RESEARCH ARTICLE

Comparative Analysis of Joint Awareness and Functional Outcomes in Robotic vs Conventional Total Knee Arthroplasty: A Retrospective Study with 1-year Follow-up

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Abstract

Aim and background: This study aimed to compare clinical and functional outcomes, including joint awareness, knee function, and pain perception, between robotic-assisted and conventional manual total knee arthroplasty (TKA) in patients with end-stage knee osteoarthritis. With rising TKA surgeries and advances in robotics, assessing their impact on patient outcomes in the Indian population is essential.

Methodology: A retrospective study was conducted with 200 patients undergoing TKA from January to March 2023. Patients were divided into two groups: robotic-assisted TKA (Cuvis system, 100 patients) and conventional TKA (subvastus approach, 100 patients). Data collected included age, Body Mass Index (BMI), gender, and preoperative scores on the Visual analog scale (VAS), Oxford knee score (OKS), and Forgotten joint score (FJS). Postoperative outcomes were assessed at 3, 6, and 12 months.

Results: Both groups completed a 1-year follow-up. At the 3- and 6-month follow-ups, no notable differences were observed in OKS between the groups. However, at 1 year, the robotic-assisted group showed a higher improvement in OKS compared to the conventional TKA group. FJS scores at 1 year also favored the robotic-assisted group, indicating higher satisfaction and reduced joint awareness during daily activities. As measured by VAS, early postoperative pain scores were markedly lower in the robotic group on days 1 and 3 post-surgery, though pain levels equalized between groups by the 1-month follow-up. Complications were minimal, with no notable differences between the groups.

Conclusion: Robotic-assisted TKA was associated with higher satisfaction (better FJS scores), reduced early postoperative pain (lower VAS scores), and improved functional outcomes (better OKS scores) after 1 year. These findings suggest that robotic-assisted TKA is a favorable option over conventional TKA in enhancing patient outcomes.

Clinical significance: Robotic-assisted TKA offers enhanced joint functionality and patient satisfaction, with evidence of reduced early postoperative discomfort, presenting a promising alternative to conventional TKA in knee arthroplasty.

Keywords: Forgotten joint score, Knee osteoarthritis, Oxford knee score, Postoperative pain, Retrospective comparative study, Robotic total knee arthroplasty.

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Introduction

Total knee arthroplasty (TKA) has become the most commonly chosen treatment for patients with end-stage knee osteoarthritis. The number of patients undergoing TKA is growing exponentially, potentially due to its clinical success and higher survival rate. Evidence reveals that with TKA, a more than 90% survival rate has been documented in patients over 10–15 years postoperatively.[1] A higher acceptance rate of TKA is attributed to improved functional and clinical outcomes. Across various studies, postoperative patient satisfaction ranges from 70 to 93% in the population undergoing TKA.[2,3] A limitation of the conventional surgical approach is the use of a traditional medial parapatellar (MPP) procedure, which impacts the functioning of the knee extensor as it requires an incision into the quadriceps tendon. Several techniques have been developed as an alternative for MPP, such as the subvastus approach, which improves postoperative outcomes and reduces hospitalization time.[4,5] The subvastus technique preserves the attachment between the quadriceps and the medial patellar border, minimizing postoperative pain and reducing the incidence of vascular flow disruption to the patella.[6] Therefore, these advantages of the subvastus technique offer improved postoperative range of motion and functional benefits for patients undergoing TKA.

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Since the introduction of TKA for end-stage knee osteoarthritis, technological advancements have transformed knee replacement surgeries. Innovations include novel implant designs, enhanced CT/MRI visualization, improved postoperative care, and patient specific procedures with computer navigation systems.

Robotics revolutionized surgery in the late twentieth century, starting with the Programmable Universal Machine for Assembly (PUMA) system in 1985 for neurosurgical biopsies, followed by the FDA-approved da Vinci Surgical System for laparoscopy.[7]

In orthopedics, surgical robot performing total hip and total knee replacement surgeries (ROBODOC) was initially developed for total hip replacements but later adapted for TKA, with over 15,000 procedures performed globally. This spurred the development of robotic systems worldwide, including CASPAR (Europe), MAKO (USA), ACROBOT (UK), and CUVIS (South Asia). Robotic systems now include fully active platforms like CUVIS, semi-active systems, and robot-guided tools, enabling precise execution in TKA surgeries.[8–11] Previous studies suggest that robot-assisted TKA improves implant placement accuracy and limb alignment.[12] However, concerns remain regarding higher surgical costs, increased operative time, and inconclusive evidence of reduced complications.[13] With the rapid adoption of robotic TKA in India and uncertainty around its clinical benefits, further research is needed.[12] Notably, while 10–20% of TKA patients report dissatisfaction, around 85% are satisfied, underscoring the importance of optimal surgical techniques.[14]

The present study aims to assess and compare patient satisfaction [Forgotten joint score (FJS)], functional outcome [Oxford knee score (OKS)], and opioid dependency pain scores [Visual analog scale (VAS) score] in 200 patients undergoing TKA. The cohort includes 100 patients assigned to conventional TKA techniques and 100 patients assigned to robot-assisted TKA. The study utilizes a large nationwide database for comprehensive analysis.

Methodology

Objectives

The primary objective of this study is to conduct a comparative analysis between two cohorts of patients undergoing TKA: One group going through TKA with a traditional approach without robotic assistance and the other group treated via TKA with robotic assistance. The primary outcome measure is the assessment of joint consciousness between the two groups as determined by the FJS at a 1-year interval.

Secondary objectives include assessing and comparing knee function in daily activities at 3, 6, and 12 months post-surgery using the OKS. Additionally, pain perception will be evaluated using the VAS on day 1, day 3, and 1 month postoperatively.

Study Design

The present retrospective study includes 200 participants who underwent TKA successfully between January 2023 and March 2023. The 200 participants were divided into two cohorts. One cohort consisted of 100 patients who received robotic-assisted TKA using the Cuvis system (MERIL) via the subvastus approach, while the second cohort consisted of 100 participants who underwent conventional TKA (cruciate retaining) via the subvastus approach. Patient demographics recorded include age, Body Mass Index (BMI), gender, and deformities (Table 1).

The surgeries were performed by an experienced orthopedic surgeon in the absence of a Tourniquet. Using the subvastus approach, cruciate-retaining implants, a suture-less and staple-less surgery was performed.

Inclusion/Exclusion Criteria

The inclusion criteria included individuals aged 50–90 years with severe osteoarthritis requiring TKA. All patients provided informed consent and underwent the procedure via the subvastus approach without the use of a tourniquet, regardless of their cohort.

Table 1: Patient demographic details

Parameter	*Robotic TKA*	*Manual TKA*
Age (years) (age range)	65 (49–71)	67 (51–80)
No. of males *N* (%)	38 (19%)	34 (17%)
No. of females *N* (%)	162 (81%)	166 (83%)
BMI (kg/m^2)	26 (19–41)	27 (19–42)

Patients were excluded if they had varus deformity exceeding 20°, were unable to interpret the study instructions, had a dual-energy X-ray absorptiometry scan (DEXA) score >−4, or had a medical history of critical conditions that could compromise their safety, clinical outcomes, or the study's results.

Data Collection

The study assessed various parameters, including VAS, OKS, and FJS-12.[15–17] The VAS, ranging from 0 to 10, was used for pain assessment, with 0 indicating no pain and 10 indicating severe pain. The OKS consists of 12 items evaluating knee function, while the FJS-12 measures awareness of the prosthetic joint during daily activities, ranging from 0 to 100, with higher scores indicating lower awareness.

Preoperative data collection included the patient's medical history, physical examination findings, demographics, VAS score, and self-reported range of motion. Medication history, particularly the use of antiemetic drugs and non-steroidal anti-inflammatory drugs (NSAIDs), was detailed. Surgeries were performed by an experienced orthopedic surgeon using the subvastus approach without a tourniquet, utilizing cruciate-retaining implants, and performing sutureless and stapleless procedures. Patients received spinal anesthesia during surgery and a femoral canal block postoperatively. A standardized rehabilitation protocol for pain management was implemented, with patellar resurfacing in all cases.

Postoperative assessments occurred at 3, 6, and 12 months. The range of motion was measured with a manual goniometer, and functional outcomes were evaluated using the OKS. Knee radiographs were obtained at each follow-up, and the FJS-12 was assessed at 12 months to evaluate long-term joint function and awareness.

Statistical Analysis

Data were collected and organized in MS Excel, and continuous variables were expressed as mean values and categorical variables as frequencies and percentages.

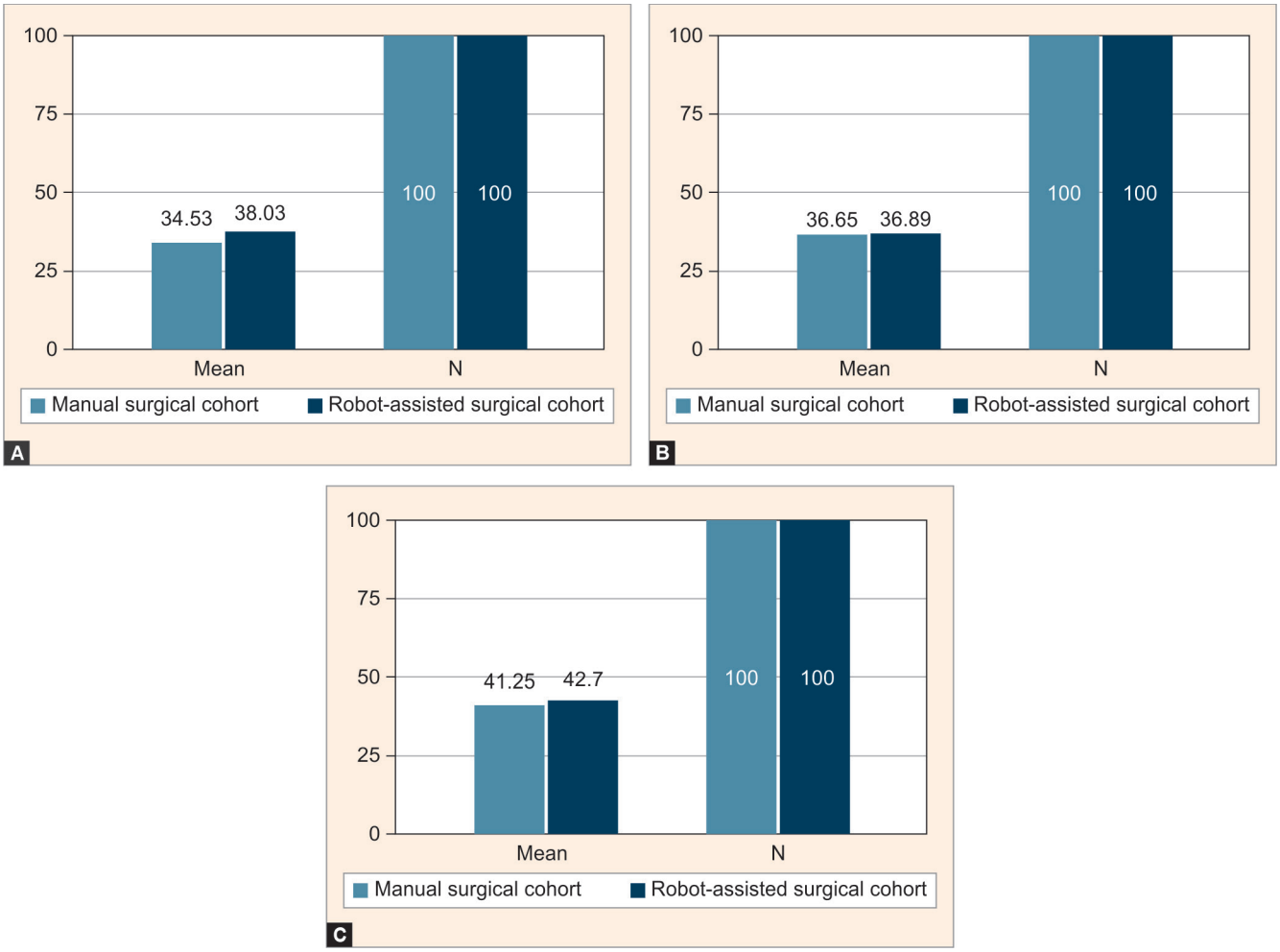
Results

Patient Demographics

A total of 200 participants were divided into two groups: Group I, with 100 participants undergoing robotic-assisted TKA, and group II, with 100 participants undergoing conventional TKA. Both groups completed a 1-year follow-up with assessments at 3, 6, and 12 months. Detailed patient demographics for both groups are presented in Table 1.

Clinical Outcomes

At the 3-month (Fig. 1A) and 6-month (Fig. 1B) postoperative follow-ups, no substantial differences in the OKS were observed between the two groups. However, at the 1-year follow-up, the robotic arm-assisted group showed a notably better OKS compared to the manual surgery group (Fig. 1C).



Figs 1A to C: (A) Oxford knee score comparison at 3 months; (B) Oxford knee score comparison at 6 months; (C) Oxford knee score comparison at 12 months

The FJS was used to assess patients' awareness of their prosthetic knee joints postoperatively. Overall, the robotic arm-assisted group demonstrated better outcomes, with a substantially higher mean FJS compared to the manual group. Participants in the robotic arm-assisted surgery group also showed improved performance in daily activities postoperatively compared to the conventional TKA group (Fig. 2). A remarkable difference was observed at the 1-year follow-up, with the robotic arm-assisted group achieving an FJS of 88 (greater than 85).

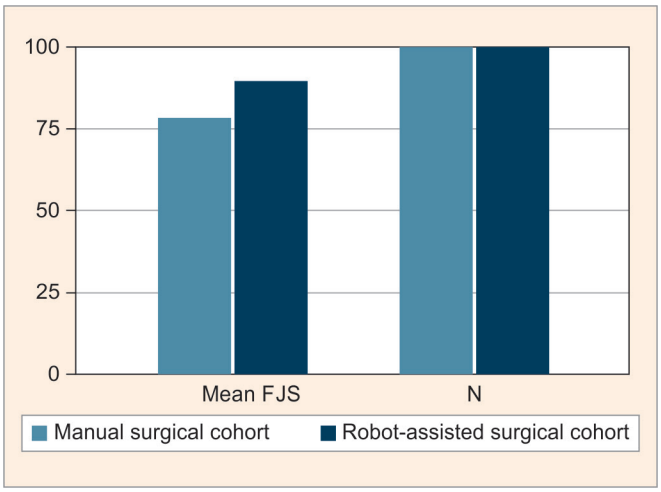


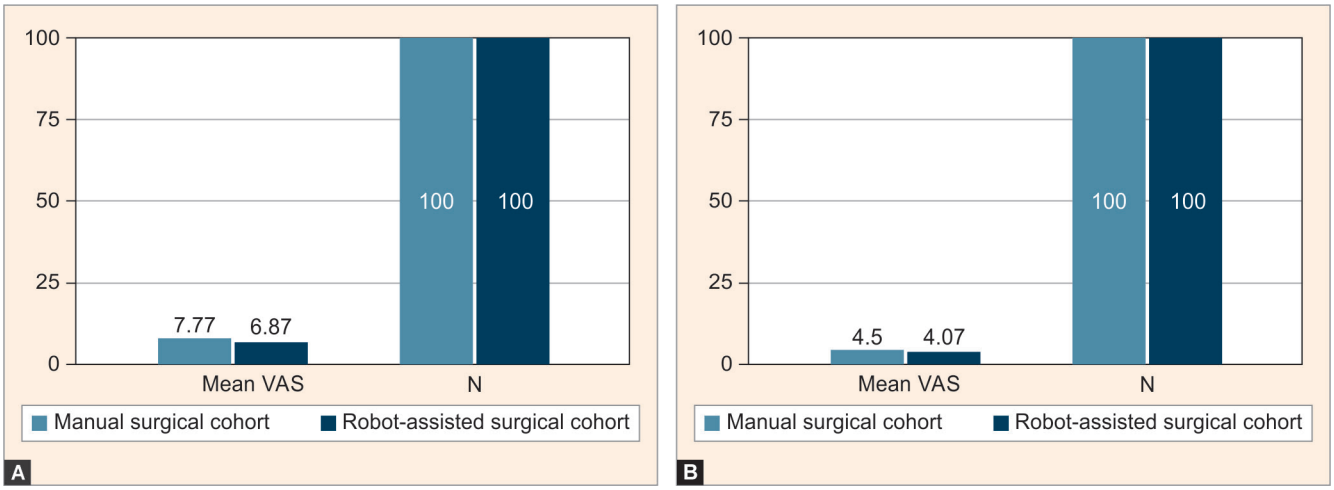
Fig. 2: Forgotten joint score comparison at 1-year

Visual Analog Scale Outcomes

Preoperative pain levels were similar between the two groups. However, notable differences emerged in the early postoperative period on day 1 (Fig. 3A) and day 3 (Fig. 3B), with the robotic arm-assisted group reporting lower pain scores. By the 1-month follow-up, pain levels had equalized between the groups, and no substantial differences were observed. Both groups received identical pain management interventions, indicating no differences in overall analgesic use.

Complications

No markable differences in complication rates were observed between the groups. Within the first postoperative year, no patients required additional surgery. Two minor wound complications occurred in the manual surgery group, but no deep infections were reported in either group. There were no surgical wound-related serious complications during follow-up in either group. In the robotic-assisted TKA group, no robot-related complications such



Figs 3A and B: (A) Visual analog scale at day 1; (B) Visual analog scale at day 3

as pin tract infections, pin tract fractures, or soft tissue injuries were observed. Only three robotic-assisted TKA and 4 conventional TKA patients had ecchymosis on the medial aspect of the knee, which resolved after discontinuation of blood thinners. One patient developed superficial skin blisters, which resolved within a few days with regular dressing and a short course of antibiotics. No patient experienced persistent knee pain, swelling, or aseptic loosening, or required reoperation during the follow-up period.

Discussion

This study compared clinical and functional outcomes in end-stage osteoarthritis patients undergoing TKA with robotic-assisted and manual approaches. Robotic-assisted TKA resulted in notably better early knee function, reduced postoperative pain (first and third days), and a greater feeling of a forgotten joint, contributing to higher patient satisfaction compared to conventional TKA. Recent studies have provided insights into the comparative outcomes of robotic-assisted TKA versus conventional TKA. A systematic review and meta-analysis of randomized controlled trials revealed that robotic-assisted TKA offers superior postoperative anatomical and mechanical alignment compared to conventional methods. However, both approaches demonstrated similar clinical and functional outcomes, as well as comparable complication rates.[18] The findings from this study suggest that robotic-assisted TKA is a positive predictor of patient satisfaction with favorable early clinical outcomes. Previous studies have reported that the poor outcomes of the surgery are primarily associated with the preoperative joint condition.[19] Additionally, a study focusing on patients with failed high tibial osteotomy found that robotic-assisted TKA resulted in better mechanical axis alignment and component positioning accuracy compared to conventional techniques.[20] The clinical performance of joint arthroplasty is impacted by both surgical and patient-related factors. Therefore, an approach focusing on patients with higher preoperative activity levels allows for a more accurate assessment of surgical factors. This study demonstrates improved clinical outcomes of robotic-assisted TKA compared to conventional TKA. The rationale behind the improved outcomes with robotic-assisted TKA is the opportunity for a patient-specific surgical approach, facilitating enhanced accuracy in the restoration of joint surfaces and achievement of near-natural joint kinetics of the knee. Additionally, the use of a robotic burr instead of a traditional high-speed saw blade minimizes bone necrosis due to heat. This allows less extensive bone resections, leading to reduced postoperative pain.[11,21] Alternatively, a placebo effect cannot be entirely ruled out, whereby patients receiving robotic-assisted TKA perceive faster recovery compared to the conventional TKA group.

Our findings suggest that robotic-assisted TKA is associated with improved early postoperative clinical outcomes compared to traditional conventional TKA and presents as a reliable option for the treatment of end-stage knee osteoarthritis. This is supported by notable differences in patient-reported outcomes measured by the OKS at 12 months, along with lower pain VAS scores during the first and third postoperative days. However, these initial differences appear to diminish by 1 month following surgery. Additionally, a higher proportion of patients in the robotic-assisted TKA cohort achieved an FJS greater than 85 compared to the conventional TKA cohort. The present study showed remarkable differences between both the groups 1 year postoperatively. However, contradictory results were reported in another study where no substantial differences were observed in the OKS between the robotic-assisted TKA and manual group. This discrepancy can be attributed to a smaller sample size in the latter study. While FJS is valuable in assessing knee joint awareness based on patients' knowledge and sensation of the joint, it has its limitations as it does not reveal the actual functional recovery following TKA.[22] Another meta-analysis indicated that while robotic-assisted TKA improves implant positioning accuracy, the differences in patient-reported outcome measures (PROMs) between robotic-assisted and conventional TKA were minimal.[23]

The postoperative range of motion in both groups showed no considerable difference. However, robotic-assisted TKA was associated with a positive joint perception. Following robotic-assisted TKA, a substantially higher number of patients reported being either satisfied or very satisfied with the treatment approach. During the final follow-up examination at 12 months, most of the patients in the robotic-assisted TKA group reported lower levels of pain and had an increased acceptance and satisfaction from robotic-assisted TKA intervention compared to those treated with conventional TKA. These results demonstrate that a larger

proportion of patients were open to recommending robotic assisted TKA to others. However, the study has certain limitations, it is retrospective, has a relatively short follow-up period of only 1 year, lacks blinding, and was conducted at a single center, limiting its generalizability.

Conclusion

The present study found that robotic-assisted TKA was associated with greater patient satisfaction and better joint perception during daily activities and a forgotten joint. Overall, robotic-assisted TKA demonstrated superior clinical outcomes compared to conventional TKA in terms of OKS, VAS, and FJS.

Clinical Significance

Robotic-assisted TKA offers enhanced joint functionality and patient satisfaction, with evidence of reduced early postoperative discomfort. It presents as a promising alternative to conventional TKA in knee arthroplasty.

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