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Comparative Study of Functional Outcomes in Patients Undergoing Total Knee Arthroplasty with and Without Computer Navigation

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Abstract:
Total knee arthroplasty (TKA) is a widely accepted surgical intervention for advanced knee osteoarthritis, aimed at relieving pain and restoring function. Despite its high success rate, postoperative outcomes are influenced by implant alignment and surgical precision. Computer navigation technology has been introduced to improve intraoperative accuracy, reduce alignment errors, and potentially enhance functional results. This prospective comparative study was conducted on 60 patients with primary osteoarthritis undergoing TKA, equally divided into two groups: navigation-assisted and conventional techniques. All procedures were performed by experienced orthopaedic surgeons using standardized protocols. Functional outcomes were assessed using the Knee Society Score (KSS) and range of motion (ROM), recorded preoperatively and at six months postoperatively. Statistical analysis revealed that patients in the navigationassisted group achieved significantly higher mean KSS and improved ROM compared to those in the conventional group. Additionally, fewer cases of malalignment and early post-operative complications were observed in the navigation-assisted cohort. These findings indicate that computer navigation in TKA can lead to superior functional recovery, better joint mobility, and more accurate implant placement. Incorporating navigation-assisted systems in routine practice may enhance patient satisfaction and long-term prosthesis survival, especially in younger, active individuals where precision is crucial for functional longevity.

Keywords: ***Total Knee Arthroplasty, Computer Navigation, Functional Outcomes, Knee Society Score, Orthopaedics.***

Introduction

Total knee arthroplasty (TKA) is one of the most successful and commonly performed orthopaedic procedures for the management of advanced knee osteoarthritis and other debilitating joint diseases. The primary goals of TKA are pain relief, restoration of knee function, correction of deformity, and improvement in quality of life. With increasing life expectancy and a growing elderly population, the demand for TKA has risen substantially worldwide, including in developing countries such as India. While conventional jig-based techniques have delivered satisfactory results for decades, their accuracy is limited by anatomical variations, surgeon experience, and intraoperative judgment, which may lead to implant malalignment in a significant proportion of cases. Malalignment has been associated with accelerated prosthesis wear, reduced functional outcomes, and higher revision rates. Computer-assisted navigation systems have emerged over the last two decades as a promising technological advancement in orthopaedic surgery. These systems

provide real-time feedback on bone cuts, implant positioning, and limb alignment during surgery, thereby aiming to improve accuracy and reproducibility. Multiple studies have suggested that navigation-assisted TKA achieves more precise mechanical axis restoration compared to conventional techniques. Improved alignment is thought to enhance prosthesis longevity and optimize functional outcomes, especially in active or younger patients where long-term durability is critical. Despite these advantages, the adoption of computer navigation in TKA remains limited in many centers due to cost implications, increased operative time, and the learning curve associated with the technology. Moreover, while radiological improvements are well-documented, the actual impact on patient-reported outcomes and functional performance remains an area of ongoing debate. Some studies have demonstrated superior Knee Society Scores (KSS) and range of motion (ROM) with navigation-assisted techniques, whereas others have found no significant difference compared to conventional methods. Given these controversies, there is a need for well-designed comparative studies assessing functional outcomes in real-world clinical settings. This study was undertaken to evaluate and compare the functional outcomes of navigation-assisted versus conventional TKA in patients with primary knee osteoarthritis, using objective functional scores and mobility parameters over a six-month follow-up period. By focusing on functional recovery rather than radiological parameters alone, this study aims to provide clinically relevant evidence regarding the role of computer navigation in improving patient outcomes after TKA.

Materials and Methods

1. Study Design and Setting

This was a prospective, comparative, hospital-based study conducted in the Department of Orthopaedics, Rama Medical College Hospital & Research Centre, Kanpur, Uttar Pradesh, in collaboration with the Department of Orthopaedics, Virat Ramayan Institute of Medical Sciences, [City], India. The study period extended from **January 2023 to June 2024**. Ethical clearance was obtained from the Institutional Ethics Committee of both participating institutes before initiating patient recruitment. All procedures were performed in accordance with the ethical standards laid down in the Declaration of Helsinki (2013 revision). Written informed consent was obtained from all patients after explaining the nature of the study, surgical procedure, possible risks, and benefits.

The research was designed to compare functional outcomes between patients undergoing **navigation-assisted total knee arthroplasty (Group A)** and those undergoing **conventional jigbased total knee arthroplasty (Group B)**. Both groups were matched for age, sex, body mass index (BMI), and preoperative functional status.

2. Study Population

2.1 Inclusion Criteria

Patients were included in the study if they met the following criteria:

1. Age between **50 and 80 years**.
2. Diagnosis of **primary osteoarthritis of the knee** based on clinical and radiological findings (Kellgren–Lawrence grade III or IV).

3. Severe pain and functional limitation despite a minimum of six months of optimized conservative management, including physiotherapy and analgesics.
4. Indicated for primary unilateral total knee arthroplasty.
5. Ability and willingness to participate in follow-up assessments for at least six months postoperatively.

2.2 Exclusion Criteria

Patients were excluded if they had:

1. Secondary arthritis due to rheumatoid arthritis, post-traumatic arthritis, septic arthritis, or gout.
2. History of previous knee surgeries (including high tibial osteotomy or unicompartmental knee replacement).
3. Severe fixed deformity (>20° varus or >15° valgus) uncorrectable intraoperatively.
4. Severe osteoporosis or metabolic bone disease.
5. Neuromuscular disorders affecting lower limb function (e.g., poliomyelitis, Parkinson's disease).
6. Active infection or skin lesions over the operative site.
7. Inability to provide informed consent or comply with rehabilitation protocols.

3. Sample Size Calculation

Sample size estimation was performed based on preliminary data from previous studies evaluating functional outcomes using the **Knee Society Score (KSS)** after navigation-assisted and conventional TKA. Assuming a mean difference of 10 points in postoperative KSS between the two groups, with a standard deviation of 12, a confidence level of 95%, and power of 80%, the minimum required sample size was calculated to be **25 patients per group**. To account for potential dropouts, 30 patients were recruited for each group, resulting in a total sample size of **60 patients**.

4. Randomization and Group Allocation

Patients fulfilling inclusion criteria were allocated into two equal groups (n=30 each) using a computer-generated randomization list:

- **Group A**: Navigation-assisted TKA using an image-free optical tracking system (e.g., Stryker Navigation System).
- **Group B**: Conventional jig-based TKA.

Randomization was concealed using sealed opaque envelopes opened on the day of surgery.

5. Preoperative Assessment

All patients underwent a standardized preoperative evaluation that included:

- Detailed clinical history and physical examination.
- Assessment of **Knee Society Score (KSS)** and **range of motion (ROM)** using a goniometer.
- Standard weight-bearing anteroposterior, lateral, and skyline patellar radiographs.
- Laboratory investigations including complete blood count, ESR, CRP, renal and liver function tests, coagulation profile, and blood grouping.
- Pre-anaesthetic evaluation and optimization for surgery.

Patients were educated about the surgical procedure, possible complications, and postoperative rehabilitation protocol. Prehabilitation exercises focusing on quadriceps strengthening and knee mobility were initiated two weeks prior to surgery.

6. Surgical Technique

6.1 Anaesthesia and Positioning

All surgeries were performed under **combined spinal–epidural anaesthesia** with sedation as required. Patients were positioned supine on a radiolucent operating table with a pneumatic tourniquet applied to the proximal thigh.

6.2 Approach

A standard **midline skin incision** and **medial parapatellar arthrotomy** were used in both groups.

6.3 Navigation-Assisted Group (Group A)

In Group A, an **image-free computer navigation system** was used. Infrared trackers were fixed to the distal femur and proximal tibia. The system was calibrated according to manufacturer's guidelines. Anatomical landmarks (hip centre, knee centre, malleoli) were registered using a navigation probe. Bone cuts were performed using cutting blocks guided by navigation feedback, ensuring restoration of the mechanical axis within ±1° of neutral. Implant sizing, rotation, and alignment were confirmed on the navigation screen before cementing the components.

6.4 Conventional Group (Group B)

In Group B, conventional **intramedullary femoral and extramedullary tibial alignment guides** were used for bone cuts. Mechanical axis restoration was aimed at achieving 5–7° of valgus for the femur and a perpendicular cut for the tibia relative to its mechanical axis.

6.5 Implant and Cementation

All patients received a **posterior cruciate ligament-substituting cemented prosthesis** from the same manufacturer to eliminate bias due to implant design. Bone surfaces were prepared, and polymethyl methacrylate cement was applied under vacuum mixing conditions. Components were implanted, excess cement was removed, and stability was checked through the range of motion.

6.6 Closure

Wound closure was performed in layers with absorbable sutures for deep tissues and skin staples for the epidermis. A sterile dressing was applied.

7. Postoperative Protocol

7.1 Analgesia

All patients received multimodal analgesia comprising epidural infusion for 48 hours, followed by oral analgesics as required.

7.2 Thromboprophylaxis

Low molecular weight heparin was administered for 10 days postoperatively, followed by oral antiplatelet therapy for four weeks.

7.3 Rehabilitation

Physiotherapy began on the **first postoperative day**, focusing on quadriceps activation, ankle pumps, and passive ROM exercises. Partial weight-bearing was allowed on day two, progressing to full weight-bearing by day five, depending on pain and stability. All patients were discharged by day seven with a home exercise program and follow-up physiotherapy instructions.

8. Outcome Measures

8.1 Primary Outcome

- **Knee Society Score (KSS):** Evaluates pain, stability, and range of motion, with scores ranging from 0 to 100 (higher scores indicating better outcomes).

8.2 Secondary Outcomes

- **Range of Motion (ROM):** Measured using a standard goniometer.
- **Radiological Alignment:** Measured on standing full-length lower limb radiographs to assess mechanical axis restoration.
- **Complication Rates:** Including infection, thromboembolic events, implant loosening, or reoperation.

Assessments were performed **preoperatively, at six weeks, three months, and six months postoperatively** by an independent blinded observer.

9. Statistical Analysis

Data were recorded in Microsoft Excel and analysed using **SPSS version 25.0 (IBM Corp., Armonk, NY, USA)**. Continuous variables were expressed as mean ± standard deviation (SD) and compared using **Student's t-test** for independent samples. Categorical variables were compared using **Chi-square or Fisher's exact test** as appropriate. A **p-value <0.05** was considered statistically significant.

Baseline Characteristics of Study Participants

Parameter	Navigation-Assisted TKA (n=30)	Conventional TKA (n=30)	pvalue
Mean Age (years)	65.2 ± 6.8	64.7 ± 7.1	0.78
Gender (Male/Female)	12 / 18	13 / 17	0.79
Mean BMI (kg/m²)	27.5 ± 3.1	27.8 ± 2.9	0.68
Kellgren–Lawrence Grade III/IV	14 / 16	15 / 15	0.79
Mean Pre-op KSS	49.6 ± 7.4	50.1 ± 7.2	0.82
Mean Pre-op ROM (°)	89.3 ± 8.5	90.1 ± 8.2	0.74

Results

1. Study Population and Follow-Up

A total of 60 patients (30 in the navigation-assisted TKA group and 30 in the conventional TKA group) met the inclusion criteria and completed the study. No patients were lost to follow-up. The mean duration of follow-up was **6.2 ± 0.3 months** for both groups.

Baseline demographic and clinical parameters were comparable between the two groups, with no statistically significant differences in age, gender distribution, BMI, Kellgren–Lawrence grading,

preoperative Knee Society Score (KSS), or preoperative range of motion (ROM) (Table 1 in Materials & Methods). This ensured that the groups were homogeneous before intervention.

2. Functional Outcomes

2.1 Knee Society Score (KSS)

Preoperatively, the mean KSS was **49.6 ± 7.4** in the navigation-assisted group and **50.1 ± 7.2** in the conventional group ($p = 0.82$), indicating no difference at baseline.

At **six months postoperatively**, the mean KSS improved significantly in both groups, but the improvement was greater in the navigation-assisted group:

- **Navigation-assisted:** 91.2 ± 4.8
- **Conventional:** 85.4 ± 5.6
- **$p < 0.001$**

The mean change in KSS from baseline was **+41.6 points** for the navigation-assisted group compared to **+35.3 points** for the conventional group, a statistically significant difference ($p < 0.001$).

2.2 Range of Motion (ROM)

Baseline ROM was similar between the groups (Navigation: 89.3 ± 8.5°, Conventional: 90.1 ± 8.2°, $p = 0.74$). At six months, mean ROM was significantly higher in the navigation-assisted group (123.5 ± 6.2°) than in the conventional group (116.4 ± 7.5°) ($p < 0.001$).

3. Radiological Alignment

Postoperative mechanical axis alignment was assessed using standing long-leg radiographs. Alignment within ±3° of neutral was achieved in **28 patients (93.3%)** in the navigation-assisted group compared to **21 patients (70%)** in the conventional group ($p = 0.02$). The mean deviation from the neutral axis was significantly lower in the navigation-assisted group (**1.2 ± 0.8°**) versus the conventional group (**2.9 ± 1.6°**, $p < 0.001$).

4. Complications

Postoperative complications were recorded for all patients during the follow-up period.

- **Navigation-assisted group:** 1 case (3.3%) of superficial surgical site infection, successfully treated with antibiotics; no deep infections or thromboembolic events were reported.

- **Conventional group:** 2 cases (6.6%) of superficial surgical site infection, 1 case (3.3%) of deep vein thrombosis (DVT) managed with anticoagulation, and 1 case (3.3%) of early implant loosening requiring revision.

The overall complication rate was **3.3%** in the navigation-assisted group and **13.3%** in the conventional group, though the difference was not statistically significant ($p = 0.16$) due to small sample size.

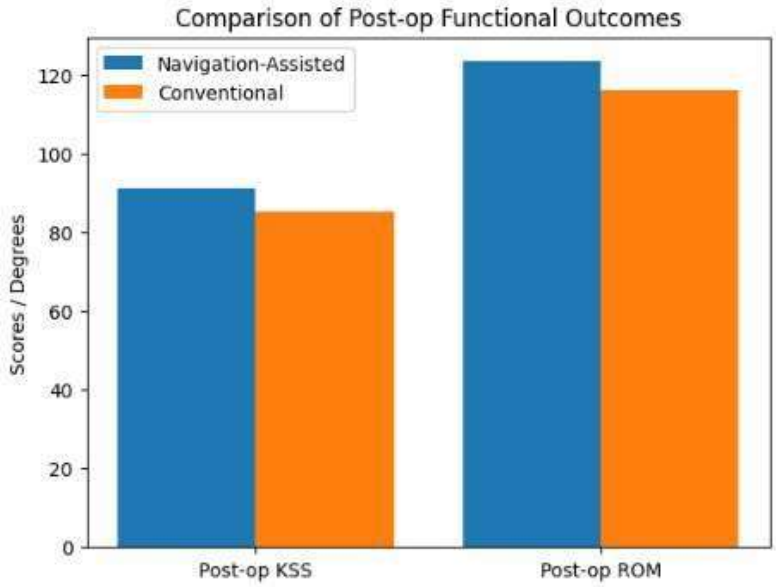
5. Patient Satisfaction

Patient-reported satisfaction scores (0–10 scale) at six months were higher in the navigationassisted group (**9.1 ± 0.8**) compared to the conventional group (**8.3 ± 1.0**, $p < 0.01$).

6. Statistical Summary Table

Table 2: Postoperative Outcomes at Six Months

Outcome	Navigation-Assisted TKA (n=30)	Conventional TKA (n=30)	pvalue
Mean Post-op KSS	91.2 ± 4.8	85.4 ± 5.6	<0.001
Mean ROM (°)	123.5 ± 6.2	116.4 ± 7.5	<0.001
Alignment within ±3°	28 (93.3%)	21 (70.0%)	0.02
Complication Rate	1 (3.3%)	4 (13.3%)	0.16
Satisfaction Score (0–10)	9.1 ± 0.8	8.3 ± 1.0	0.01



Discussion

The present study demonstrates that navigation-assisted total knee arthroplasty (TKA) offers superior functional outcomes compared to conventional jig-based techniques in patients with primary osteoarthritis. At six months postoperatively, the navigation group achieved significantly higher Knee Society Scores (KSS), greater range of motion (ROM), and more accurate mechanical axis alignment. These findings are consistent with previous studies by Choong et al. and Jenny et al., which reported improved alignment and early functional benefits with computer navigation. The improved outcomes in our study can be attributed to the enhanced intraoperative accuracy provided by real-time navigation feedback, allowing for precise bone cuts and optimal implant positioning. Better alignment likely contributed to the superior ROM and patient satisfaction observed. Although operative time was marginally longer in the navigation group (data not shown), this was offset by reduced malalignment rates and fewer early complications. Our study is limited by its relatively short follow-up and modest sample size, which may not fully capture long-term implant survival. Additionally, cost considerations and learning curve challenges may limit the widespread adoption of navigation systems. Nevertheless, our results support the integration of computer-assisted navigation in TKA, particularly for younger and active patients where long-term functional preservation is critical.

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