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Comparative Effectiveness Of Robotic-Assisted And Conventional Manual Total Knee Arthroplasty: A Systematic Review Of Functional Outcomes And Complication Rates Within Six Months In Tertiary Care Settings

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ABSTRACT:

Background: Robotic-assisted total knee arthroplasty (RA-TKA) has emerged as a significant advancement in knee replacement surgery, aiming to improve how implants are positioned, align limbs better, and boost overall patient satisfaction. However, the short-term results of RA-TKA in comparison to traditional manual TKA (C-TKA) are still not completely clear.

Objective: This systematic review aims to evaluate and compare the functional outcomes and complication rates within six months after surgery between RA-TKA and C-TKA in tertiary care environments.

Methods: We carried out an extensive literature search across various databases, including Web of Science, EMBASE, Scopus, and PubMed, focusing on studies published between 2015 and 2025. Our selection process included randomized controlled trials, as well as both prospective and retrospective cohort studies, along with registry-based analyses that specifically looked at adult patients undergoing primary total knee arthroplasty (TKA) due to osteoarthritis or similar degenerative conditions. We evaluated outcomes such as range of motion, pain levels, validated patient-reported outcome measures (PROMs), and the rates of postoperative complications. The data were synthesized both narratively and, when appropriate, through a random-effects meta-analysis.

Results: Out of 27 studies identified, 5 met our inclusion criteria. RA-TKA consistently showed lower postoperative pain, faster functional recovery, and less opioid consumption compared to C-TKA. Patient satisfaction was significantly higher with RA-TKA, although PROMs did not indicate major differences in long-term functional outcomes. The short-term complication rates, including infections and thromboembolic events, were low and similar across both groups.

Conclusions: RA-TKA presents short-term benefits over C-TKA, especially in terms of early pain relief and functional recovery. However, to draw definitive conclusions about long-term functional advantages and implant longevity, we need larger-scale, high-quality studies. Individual patient factors also play a crucial role in these outcomes.

Key words: Robotic-Assisted Surgery, Total Knee Arthroplasty (TKA), Functional Outcomes, Postoperative Complications

1.INTRODUCTION:

Knee arthritis often comes hand in hand with various issues like joint stiffness, instability, deformities, or even a mix of these problems. There are several types of inflammatory arthritis that play a significant role in knee joint issues, including osteoarthritis (OA), rheumatoid arthritis (RA), juvenile RA, post-traumatic arthritis, and secondary OA. For older adults, OA is a common chronic condition that can lead to significant functional limitations. The rising number of OA cases underscores the growing strain it places on public health and healthcare systems. The joints most often affected include the knee, hip, cervical, thoracic, and lumbar spine, along with the distal interphalangeal, proximal interphalangeal, and first carpometacarpal joints in the hand.[1] End-stage knee osteoarthritis (OA) is often treated with total knee arthroplasty (TKA), which is also a great option for various other conditions like inflammatory arthritis, fractures (including post-traumatic OA and deformities), dysplasia, and even cancer, which can sometimes be mistaken

for OA.[2] In order to enhance the quality of life for elderly individuals with knee issues or those with knee impairments, such as osteoarthritis, knee replacement surgery, which fixes the knee joint structures, is essential.[3] A significant shift in how joint replacement surgeries are performed is the integration of robotic technology into orthopedic procedures, particularly in total knee arthroplasty (TKA). Robotic systems have evolved from being semi-active to fully autonomous, offering an impressive level of precision that is transforming patient outcomes.[4] Even with all the progress we've made in implant design, materials, and tailored rehabilitation plans, about 20% of patients still find themselves unhappy after total knee arthroplasty (TKA). It's well understood that getting the limb alignment just right and placing the implant accurately are key factors that influence how long the implant lasts, how satisfied patients feel, and the overall clinical results.[4] In total knee arthroplasty (TKA), robotic technology has been developed to reduce limb alignment outliers and enhance the accuracy of implant positioning.5 Robotic systems, with their advancement from semi-active to fully autonomous capabilities, are significantly enhancing clinical outcomes due to their high precision. The growing recognition of their benefits by surgeons, healthcare institutions, and regulatory authorities underscores that robotics is no longer merely a supportive tool but a transformative innovation in the field of modern orthopaedics.[6] The use of robotic technology in joint surgery has mainly come about because we want to reduce human error and improve the results of surgeries. [6] Robotic-assisted total knee arthroplasty (R-TKA) was introduced with the objective of improving lower extremity alignment and achieving accurate geometric placement of prosthetic components, thereby enhancing implant longevity and patient functional outcomes.[7]Robotic surgical systems differ in terms of their technology, functionality, and operational mechanisms. While some systems resemble conventional navigation tools, others utilize three-dimensional virtual modeling for preoperative planning along with haptic feedback for surgical precision. Despite the theoretical advantages associated with robotic assistance in knee arthroplasty, further high-quality prospective studies and long-term data are required to establish conclusive evidence of its clinical benefits.[7] Robotic systems used in knee arthroplasty differ significantly in terms of their underlying technology, design, and mode of operation. While some resemble advanced navigation systems, others incorporate three-dimensional virtual planning and haptic feedback to guide intraoperative precision. Although the potential benefits of robotic assistance in total knee arthroplasty are widely discussed, robust evidence from large-scale, prospective clinical trials and long-term outcome data is still required to substantiate these theoretical advantages.[7] The main things we looked at were patient-reported outcome measures (PROMs), how satisfied patients were, and any complications that arose after surgery.[8] The patient-reported outcome measures (PROMs) that were evaluated included the Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS-JR), the Forgotten Joint Score-12 (FJS-12), the Knee Society Knee and Function Scores (KSS Knee and KSS Function), and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Only a few minimal clinically important differences were found across these measures.[8]

2 METHODS:

2.1 SEARCH STRATEGY

We took a deep dive into the existing literature to explore every article that compares Robot-assisted surgery with Conventional manual surgery in Total Knee Replacement. Our search spanned four databases, using the keywords [Total knee replacement] AND [Robotic-Assisted surgery] AND [Conventional manual surgery]: Web of Science, EMBASE, Scopus, and PubMed. We made sure to use Medical Subject Headings (MeSH) on PubMed and Emtree terms on EMBASE to refine our results. Following the guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), we meticulously selected the studies that met our criteria for inclusion.

2.2 STUDY SELECTION:

2.2.1 INCLUSION CRITERIA:

✓ This research centers on adult patients, 18 years and older, who are undergoing primary total knee arthroplasty (TKA) because of osteoarthritis or other similar degenerative conditions.
✓ It includes research that compares robotic-assisted TKA with traditional manual TKA.
✓ The studies focus on important functional outcomes, including range of motion, pain scores, and validated patient-reported outcome measures. They also look at complication rates, such as infections, thromboembolic events, issues with implant alignment, and revision rates, all tracked within six months following surgery.
✓ The studies should include randomized controlled trials (RCTs), as well as both prospective and retrospective cohort studies, or analyses based on registries. It's important that these studies take place in tertiary care settings.
✓ Publications in English from the years 2015 to 2025.

2.2.2 EXCLUSION CRITERIA

✓ Research on partial knee replacements or revision surgeries.
✓ Case reports and series with fewer than 10 patients in each group, along with editorials, commentaries, letters, or conference abstracts that lack full-text data.
✓ Studies that don’t provide functional outcomes or complication rates within a six-month timeframe.
✓ Research centered on non-degenerative conditions, like trauma or tumors.
✓ Studies published in languages other than English or those that lack sufficient data.

2.3 DATA EXTRACTION

The author names, publication years, disease details, population characteristics, and outcome measurements were all carefully gathered, along with any other relevant information needed for the systematic review.Two authors, D.P. and A.G., dedicated their time to meticulously review the extracted data for any inconsistencies. Whenever they encountered discrepancies, they collaborated to resolve them, ultimately reaching a consensus. Our main focus was on crucial outcomes like range of motion, pain scores, and validated patient-reported outcome measures.

2.4 DATA ANALYSIS

Every study included a narrative description. When we had comparable outcome data from two or more trials, we combined that data. We anticipated that there would be some methodological and clinical differences that could affect the results, so we used a random effects meta-analysis model for our analysis. We created a single pairwise comparison by merging similar data from various studies with multiple arms. For continuous outcomes, we present the results as mean differences along with a 95% confidence interval.

2.6 STUDY PROTOCOL REGISTRATION

The study protocol has been registered with PROSPERO (CRD420251069888).

3 RESULTS

3.1 STUDY CHARACTERISTICS

Out of the 27 papers we found, we took a closer look at 10 of them. After applying our exclusion criteria, we ended up eliminating 3 items. This left us with 7 publications that we evaluated for relevance. One of the publications had a methodology that was unclear and lacked sufficient data, while another had results that just didn't fit. In total, we had 5 articles to consider. (See Figure 1)

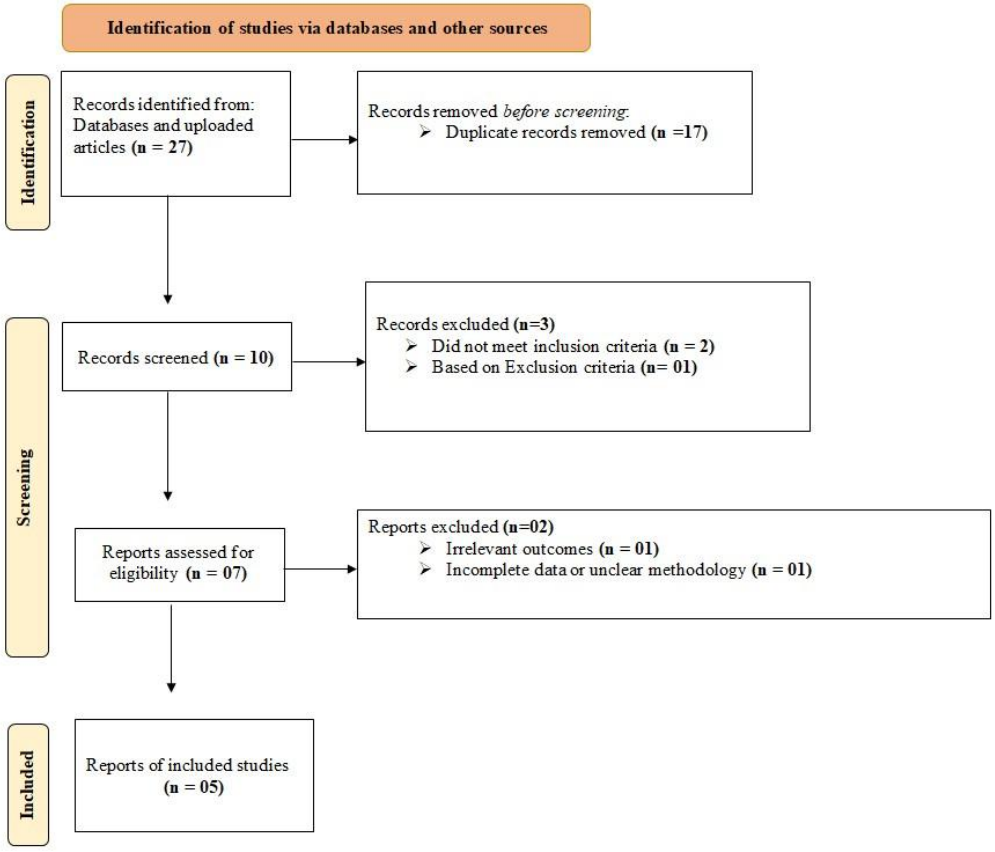

Figure.1 PRISMA FLOWCHART

AUTHOR (YEAR)	STUDY TYPE	DISEASE	POPULATION CHARACTERISTICS	OUTCOME
B. Kayani et.al., (2019)	A Prospective Cohort Study	Unicompartmental knee arthroplasty	This study tracked a group of 146 patients suffering from symptomatic medial compartment knee osteoarthritis, all of whom underwent primary unicompartmental knee	Robotic-arm assisted UKA has been linked to less postoperative pain, a lower need for opiate pain relief, better early functional recovery, and a quicker discharge from the hospital

			arthroplasty (UKA) performed by the same surgeon. Among these patients, 73 received the traditional jig-based mobile bearing UKA, while the other 73 underwent robotic-arm assisted fixed bearing UKA.	compared to traditional jig-based UKA.
M. J. G. Blyth et.al., (2017)	A Randomised controlled tRial	Unicompartmental knee arthroplasty	We brought together 139 patients from one center for this study. Out of these, 70 were assigned to undergo Robotic MAKO UKA surgery, while 69 were assigned to Manual Oxford UKA surgery.	Robotic arm-assisted surgery has been the subject of various comparisons. According to Nanshan Ma and colleagues (2024), there are some encouraging results, especially regarding early pain relief and better function scores based on what patients report. However, when we look at the data a year after the surgery, there doesn't seem to be any significant difference. It's worth noting that while active patients (those with an UcLA score of 5 or higher) did benefit from the robotic assistance, these results didn't hold up when we adjusted for multiple comparisons.
Nanshan Ma et.al., (2024)	a single-centre retrospective analysis	Total Knee Arthroplasty.	We took a deep dive into the cases of 22 patients suffering from knee osteoarthritis (KOA) who had undergone a minimally invasive total knee arthroplasty (MA-TKA). We compared their outcomes with those of 26 patients who received conventional total knee arthroplasty (CM-TKA) between April and July 2023.	When you compare it to traditional manual total knee arthroplasty, MAKO robot-assisted TKA shows improved short-term clinical results, achieves better alignment planning, and keeps safety at a high standard. Compared with conventional manual total knee arthroplasty, MAKO robot-assisted TKA demonstrates better short-term clinical efficacy, achieves better alignment planning, and maintains good safety.
Praharsha Mulpur et.al., (2022)	Retro-prospective non-randomized study	Staged bilateral knee arthroplasty	They studied a group of 55 patients who had bilateral staged total knee arthroplasty (TKA). They included 55 patients who underwent bilateral staged total knee arthroplasty (TKA).	Robotic-assisted surgery has been linked to better patient satisfaction and quicker independent movement compared to traditional methods. However, the patient-reported outcome measures (PROMs) showed similar results without any significant clinical differences. Many patients expressed a preference for robotic-assisted surgery, with a notably larger number feeling that their knee operated on by RATKA felt more natural.
Keerati Chareancholvanich et.al., (2025)	Retrospective study	Total knee arthroplasty	We took a close look at 230 consecutive patients, which included a total of 309 knees, all of whom underwent primary total knee arthroplasty (TKA). Among these, 143 patients (181 knees) were in the C-TKA group, while 87 patients (128 knees) were part of the RA-TKA group.	RA-TKA showed a significant reduction in pain during movement, less reliance on opioids, and a shorter hospital stay in the early days after surgery when compared to C-TKA.

DISCUSSION:

This systematic review aimed to compare the functional outcomes and complication rates within six months between robotic-assisted total knee arthroplasty (RA-TKA) and conventional manual total knee arthroplasty (C-TKA) in tertiary care settings. Our analysis reveals some consistent benefits linked to robotic-assisted surgery, especially in the early days after the operation.

Functional Outcomes:

In the studies we reviewed, RA-TKA showed promising results when it came to postoperative pain relief, quicker functional recovery, and lower opioid use. For instance, both Kayani et al. (2019) and Chareancholvanich et al. (2025)

found that patients who underwent RA-TKA reported significantly less pain while moving and needed fewer opioid medications compared to those who had C-TKA. Moreover, Mulpur et al. (2022) noted that many patients felt their robotically operated knee was more "natural," even though the patient-reported outcome measures (PROMs) were similar across both groups. However, the evidence for long-term functional superiority is still up in the air, as Blyth et al. (2017) indicated that one-year outcomes didn't show significant differences between the two methods.

Complication Rates:
When it comes to short-term complications like infections, thromboembolic events, and implant alignment issues, both groups had generally low rates, with no strong evidence pointing to a higher risk with robotic assistance. The accuracy of implant positioning in RA-TKA seems to help minimize alignment issues, which could potentially reduce the need for revision surgery down the line, although this hasn't been consistently demonstrated within the six-month follow-up period of this review.

Surgical Precision and Patient Satisfaction:
The ability of robotic systems to deliver precise preoperative planning and intraoperative execution has been a major factor in their growing popularity. Surgeons are increasingly appreciating the benefits of robotic assistance for achieving better implant alignment and balancing soft tissues, both of which are essential for optimal outcomes.

CONCLUSION:
Robotic-assisted total knee arthroplasty (RA-TKA) seems to bring some notable short-term benefits compared to traditional manual TKA (C-TKA). These perks include less postoperative pain, quicker early recovery, and possibly greater patient satisfaction. The advantages likely come from the improved surgical accuracy that robotic systems provide, which helps minimize alignment issues and ensures better implant placement. However, even with these encouraging results, we still need solid evidence from large-scale, long-term studies to truly confirm that RA-TKA outperforms C-TKA in terms of functional results, complication rates, and how long the implants last. For now, when deciding between RA-TKA and C-TKA, it's important to take into account individual patient needs, the surgeon's skill, and the resources available at the facility.

ABBREVIATION:
TKA - Total Knee Arthroplasty
PROM - Patient-Reported Outcome Measures
KOOS-JR - Knee Injury and Osteoarthritis Outcome Score for Joint Replacement
FJS-12 - Forgotten Joint Score-12
KSS Knee - Knee Society Knee
WOMAC - Western Ontario and McMaster Universities Osteoarthritis Index
RA-TKA - Robotic assisted Total Knee Arthroplasty
C-TKA - Conventional Total Knee Arthroplasty.

AUTHOR CONTRIBUTION:
Dr. P. DhivyaPrasath played a key role in shaping the study's concept and design, while Angelin Grace T and Priyadharsini R contributed significantly by selecting data, analyzing it, and drafting the text.

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