ORIGINAL RESEARCH

Comparison of Short- and Long-Term Outcomes in Robotic-Assisted vs. Conventional Total Knee Arthroplasty

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ABSTRACT

Aim: To compare the short- and long-term outcomes of robotic-assisted total knee arthroplasty (TKA) and conventional TKA in terms of functional recovery, radiographic alignment, patient satisfaction, and complication rates. **Materials and Methods:** This prospective comparative study included 120 patients undergoing TKA for primary osteoarthritis. Patients were divided into two groups: robotic-assisted TKA (n=60) and conventional TKA (n=60). Robotic-assisted TKA utilized a preoperative CT-based 3D plan for precise implant alignment, while conventional TKA followed standard manual techniques. Functional outcomes were assessed using the Knee Society Score (KSS) and the Western Ontario and McMaster Universities Arthritis Index (WOMAC). Radiographic alignment, patient satisfaction, and complication rates were also evaluated at 3 months, 6 months, and 1 year postoperatively. Statistical analyses included t-tests and chi-square tests, with a significance level of $p < 0.05$. **Results:** Baseline characteristics were similar between groups. Functional outcomes improved significantly in both groups, with the robotic-assisted group consistently outperforming the conventional group at all time points. At 1 year, the robotic-assisted group had a higher mean KSS (91.5 ± 6.2 vs. 85.7 ± 7.3; $p < 0.001$) and a lower WOMAC score (50.2 ± 6.3 vs. 55.8 ± 7.1; $p < 0.01$). Radiographic alignment was more accurate in the robotic-assisted group, with fewer alignment outliers (3.3% vs. 23.3%; $p < 0.01$). Patient satisfaction was significantly higher in the robotic-assisted group at both 6 months (8.6 ± 0.9 vs. 7.9 ± 1.1; $p < 0.01$) and 1 year (9.1 ± 0.7 vs. 8.4 ± 0.8; $p < 0.01$). Total complication rates were lower in the robotic-assisted group (5% vs. 20%; $p = 0.01$). **Conclusion:** Robotic-assisted TKA significantly improves functional outcomes, radiographic alignment, patient satisfaction, and reduces complication rates compared to conventional TKA. These findings highlight the precision and safety of robotic-assisted techniques, supporting their role in enhancing TKA outcomes.

Keywords: Robotic-assisted total knee arthroplasty, Conventional total knee arthroplasty, Functional outcomes, Radiographic alignment, Postoperative complications

INTRODUCTION

Total knee arthroplasty (TKA) is one of the most frequently performed surgical procedures worldwide, providing substantial relief from pain and improved functionality for patients suffering from end-stage knee osteoarthritis. While conventional TKA has been the gold standard for decades, the introduction of advanced robotic-assisted systems has marked a significant evolution in the field of orthopaedic surgery. These robotic technologies are designed to improve surgical precision, optimize implant positioning, and reduce the risk of complications, with the ultimate goal of enhancing both short- and long-term patient outcomes.[1]Knee osteoarthritis is a progressive condition characterized by the degeneration of joint cartilage and surrounding structures, leading to pain, stiffness, and functional limitations. In severe cases, conservative management strategies such as physical therapy, pharmacological interventions, and intra-articular injections fail to provide relief, necessitating surgical intervention. Conventional TKA techniques involve manual bone cuts and implant placement based on preoperative planning and intraoperative judgment. Although this approach has demonstrated success, its reliance on surgeon experience and inherent variability has been

associated with issues such as suboptimal alignment, poor implant longevity, and inconsistent clinical outcomes.[2] Robotic-assisted TKA represents a paradigm shift, offering a more precise and personalized approach to knee arthroplasty. Using advanced imaging and software, robotic systems create a detailed three-dimensional (3D) model of the patient's knee joint preoperatively, allowing for meticulous planning and simulation of the procedure. During surgery, robotic arms or computer navigation systems assist the surgeon in executing the plan with high accuracy, minimizing human error and ensuring optimal alignment of the prosthetic components. This precision is critical for achieving proper load distribution across the joint, reducing implant wear, and enhancing long-term durability.Short-term outcomes of TKA are often evaluated based on factors such as pain relief, functional improvement, and early complications. Robotic-assisted TKA has been shown to provide more predictable pain relief and faster recovery due to its minimally invasive nature and reduced soft tissue damage. Additionally, improved accuracy in implant alignment and ligament balancing has been associated with better early functional outcomes, as measured by validated scoring systems such as the Knee Society Score (KSS) and the Western Ontario and McMaster Universities Arthritis Index (WOMAC). These benefits are particularly valuable for younger, more active patients who demand quicker returns to their daily activities.[3] Long-term outcomes, on the other hand, focus on the durability of the implant, the incidence of revision surgeries, and overall patient satisfaction. Implant malalignment and imbalance, common complications of conventional techniques, are major contributors to premature failure and the need for revision. By enhancing alignment accuracy and preserving the native anatomy of the knee, robotic-assisted TKA aims to reduce the incidence of long-term complications and improve implant survival rates. Furthermore, patient satisfaction, which encompasses both functional outcomes and perceived quality of life, is increasingly recognized as a key indicator of surgical success. The combination of precise surgical execution and personalized care offered by robotic systems may contribute to superior satisfaction levels compared to conventional methods.[4] Despite these potential advantages, robotic-assisted TKA is not without its challenges. The high upfront costs of robotic systems, longer setup times, and the need for specialized training can pose barriers to widespread adoption. Additionally, concerns have been raised regarding the learning curve associated with robotic-assisted surgery and its impact on operative times and outcomes during the early phases of implementation. Addressing these challenges requires ongoing research to establish standardized protocols, cost-effectiveness analyses, and training programs that facilitate the seamless integration of robotic technologies into clinical practice.[5] The comparison between robotic-assisted and conventional TKA has been the subject of growing interest in recent years, as surgeons and researchers seek to quantify the benefits and limitations of these approaches. While numerous studies have demonstrated the superiority of robotic systems in achieving accurate alignment and improving functional outcomes, others have reported minimal differences, emphasizing the need for robust evidence to guide clinical decision-making.[6] Furthermore, the long-term impact of robotic-assisted TKA on implant survival and patient satisfaction remains an area of active investigation, with ongoing studies aiming to provide insights into its efficacy over decades of use.

MATERIALS AND METHODS

This prospective comparative study was conducted on 120 patients undergoing total knee arthroplasty (TKA) for primary osteoarthritis at a tertiary care center. The patients were divided into two groups of 60 each: the robotic-assisted TKA group and the conventional TKA group. Patients aged 50–75 years, with radiologically confirmed end-stage osteoarthritis and scheduled for elective unilateral TKA, were included in the study. Exclusion criteria were patients with inflammatory arthritis, prior knee surgeries, significant deformities (>15° varus/valgus), or contraindications to robotic surgery.

In the robotic-assisted group, a preoperative CT-based 3D plan was developed for precise implant positioning and alignment using a robotic system. The robotic arm was used intraoperatively for guided bone resections and component placement. In the conventional group, TKA was performed using standard manual techniques with mechanical alignment guides. Both groups received the same implant design to eliminate variability due to prosthetic differences. The same team of experienced surgeons performed all procedures to ensure consistency.

Postoperative protocols, including pain management, physiotherapy, and rehabilitation, were standardized for both groups. Outcome measures were assessed at multiple time points: preoperatively, 3 months, 6 months, and 1 year, postoperatively. Primary outcomes included functional improvement, measured using the Knee Society Score (KSS) and the Western Ontario and McMaster Universities Arthritis Index (WOMAC). Secondary outcomes included radiographic alignment accuracy, postoperative complications, and patient-reported satisfaction on a 10-point Likert scale.

Data collection was performed by independent observers blinded to the surgical technique. Statistical analysis was conducted using SPSS software. Continuous variables were compared using an independent t-test, and categorical variables were analyzed with the chi-square test. A p-value <0.05 was considered statistically significant. Ethical approval was obtained from the institutional review

board, and written informed consent was obtained from all participants before enrollment.

RESULTS

The baseline characteristics of the robotic-assisted and conventional TKA groups were comparable, with no statistically significant differences across key parameters. The mean age of participants was 64.2 ± 6.1 years in the robotic-assisted group and 63.7 ± 6.4 years in the conventional group ($p = 0.68$). The male-to-female ratio and BMI were also similar between the groups ($p = 0.75$ and $p = 0.52$, respectively). Preoperative functional scores, including the Knee Society Score (KSS) and Western Ontario and McMaster Universities Arthritis Index (WOMAC), were nearly identical in both groups, with no significant differences ($p = 0.67$ and $p = 0.71$). These results confirm that the groups were well-matched, ensuring that observed differences in outcomes could be attributed to the surgical technique rather than baseline variability.

Functional outcomes, as measured by KSS and WOMAC, showed significant improvements in both groups, with the robotic-assisted group consistently outperforming the conventional group at all time points. At 3 months, the mean KSS in the robotic-assisted group was 78.4 ± 9.3 compared to 72.1 ± 10.4 in the conventional group ($p < 0.01$). This trend continued at 6 months (84.2 ± 7.8 vs. 79.6 ± 8.7; $p < 0.01$) and 1 year (91.5 ± 6.2 vs. 85.7 ± 7.3; $p < 0.001$). Similarly, WOMAC scores demonstrated greater improvement in the robotic-assisted group. At 3 months, the WOMAC score in the robotic-assisted group was 65.4 ± 8.9 compared to 70.8 ± 9.7 in the conventional group ($p < 0.01$). At 1 year, the robotic-assisted group achieved a significantly lower (better) WOMAC score of 50.2 ± 6.3 compared to 55.8 ± 7.1 in the conventional group ($p < 0.01$). These findings highlight the superior functional recovery associated with robotic-assisted TKA.

Radiographic alignment outcomes were significantly better in the robotic-assisted TKA group. The mean mechanical alignment deviation was 0.9 ± 0.5° in the robotic group compared to 2.3 ± 0.9° in the conventional group ($p < 0.001$). Component positioning was also more accurate in the robotic group, with the mean femoral and tibial component angles closer to the target 90° (90.3 ± 0.6° and 90.5 ± 0.7°, respectively) compared to the conventional group (88.8 ± 1.2° and 89.2 ± 1.3°; $p < 0.001$ for both).

Outliers, defined as alignment deviations greater than 3°, were significantly fewer in the robotic-assisted group (3.3%) compared to the conventional group (23.3%; $p < 0.01$). These results emphasize the precision of robotic systems in achieving optimal alignment, which is critical for long-term implant durability and function.

Patient-reported satisfaction scores were consistently higher in the robotic-assisted group at both 6 months and 1 year. At 6 months, the mean satisfaction score was 8.6 ± 0.9 in the robotic group compared to 7.9 ± 1.1 in the conventional group ($p < 0.01$). At 1 year, this difference persisted, with scores of 9.1 ± 0.7 in the robotic group versus 8.4 ± 0.8 in the conventional group ($p < 0.01$). These findings suggest that patients perceived better outcomes and overall satisfaction with robotic-assisted TKA, likely due to improved functionality and reduced complications.

Postoperative complications were lower in the robotic-assisted group compared to the conventional group. Infection rates were lower in the robotic group (1.67%) compared to the conventional group (8.33%), though this difference did not reach statistical significance ($p = 0.09$). Deep vein thrombosis (DVT) occurred in 3.33% of robotic-assisted cases versus 6.67% in conventional cases ($p = 0.40$). No revision surgeries were needed in the robotic group, whereas 5% of patients in the conventional group required revisions ($p = 0.08$).

Total complication rates were significantly lower in the robotic-assisted group (5%) compared to the conventional group (20%; $p = 0.01$). These results underscore the safety and effectiveness of robotic-assisted TKA in minimizing postoperative complications, potentially due to improved precision and reduced tissue trauma.

Table 1: Baseline Characteristics of the Study Groups

Characteristic	Robotic-Assisted TKA (n=60)	Conventional TKA (n=60)	p-value
Age (years, mean ± SD)	64.2 ± 6.1	63.7 ± 6.4	0.68
Male/Female Ratio	26/34	28/32	0.75
BMI (kg/m², mean ± SD)	28.5 ± 3.7	29.1 ± 4.0	0.52
Preoperative KSS (mean ± SD)	52.4 ± 8.6	53.1 ± 9.1	0.67
Preoperative WOMAC (mean ± SD)	75.8 ± 10.3	76.5 ± 9.8	0.71

Table 2: Functional Outcomes at Follow-Up (KSS and WOMAC)

Time Point	Robotic-Assisted TKA (Mean ± SD)	Conventional TKA (Mean ± SD)	p-value
KSS			
3 months	78.4 ± 9.3	72.1 ± 10.4	<0.01
6 months	84.2 ± 7.8	79.6 ± 8.7	<0.01
1 year	91.5 ± 6.2	85.7 ± 7.3	<0.001

WOMAC			
3 months	65.4 ± 8.9	70.8 ± 9.7	<0.01
6 months	58.1 ± 7.4	62.6 ± 8.2	<0.01
1 year	50.2 ± 6.3	55.8 ± 7.1	<0.01

Table 3: Radiographic Alignment Accuracy

Parameter	Robotic-Assisted TKA (n=60)	Conventional TKA (n=60)	p-value
Mechanical Alignment (°)	0.9 ± 0.5	2.3 ± 0.9	<0.001
Femoral Component Angle (°)	90.3 ± 0.6	88.8 ± 1.2	<0.001
Tibial Component Angle (°)	90.5 ± 0.7	89.2 ± 1.3	<0.001
Outliers (alignment >3° from neutral)	2 (3.3%)	14 (23.3%)	<0.01

Table 4: Patient Satisfaction Scores

Time Point	Robotic-Assisted TKA (Mean ± SD)	Conventional TKA (Mean ± SD)	p-value
6 months	8.6 ± 0.9	7.9 ± 1.1	<0.01
1 year	9.1 ± 0.7	8.4 ± 0.8	<0.01

Table 5: Postoperative Complications

Complication	Robotic-Assisted TKA (n=60)	Conventional TKA (n=60)	p-value
Infection (%)	1 (1.67%)	5 (8.33%)	0.09
DVT (%)	2 (3.33%)	4 (6.67%)	0.40
Revision Surgery (%)	0 (0%)	3 (5%)	0.08
Total Complications (%)	3 (5%)	12 (20%)	0.01

DISCUSSION

The comparable baseline characteristics of the robotic-assisted and conventional TKA groups in this study confirm that differences in outcomes were not influenced by demographic or clinical variability. The similarity in preoperative functional scores (KSS and WOMAC) across groups ($p = 0.67$ and $p = 0.71$) aligns with the findings of Marchand et al. (2019), emphasizing the importance of well-matched cohorts in comparative analyses of robotic-assisted and conventional TKA.[6]The superior functional recovery observed in the robotic-assisted group is consistent with previous studies. At 1 year, the robotic-assisted group had a mean KSS of 91.5 ± 6.2 compared to 85.7 ± 7.3 in the conventional group ($p < 0.001$). Similarly, WOMAC scores in the robotic group at 1 year (50.2 ± 6.3) demonstrated faster and more sustained recovery than the conventional group (55.8 ± 7.1, $p < 0.01$). These results align with Song et al. (2019), who reported significant improvements in early functional outcomes with robotic-assisted TKA, attributing the benefits to better alignment and soft tissue preservation.[7] Cho et al. (2018) similarly noted better WOMAC scores with robotic-assisted TKA, highlighting enhanced patient mobility and reduced pain as contributing factors.[8]Radiographic alignment accuracy in the robotic-assisted group was significantly better, with fewer outliers exceeding 3° from neutral (3.3% vs. 23.3%; $p < 0.01$). This aligns with the work of Mason et al. (2018), who demonstrated that robotic systems improve alignment precision, resulting in more consistent implant positioning.[9] The mechanical alignment deviation of 0.9 ± 0.5° in the robotic group compared to 2.3 ± 0.9° in the conventional group ($p < 0.001$) mirrors findings by Ishikawa et al. (2020), who reported similar improvements in component alignment using robotic assistance, thereby enhancing long-term implant survival.[10]Patient satisfaction scores at 6 months and 1 year were significantly higher in the robotic-assisted group (8.6 ± 0.9 and 9.1 ± 0.7, respectively) compared to the conventional group (7.9 ± 1.1 and 8.4 ± 0.8; $p < 0.01$ for both). This is consistent with research by Hampp et al. (2019), which demonstrated higher satisfaction in robotic-assisted TKA due to reduced complications and faster functional recovery.[11] Han et al. (2019) further supported these findings, attributing improved satisfaction to reduced postoperative pain and improved mobility associated with robotic precision.[12]Postoperative complications were significantly lower in the robotic-assisted group (5% vs. 20%; $p = 0.01$). Reduced infection rates (1.67% vs. 8.33%) align with findings by Naziri et al. (2019), who reported lower infection risks with robotic-assisted systems due to minimized soft tissue disruption and precise incisions.[13] Similarly, Kim et al. (2018) observed fewer revisions in robotic-assisted TKA, citing optimal component placement as a key factor.[14] The reduced incidence of DVT (3.33% vs. 6.67%) in the robotic-assisted group aligns with Park et al. (2020), who noted that precise alignment reduces the risk of venous stasis and associated thromboembolic events.[15]

CONCLUSION

This study demonstrates that robotic-assisted total knee arthroplasty (TKA) offers significant advantages over conventional TKA in both short- and long-term

outcomes. The robotic-assisted group showed superior functional recovery, with higher Knee Society Scores (KSS) and lower WOMAC scores, better radiographic alignment accuracy, and higher patient satisfaction rates. Additionally, complication rates, including infections and revisions, were lower in the robotic-assisted group, underscoring its safety and precision. These findings highlight the potential of robotic-assisted TKA to improve surgical outcomes, reduce complications, and enhance patient satisfaction, supporting its growing role in modern orthopaedic practice.

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