Original Article

A comparative study on early postoperative outcomes among patients undergoing robotic and traditional knee replacement surgeries

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Abstract

Background: This study aimed to assess the effectiveness of robotic versus traditional knee replacement surgeries regarding early postoperative outcomes, specifically pain levels, range of motion (ROM), and joint mobility.

Materials and Methods: A cross-sectional study design was employed. Eligible participants included patients aged 45 to 70 years who had undergone unilateral total knee replacement (TKR) and were within the first postoperative day. The study occurred at Care Hospital and the Abhinav Bindra Sports Medicine and Research Institute in Bhubaneswar, India. Outcome measures included the Numerical Pain Rating Scale (NPRS), Knee ROM (KROM), and the Lower Extremity Functional Scale (LEFS).

Results: Thirty patients were enrolled and randomly assigned to two groups, with 15 patients in each group. Both groups showed significant improvement ($P < 0.05$) in NPRS scores, as well as knee flexion and extension ROM, from day 1 to day 7 post-surgery. Between-group comparisons revealed that only knee flexion improved significantly ($P < 0.05$) in the traditional group. No significant differences ($P > 0.05$) were observed between the two groups in other outcome measures, including lower-extremity functional scores, by the end of the seventh postoperative day.

Conclusion: The findings indicate that robotic total knee replacement (TKR), when combined with a structured and intensive rehabilitation program, provides greater short- to mid-term benefits in pain management, flexion recovery, and functional improvement. However, these benefits do not extend into the long term.

Keywords: Osteoarthritis, physiotherapy, robotic surgeries, total knee replacement (TKR), traditional surgeries

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INTRODUCTION

Total knee replacement (TKR) is generally viewed as the final treatment option for patients with grade 4 arthritis, especially those suffering from severe pain, noticeable leg deformities, and a range of motion (ROM) of less than 90 degrees, who do not respond to conservative management. Surgical outcomes can differ based on whether the procedure is completed using a robotic-assisted technique or a traditional manual jig-based approach. Furthermore, the type of implants utilized in TKR affects the variability in patient recovery and satisfaction. Despite the overall durability of primary total knee replacement (TKR), studies show that 10% to 20% of patients remain dissatisfied postoperatively, even in the absence of surgical complications.[1]

Comprehensive patient recovery is influenced not only by surgical intervention but also significantly by the rehabilitation process. Successful outcomes rely on a multidisciplinary approach, with both the surgeon and physical therapist playing crucial roles in guiding recovery and enhancing patient satisfaction. Although robotic-assisted total knee replacement (raTKR) is associated with higher intraoperative costs due to the expense of the robotic system, ongoing maintenance, and specific disposable instruments, evidence suggests it may lead to cost savings over time. These savings result from reduced postoperative care costs, shorter hospital stays, and decreased opioid use compared to manual total knee replacement (mTKR). However, cost variability can also shape the perceptions of patients and their caregivers, potentially affecting their psychological outlook and recovery trajectory.[2]

Research shows that patients undergoing total knee replacement (TKR) often hold unrealistic expectations, which can lead to dissatisfaction and disappointment. Therefore, it is essential to provide patients with accurate information about the expected outcomes and the goals of physical therapy. Postoperative physical therapy for total knee replacement (TKR) typically includes interventions aimed at improving knee stability, enhancing ROM, correcting extension deficits, and providing gait training with assistive devices.[3] Since TKR is primarily performed to relieve pain and restore joint function, resuming physical activity followed by structured rehabilitation is crucial for optimal recovery. In this context, pain relief is viewed as a short-term goal, while fully restoring the functional capacity is a long-term objective of physical therapy.[4]

Although evidence supports the rehabilitation following TKR, there is a lack of studies focusing on early outcome measures during the initial hospital stay and comparisons of early outcomes between manual TKR (mTKR) and robotic-assisted TKR (raTKR). This study aims to assess whether early postoperative differences exist in pain, ROM, and mobility between patients undergoing mTKR and those receiving raTKR.

MATERIALS AND METHODS

Following ethical consent from Care Hospitals and the Abhinav Bindra Sports Medicine and Research Institute in Bhubaneswar, a comparative study was conducted among patients undergoing unilateral TKR. All subjects were informed about the research protocol before participation, and their agreement was obtained based on their level of interest. There were no restrictions, and participants could opt out of the study by informing the researcher.

The study included 30 participants (both male and female) aged 45 to 70 years who were on postoperative Day 1 following unilateral TKR. Participants were excluded if they were medically unfit to exercise, unwilling to participate in the postoperative exercise regimen, unable to provide informed consent, or experienced any postoperative complications. Eligible participants were randomly allocated into groups using the block randomization method. To minimize bias, outcome assessors were blinded to group allocation, as outlined in the study protocol.

Inclusion criteria

1. The patient's age range is 45–70 years.
2. The study comprised both male and female participants.
3. Day 1 of a patient undergoing unilateral TKR.

Exclusion criteria

1. Due to medical reasons, the subject is unable to exercise.
2. Unwilling to participate in the postoperative exercise regimen.
3. Inability to provide informed consent.
4. Any postoperative concerns.

Outcome measure and instrument

(i) The numerical pain rating scale (NPRS), knee ROM (KROM), and lower extremity functional scale (LEFS) will be used as outcome measures for patients with early postoperative unilateral TKR. KROM is the primary outcome measure, followed by NPRS and LEFS as secondary outcome measures.

(ii) Universal goniometer for determining the range of motion

PROCEDURE

On the first postoperative day, the NPRS, KROM, and LEFS baseline values were recorded after obtaining consent from the patient. Due to its ease of application in clinical practice, the NPRS scale is both reliable and valid. The NPRS is a qualitative measure of pain in which patients rate their pain on an 11-point scale ranging from 0 to 10. "0" denotes no pain, while "10" indicates the worst suffering imaginable.[5] KROM was measured using a goniometer, a valid and reliable tool widely recognized for measuring the ROM.[6] In unilateral TKR patients, KROM was measured first, followed by an assessment of the LEFS. The LEFS is a valid and accurate measure for evaluating the lower limb functional status in individuals with musculoskeletal issues. It consists of 20 items, with a maximum score of "4" indicating no difficulty and a minimum score of "0" indicating that the function is exceedingly difficult or impossible to perform.[7]

Following the evaluation of baseline measurements, patients were asked to perform ankle pump exercises and knee stability exercises, which included isometric holds for the gluteus, adductors, quadriceps, and hamstring muscles. These were followed by co-contraction of knee muscles to reduce pain, increase the stability, and increase KROM. KROM improves with multi-angle hamstring activation during knee bending, accompanied by 10-s holds at various angles.

Patients with unilateral TKR begin walking with a walker on the first day and can walk at their own pace. A functional scale for the lower extremity was taken after walking. A total of two physical therapy sessions were given in a single day. The exercise program for the patients mentioned above lasted 7 days, with 14 sessions administered upon discharge. Post-NPRS, KROM, and LEFS measurements were taken on the discharge day. Each patient was also given home workouts to help them maintain their development for the next 15 days

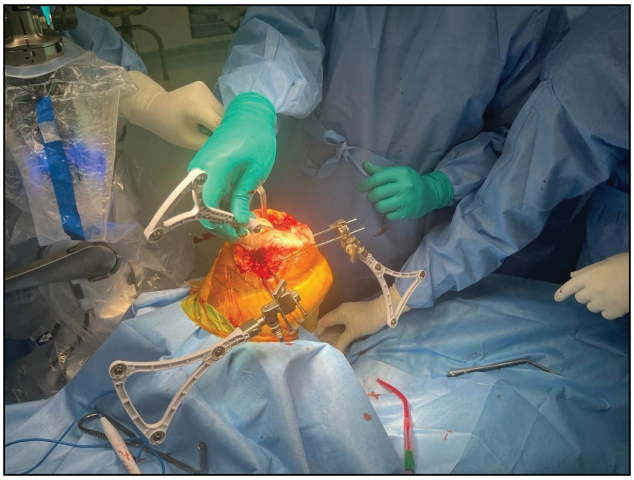

Figure 2: Surgical procedure (knee joint position)

Figure 3: Measurement of bony configuration

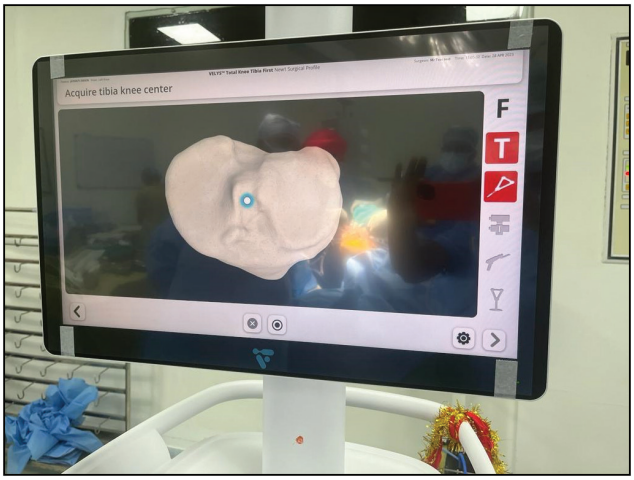

Figure 1: Display of bony configuration during surgery

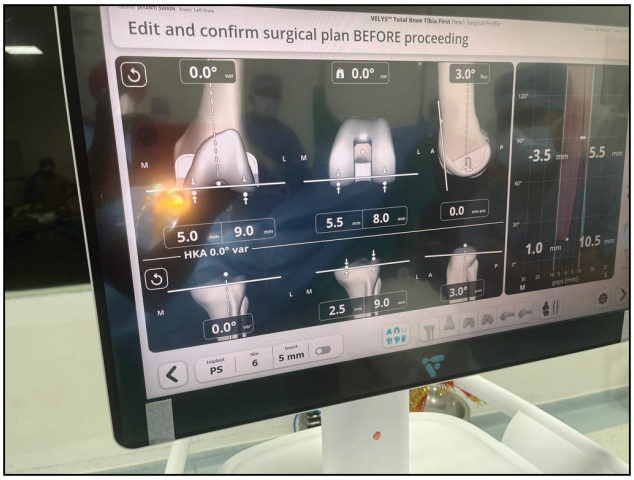

Figure 4: Prosthesis fitting display

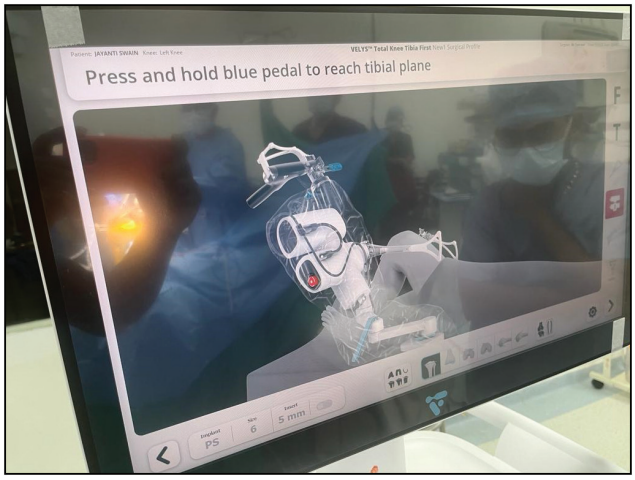

Figure 5: Robotic assessment

before the stitches were removed. Follow-up readings of NPRS, KROM, and LEFS were taken on the 15th day for data review. The references (patient positioning and techniques) for the surgical interventions for both traditional and robotic procedures are provided in Figures 1–5.

The sample size was calculated using G*Power software based on an *a priori* calculation method. The parameters used were a significance level (α) of 0.05, a power of 90%, and an expected effect size of 0.7. The estimated sample size was 11 participants per group. However, to account for potential dropouts, 15 participants were recruited for each group.

Statistical analysis

Statistical analysis was done using IBM Statistical Package for Social Sciences (SPSS), version 26, for Windows [Chicago, Illinois, USA]. The descriptive statistics were analyzed using a paired *t* test to compare the demographic and baseline details of both groups. In interferential statistics, time factor analysis was performed using a paired *t* test, and group factor analysis was conducted using an independent *t* test. The level of significance value was kept at 0.05.

RESULTS

Each group included 15 participants who underwent TKR surgery using either the traditional or robotic-assisted technique. Demographic characteristics and baseline scores for the outcome measures were reported as mean and standard deviation, respectively [Table 1].

The study's findings indicated that all outcome measures, including the NPRS, knee flexion, and extension angles,

Table 1: Demographic details

Variables	Traditional total knee replacement	Robotic TKR
Total	15	15
Age	60.6 (6.35)	54.4 (9.82)
Gender (male/female)	5/10	5/10
Side (right/left)	7/8	6/9
NPRS	8.26 (.88)	8.4 (0.82)
KFA	40.66 (10.76)	45.73 (8.04)
KEA	8.53 (2.13)	8.06 (3.59)
LEFS	46.91 (4.30)	46.16 (4.59)

NPRS – Numeric Pain Rating Scale, KFA – Knee Flexion Angle, KEA – Knee Extension Angle
LEFS – Lower Extremity Functional Scale

Table 2: Outcome measures

Outcomes	Intervention	Day 1	Day 7	P-value	Between-group- P
	Traditional	8.5	3.77	0.00**	0.71
NPRS	Robotic	8.1	3.5	0.00**	–
–	Traditional	20.45	66.05	0.00**	0.017**
KFA	Robotic	25.32	59.38	0.00**	-
–	Traditional	10.22	16.02	0.00**	0.604
KEA	Robotic	11.5	17.03	0.00**	-
–	Traditional	14	46.91	-	0.614
LEFS	Robotic	16	46.16	-	-

** – Statistically significant

showed significant improvement ($P < 0.05$) in both groups from postoperative day 1 to day 7. However, the between-group analysis revealed that only the knee flexion angle demonstrated a statistically significant difference ($P < 0.05$). No other outcome measures showed significant differences between the two groups ($P > 0.05$) [Table 2].

Assessment of lower-extremity function on the 7th postoperative day showed no significant differences between the groups ($P > 0.05$). Overall, the results suggest that the traditional TKR group experienced greater improvements in pain relief and knee flexion compared to the robotic group. In contrast, the robotic group exhibited less of a knee extension lag than the traditional group.

DISCUSSION

Our study compared the effects of robotic-assisted total knee replacement (TKR) to conventional TKR on patients' functional outcomes. The findings revealed a significant difference in the knee flexion range between robotic and traditional groups. Although both groups demonstrated similar improvements in functional scores, patients in the robotic group exhibited a greater ROM in flexion and

experienced less pain compared to the control group. Nevertheless, both techniques were equally effective in enhancing knee extension ROM and overall quality of life.

To date, few studies have evaluated the clinical and functional benefits of robot-assisted knee replacement compared to traditional methods, with most existing research studies primarily focusing on unilateral knee arthroplasty.[8-13]

Few studies have examined the efficacy of traditional TKR compared to robotic total knee replacement in terms of clinical and functional outcomes.[8-12,14,15]

The significant reductions in pain and knee flexion observed in patients undergoing robot-assisted knee replacements may result from enhanced precision and dexterity in manipulating bone slices to create the necessary gaps for flexion and extension. Additionally, this may lead to reduced inflammation, improved soft tissue balance, and a decrease in soft tissue injury.[11]

Most of the data in the literature and our investigation's findings align. The few studies on the use of the robotic TKR technique for patients undergoing unicompartmental knee prosthesis surgery report better bone alignment from a radiological standpoint,[9-11] improved pain outcomes after surgery, increased patient satisfaction, a lower revision rate, and shorter hospital stay.[10,12]

Conversely, a 1- and 2-year prospective study shows that robotically assisted surgery improves patient outcomes in overall health and performance in sports and leisure activities. This demonstrates that it meets or exceeds the industry's current benchmarks for patient-reported outcomes.[16] In prospective cohort research, Kayani *et al*.[17] compared the early functional outcomes of 40 conventional manual TKA procedures with those of 40 robotic TKA procedures. The researchers found that robotic TKA was associated with lower rates of postoperative stiffness, improved early maximal knee flexion at discharge, and reduced postoperative discomfort.

A meta-analysis found that both TKR methods are reliable and safe procedures. Although there were no significant differences in clinical outcomes, ROM, or postoperative complications, the intervention with robotic TKR yielded better results regarding alignment and axes, with less blood loss.[18-21]

Limitations

The study was limited by a small sample size, with only 15 participants in each group (traditional and robotic-assisted TKR), which may restrict the generalizability of the results to the broader population. Additionally, the study focused solely on short- to mid-term outcomes, primarily assessing early postoperative effects up to 7 days, with some follow-up data collected on the 15th day. The outcomes observed are closely associated with the postoperative rehabilitation program. Given that the rehabilitation protocol was structured and intensive, it may have influenced recovery outcomes independently of the surgical technique employed.

CONCLUSION

Achieving optimal clinical outcomes requires knee replacement surgery and comprehensive rehabilitation. While our study's findings are preliminary, they suggest that robotic-assisted TKR, combined with a structured and intensive rehabilitation program, leads to effective pain management, improved knee flexion, and enhanced functional capacity in the short to mid term. However, the long-term benefits remain uncertain and warrant further investigation.

Ethical policy and Institutional Review Board statement

The Institutional Ethics Committee of the Abhinav Bindra Sports Medicine and Research Institute in Bhubaneswar, Odisha, reviewed the protocol titled "A Comparative Study on Early Postoperative Outcomes among Patients Undergoing Robotic and Traditional Knee Replacement Surgeries" on June 19, 2023. After evaluation, the committee found the study suitable and granted ethical approval, which is confirmed in Reference Letter No. 10MCTP/2341 dated June 19, 2023.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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