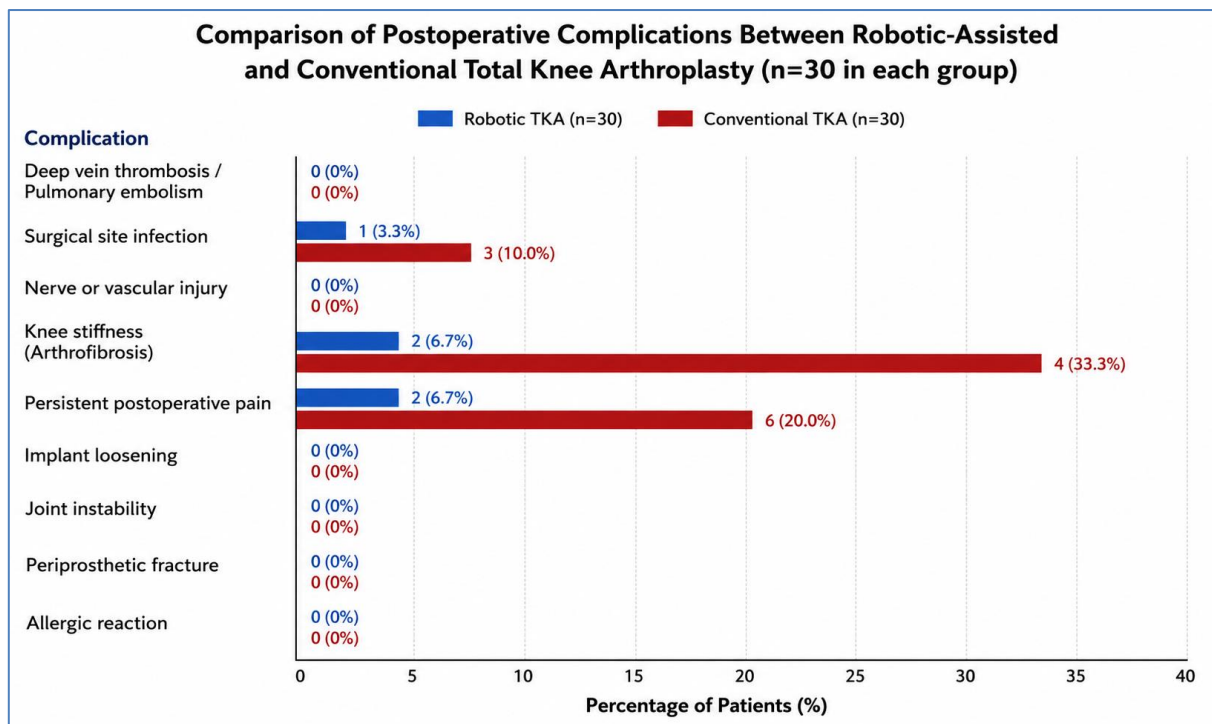


Figure 2: Comparison of Associated Complications in Robotic Assisted Knee Arthroplasty and Conventional Knee Arthroplasty



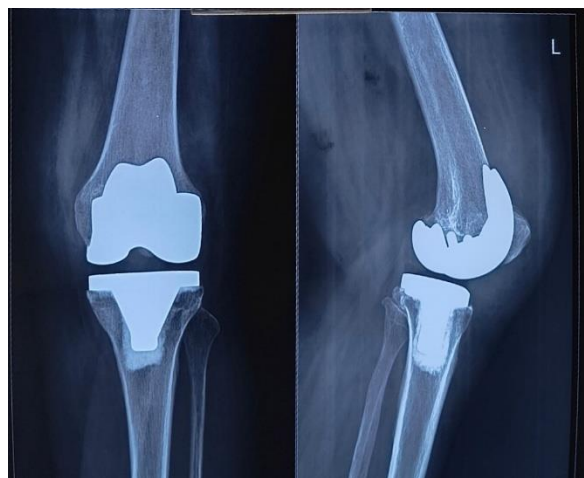
Pre-operative clinical images



PRE OPERATIVE XRAYS



POST OPERATIVE XRAY



3 months follow up Xray



6 months follow up Xray



6 months follow up clinical image

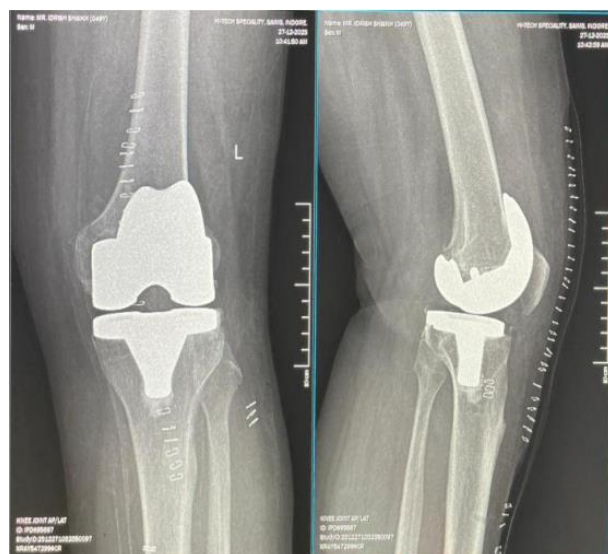
Figure 3: Figure 3. Representative Conventional Total Knee Arthroplasty (C-TKA) Case Showing Preoperative Clinical and Radiographic Findings with Three- and Six-Month Postoperative Follow-up



Pre operative clinical images



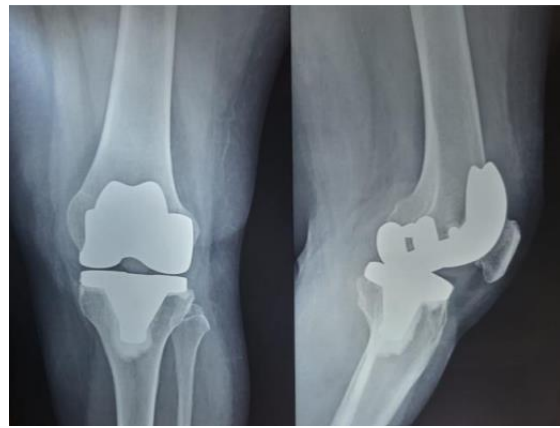
Pre-operative X ray



Post-operative X ray



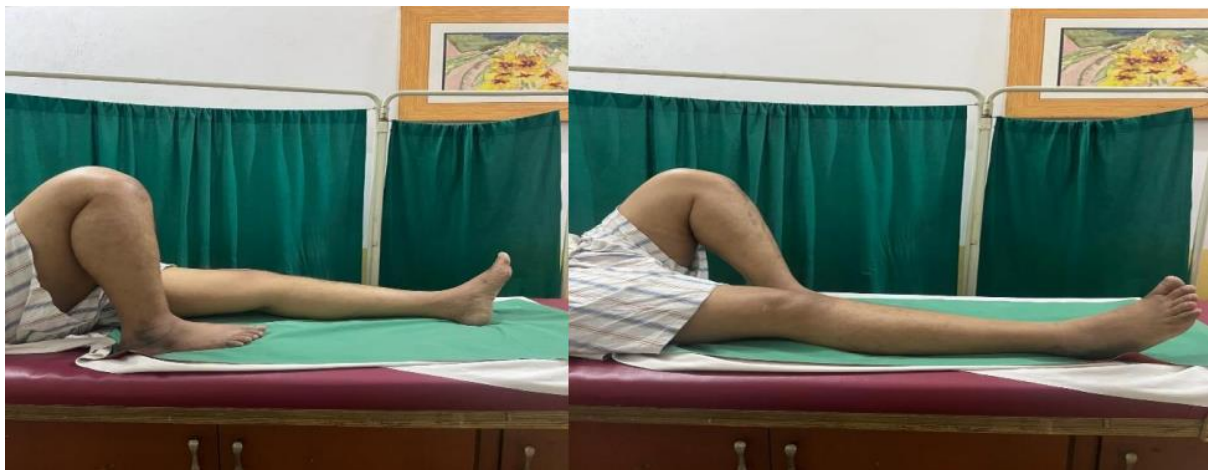
1-month X ray



3-month X ray



6 Months



Post operative clinical images

Figure 4: Figure 4. Representative Case of Robotic-Assisted Total Knee Arthroplasty (RA-TKA) Demonstrating Preoperative Clinical and Radiographic Findings and Postoperative Clinical and Radiographic Outcomes from Immediate Postoperative to Six-Month Follow-up

DISCUSSION

Osteoarthritis (OA) is the most common form of arthritis and a major cause of pain, disability, and reduced quality of life worldwide. It is a progressive degenerative joint disease affecting the articular cartilage, with the knee being the most commonly involved joint. The global prevalence of knee OA is estimated at 16% in the general population and 22.9% among adults aged ≥ 40 years. Progressive disease leads to chronic pain, impaired mobility, and functional limitation, often requiring surgical intervention.^[1,2,4,6]

Total knee arthroplasty (TKA) is the treatment of choice for end-stage knee OA when conservative management fails. Although conventional TKA provides effective pain relief and functional improvement, approximately 20% of patients remain dissatisfied because of persistent pain, stiffness, instability, or suboptimal functional recovery. These limitations have driven the development of robotic-assisted TKA (RA-TKA), which aims to improve implant positioning, alignment, and soft-tissue balancing. While robotic systems have demonstrated greater surgical accuracy, evidence regarding their superiority in functional outcomes remains inconsistent, necessitating further comparative clinical studies.^[4,7-17]

Both the robotic-assisted (RA-TKA) and conventional (C-TKA) groups had comparable baseline characteristics. The mean age was 64.0 ± 12.27 years and 65.0 ± 11.77 years, respectively, with most patients belonging to the 66–75 years age group. Females predominated in both groups (76.67% vs. 73.33%). These findings are consistent with those reported by Sanadhya et al.^[18], Borde et al.^[19], and Mukartihal et al.^[20], who also observed no significant differences in age or sex distribution between robotic-assisted and conventional TKA groups.

Right-sided TKA was performed slightly more frequently than left-sided TKA in both groups, although operative side distribution remained comparable. Similar observations have been reported by Leech et al.^[21], while Wang et al.^[22] reported a predominance of left-sided procedures. Ishii et al.^[23] suggested that operative side may influence postoperative outcomes; however, the balanced laterality in the present study minimized potential side-related bias.

The study included 60 patients, equally allocated to the robotic-assisted and conventional TKA groups (30 patients each), ensuring methodological uniformity and minimizing selection bias. A similar balanced study design was reported by Wang et al.^[22], whereas Horikawa et al.^[24] and Srinivasan et al.^[25] evaluated treatment groups with unequal or varying sample sizes. The equal distribution in the present study strengthens the validity of comparisons between the two surgical techniques.

Diabetes mellitus was the most common comorbidity in both the robotic-assisted (RA-TKA) and conventional (C-TKA) groups, followed by hypertension. The distribution of comorbidities was comparable between the groups, indicating similar baseline clinical status. Similar findings have been reported by Srinivasan et al.^[25], Shih et al.^[26] and Satilmis et al.^[27], who also identified diabetes mellitus and hypertension as the predominant comorbid conditions among patients undergoing knee arthroplasty. These observations emphasize the importance of appropriate preoperative optimization to improve surgical outcomes.

The primary objective of the present study was to compare functional outcomes using the Oxford Knee Score (OKS). Preoperative OKS was comparable between the two groups (21.4 ± 4.8 vs. 22.1 ± 5.2 ; $p = 0.59$). However, the robotic-assisted group demonstrated significantly better postoperative recovery, with higher OKS at 2 weeks ($p = 0.01$) and at 1, 3, and 6 months ($p < 0.001$). These findings suggest faster and superior early functional recovery following robotic-assisted TKA. Similar improvements have been reported by Mukartihal et al.^[20], and Satilmis et al.^[27], whereas Horikawa et al.^[24] found no significant difference in functional scores despite improved radiological alignment. Overall, the present findings support the growing evidence that robotic-assisted TKA provides superior early postoperative functional outcomes.

Postoperative complications were less frequent in the robotic-assisted group than in the conventional group. Arthrofibrosis was the most common complication, followed by persistent postoperative pain and surgical site infection, all of which occurred less frequently after robotic-assisted TKA. No cases of deep vein thrombosis, pulmonary embolism, implant loosening, joint instability, periprosthetic fracture, or nerve and vascular injury were observed in either group. Similar findings were reported by Shih et al.^[26], who demonstrated a significantly lower overall complication rate following robotic-assisted arthroplasty than conventional arthroplasty (3.7% vs. 13.2%; $p < 0.001$). These findings suggest that improved surgical precision and implant positioning achieved with robotic assistance may contribute to reduced postoperative morbidity and enhanced patient recovery.

Despite demonstrating favorable outcomes, the study was limited by a small sample size, single-center design, non-randomized allocation, and a short six-month follow-up. Radiological alignment, implant survivorship, cost-effectiveness, and the surgeon learning curve were not evaluated, limiting the generalizability and long-term applicability of the findings.

CONCLUSION

The present study demonstrated that robotic-assisted total knee arthroplasty (RA-TKA) provides superior early functional outcomes compared with conventional total knee arthroplasty (C-TKA). Although both techniques significantly improved knee function, patients undergoing RA-TKA achieved significantly higher Oxford Knee Scores from the second postoperative week through six months. Robotic-assisted surgery was also associated with fewer postoperative complications, particularly lower rates of knee stiffness, persistent pain, and infection. These benefits are likely attributable to improved implant positioning, precise bone resection, and better soft tissue balancing. Overall, RA-TKA appears to be a safe and effective option for managing advanced knee osteoarthritis, offering enhanced postoperative recovery and functional improvement.

Declarations

Ethics Approval and Consent to Participate

The study was conducted after obtaining approval from the Institutional Ethics Committee of Sri Aurobindo Medical College and Post Graduate Institute, Indore, Madhya Pradesh, India. Written informed consent was obtained from all participants before enrollment in the study.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

Funding

No specific funding was received for this study.

Authors' Contributions

All authors contributed to the conception and design of the study, data collection, analysis and interpretation of data, and preparation and critical revision of the manuscript. All authors approved the final version of the manuscript.

Data Availability

The data generated and analyzed during the present study are available from the corresponding author on reasonable request, subject to applicable ethical and institutional requirements.

AI Use Disclosure

No generative AI tools were used in the writing, data analysis, or interpretation of this manuscript. The authors remain fully responsible for the content.

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