Research Article

Assessment of Rehabilitation Protocol After Primary Unilateral Total Knee Arthroplasty With Kinematic Alignment

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Abstract

Background: Total knee arthroplasty (TKA) is an established surgical treatment for advanced knee osteoarthritis. However, postoperative pain, muscle weakness, restricted range of motion, gait impairment, and reduced functional independence may delay recovery. Kinematic alignment (KA) aims to restore patient-specific knee anatomy, while structured rehabilitation seeks to translate surgical correction into meaningful functional improvement.

Aim: To assess outcomes following a structured rehabilitation protocol after primary unilateral TKA performed using kinematic alignment.

Methods: An observational longitudinal study was conducted at the Department of Physiotherapy, Vivekananda Polyclinic and Institute of Medical Sciences, Lucknow. The cohort of 240 patients who underwent primary unilateral TKA using KA. Rehabilitation comprised three phases: acute inpatient rehabilitation during postoperative days 0–2, transitional home-based rehabilitation during days 3–14, and progressive strengthening during weeks 3–6. Outcomes included Visual Analogue Scale (VAS) pain scores, Oxford Knee Score (OKS), knee range of motion (ROM), muscle strength, quality-of-life scores. Pre- and post-rehabilitation outcomes were compared using the Wilcoxon signed-rank test.

Results: Mean VAS pain score decreased from 7.55 ± 1.08 to 2.94 ± 1.53. Mean OKS increased from 22.49 ± 4.49 to 38.63 ± 5.31, while mean ROM improved from 89.15 ± 10.30° to 116.30 ± 11.22°. Mean muscle strength grade increased from 1.71 ± 0.79 to 4.03 ± 0.81, and the mean quality-of-life score increased from 47.32 ± 7.56 to 77.04 ± 9.59. All five outcome measures demonstrated statistically significant pre–post differences ($p < 0.0001$).

Conclusion: Significant improvements in pain, knee function, ROM, muscle strength, and quality-of-life scores were observed following the structured rehabilitation programme. These findings support the clinical relevance of organised, progressive rehabilitation after KA TKA.

Keywords: Total knee arthroplasty; kinematic alignment; rehabilitation; physiotherapy; knee function; muscle strength; range of motion; quality of life.

Introduction

Osteoarthritis is a major cause of pain, mobility restriction, physical disability, and reduced quality of life among adults. Progressive degeneration of the knee joint may lead to cartilage loss, osteophyte formation, deformity, stiffness, and difficulty performing activities of daily living. When conservative treatment no longer provides adequate symptom relief, total knee arthroplasty (TKA) is an established surgical option for appropriately selected patients [1–3].

The success of TKA depends on several interacting factors, including patient selection, surgical technique, implant positioning, perioperative pain management, and postoperative rehabilitation. Although surgery addresses structural joint disease, postoperative weakness, swelling, pain, reduced knee flexion, impaired balance, and altered gait may persist. Rehabilitation is therefore essential for helping patients regain mobility, strength, confidence, and independence.

Mechanical alignment has traditionally aimed to position the lower limb around a neutral mechanical axis. Kinematic alignment, in contrast, attempts to restore the patient's individual pre-arthritic joint-line orientation and native knee anatomy while maintaining appropriate implant positioning and stability. This patient-specific approach has attracted attention because knee anatomy and joint-line orientation vary between individuals [4,5]. Evidence comparing KA with mechanical alignment remains mixed. Some studies have reported advantages in selected gait or patient-reported outcomes, but systematic reviews have not consistently established superiority across all clinical outcomes. Xu et al. and other reviewers have reported that differences between alignment strategies vary according to the outcomes and studies examined [4,5]. Consequently, improvements following KA TKA should not automatically be attributed to the alignment technique alone.

Postoperative rehabilitation aims to reduce pain and swelling, restore knee extension and flexion, activate the quadriceps, improve lower-limb strength, retrain gait, enhance balance, and promote independence in daily activities. Dávila Castrodad et al. reviewed rehabilitation studies following TKA and found considerable variation in intervention content, duration, intensity, and outcome measurement. Their review suggested that early rehabilitation, outpatient therapy, telerehabilitation, and appropriately progressed exercise may support recovery, while also emphasising the need for more standardised protocols [6].

Early quadriceps activation is particularly important because postoperative pain and swelling can inhibit muscle recruitment and impair walking and transfers. Stevens-Lapsley et al. demonstrated that early neuromuscular electrical stimulation can improve quadriceps strength and functional performance after TKA, supporting the importance of addressing early muscle weakness [7].

A phased rehabilitation programme provides a practical framework for progressive recovery. The acute phase emphasises safe mobilisation, pain management, swelling control, and protection of the operated limb. The transitional phase focuses on improving mobility and independence at home. The later strengthening phase introduces progressive resistance, balance, proprioceptive, and task-specific exercises as the patient's condition permits.

Despite established rehabilitation principles, delivery varies across institutions. Outcomes may be influenced by baseline function, age, comorbidities, pain, exercise adherence, and access to physiotherapy. It is also important to evaluate outcomes beyond pain, including knee function, ROM, muscle strength, quality of life.

The present study assessed outcomes following a structured three-phase rehabilitation protocol in patients who underwent primary unilateral TKA using KA. The principal outcomes were pain, knee function, ROM, muscle strength, quality of life. Aim of the study to assess outcomes of an advanced rehabilitation protocol after primary unilateral total knee arthroplasty performed using kinematic alignment.

Materials and methods

Study design and setting

The study was designed as an observational longitudinal investigation of patients undergoing primary unilateral TKA using the KA technique. The study was conducted on 240 patients at the Department of Physiotherapy, Vivekananda Polyclinic and Institute of Medical Sciences, Lucknow. Patients were assessed before and after participation in a structured postoperative rehabilitation programme.

Inclusion criteria

- Patients of any age and either sex.
- Patients undergoing primary unilateral TKA for degenerative joint disease.
- Patients receiving posterior-stabilised implants, with or without a mid-vastus or medial parapatellar approach.
- Patients willing to participate and provide informed consent.

Exclusion criteria

The exclusion criteria were:

- Patients scheduled for revision TKA.
- Patients undergoing TKA for post-traumatic conditions.
- Patients with non-degenerative joint diseases, including inflammatory arthropathies.
- Patients or guardians unwilling to participate.

Surgical procedure

All included patients underwent primary unilateral TKA using the kinematic alignment technique according to the institution's standard orthopaedic protocols.

Rehabilitation protocol

The intervention consisted of three phases progressing from early postoperative mobilisation to home-based recovery and advanced strengthening.

Phase I: Acute inpatient phase (postoperative days 0–2)

This phase aimed to initiate safe mobilisation, manage pain and swelling, protect the operated limb, and begin restoration of knee movement. Exercises and activities included deep-breathing exercises, ankle pumps, static and dynamic quadriceps exercises, active knee ROM up to 90°, walker-assisted full weight-bearing ambulation, sitting, toileting, and stair practice as appropriate.

Phase II: Transitional home-based phase (days 3–14)

This phase aimed to improve lower-limb strength, ROM, gait, and functional independence. It included a structured home exercise programme, supervised physiotherapy visits, pain and swelling management,

progressive strengthening, active knee ROM targeted up to 120°, and gait training with progression from a walker to a cane or stick when clinically appropriate. Activities of daily living were incorporated into functional retraining.

Phase III: Progressive strengthening phase (weeks 3–6)

This phase focused on progressive strengthening, balance, proprioception, and return to usual activities. Interventions included resistance exercises for the quadriceps, hamstrings, and hip muscles; closed-chain exercises such as wall slides, step-ups, and leg press; balance training; single-leg stance; stationary cycling; sit-to-stand practice; and functional mobility training.

The protocol's exercise selection was intended to support gradual recovery. Progression in clinical practice should be guided by pain, swelling, wound status, strength, gait safety, and the treating team's advice.

Outcome measures

Pain: The Visual Analogue Scale was used to assess pain intensity. Lower scores indicated less pain.

Knee function: The Oxford Knee Score assessed knee-related symptoms and function. Higher scores indicated better status according to the scoring approach.

Range of motion: Knee ROM was measured in degrees to assess mobility.

Muscle strength: Muscle strength was graded using manual muscle testing on a 0–5 scale, with higher grades indicating greater strength.

Quality of life: Quality of life was measured by EQ-5D questionnaire, a score on a 0–100 scale was reported, with higher scores indicating better quality of life.

Statistical analysis

Continuous variables were summarised using means and standard deviations, while categorical variables were presented as frequencies and percentages. The Wilcoxon signed-rank test was used to compare pre- and post-rehabilitation outcomes. A p-value below 0.05 was considered statistically significant.

Results

The results section reported a cohort of 240 patients. The mean age was 63.69 ± 7.30 years, and the median age was 65 years (IQR 60–69). Women constituted 76.25% of the cohort. Right (53.75%) and left knees (46.25%) were represented in nearly equal proportions.

Table 1. Demographic characteristics of the study population

Characteristics		n = 240	In %
Age	40 - 50	16	6.67%
	51 - 60	47	19.58%
	61 - 70	135	56.25%
	71 - 75	42	17.50%
	Mean ± SD	63.69 ± 7.30	
Gender	Male	57	23.75%
	Female	183	76.25%
Operated Side	Right Knee	129	53.75%
	Left Knee	111	46.25%

Pain intensity: Mean VAS pain score decreased from 7.55 ± 1.08 before rehabilitation to 2.94 ± 1.53 after rehabilitation, representing a reduction of 4.61 points. The Wilcoxon signed-rank test demonstrated a statistically significant difference ($Z = -13.54$, $p < 0.0001$), indicating a substantial reduction in reported pain during the observation period.

Knee function: Mean OKS increased from 22.49 ± 4.49 to 38.63 ± 5.31, a gain of 16.14 points. The reported pre–post difference was statistically significant ($Z = -13.45$, $p < 0.0001$).

Knee range of motion: Mean ROM increased from 89.15 ± 10.30° before rehabilitation to 116.30 ± 11.22° after rehabilitation, representing a gain of 27.15°. The pre–post difference was statistically significant ($Z = -13.44$, $p < 0.0001$).

Muscle strength: Mean muscle strength grade increased from 1.71 ± 0.79 to 4.03 ± 0.81, an increase of 2.32 grades. The difference was statistically significant ($Z = -13.68$, $p < 0.0001$).

Quality of life: Mean quality-of-life score increased from 47.32 ± 7.56 before rehabilitation to 77.04 ± 9.59 after rehabilitation, a gain of 29.72 points. The difference was statistically significant (Z = −13.43, p < 0.0001).

Table 2. Comparing outcomes between pre and post rehabilitation by using Wilcoxon signed-rank test

Variables	Before rehabilitation (mean ± SD)	After rehabilitation (mean ± SD)	Mean change	Wilcoxon Z	p-value
VAS pain score	7.55 ± 1.08	2.94 ± 1.53	−4.61	−13.54	<0.0001
Oxford Knee Score	22.49 ± 4.49	38.63 ± 5.31	16.14	−13.45	<0.0001
Knee ROM	89.15 ± 10.30°	116.30 ± 11.22°	27.15°	−13.44	<0.0001
Muscle strength grade	1.71 ± 0.79	4.03 ± 0.81	2.32	−13.68	<0.0001
Quality-of-life score	47.32 ± 7.56	77.04 ± 9.59	29.72	−13.43	<0.0001

Discussion

This study assessed outcomes following a structured three-phase rehabilitation programme in patients undergoing primary unilateral TKA with kinematic alignment. Significant pre–post improvements were reported in pain, knee function, ROM, muscle strength, and quality-of-life scores.

Reduction in pain

The mean VAS score decreased from 7.55 to 2.94, suggesting a substantial reduction in pain during the study period. Pain reduction is a central objective of TKA, while effective rehabilitation can support recovery by encouraging safe mobilisation, reducing fear of movement, and restoring confidence in the operated limb.

The acute phase of the programme included ankle pumps, quadriceps exercises, active knee movement, and walker-assisted ambulation. These activities are consistent with the general goals of early postoperative rehabilitation. Dávila Castrodad et al. reported that early rehabilitation and appropriately selected exercise interventions may support recovery, although the optimal programme remains uncertain because of variation between studies [6].

Improvement in knee function

Mean OKS increased by 16.14 points, from 22.49 to 38.63. The reported distribution also shifted away from severe symptoms, with no patients remaining in the severe category after rehabilitation.

These findings suggest that improvements extended beyond pain relief to patient-reported knee function. The OKS is useful for evaluating symptoms and functional limitations relevant to everyday activities after knee replacement.

KA aims to restore aspects of individual knee anatomy and joint-line orientation. Blakeney et al. reported that kinematically aligned TKA reproduced aspects of normal gait more closely than mechanical alignment in their study [8]. Nevertheless, systematic reviews have found variable differences between alignment approaches [4,5].

Improvement in range of motion

Mean knee ROM increased by 27.15°, from 89.15° to 116.30°. The proportion of patients achieving more than 100° increased from 16.3% to 90.4%.

ROM is important for walking, stair negotiation, transfers, sitting, and other activities of daily living. The study protocol introduced active knee movement during the acute phase and continued progressive mobility exercises during the home-based phase.

However, ROM is affected by several factors, including preoperative stiffness, swelling, pain, surgical technique, implant factors, and individual biological responses.

Improvement in muscle strength

Mean muscle strength grade increased from 1.71 to 4.03. Before rehabilitation, no patients were graded at Grade 4 or Grade 5, whereas 75.0% reached these grades after rehabilitation.

Quadriceps weakness is a common functional problem after TKA. Pain, swelling, and reduced voluntary activation may impair walking, transfers, and stair climbing. The study's progression from quadriceps activation to resistance training, closed-chain exercises, cycling, and balance activities is consistent with the broad objective of restoring strength and functional control[9,10]

Stevens-Lapsley et al. reported that early neuromuscular electrical stimulation improved quadriceps strength and functional performance after TKA [7]. Their findings support the importance of addressing postoperative muscle weakness.

Improvement in quality of life

The mean quality-of-life score increased from 47.32 to 77.04. Following rehabilitation, 97.1% of patients were reported to score above 60.

Improved pain, mobility, strength, and independence may contribute to better perceived quality of life following TKA. The findings are consistent with the clinical expectation that improved physical function may facilitate participation in everyday activities[11].

Conclusion

This study evaluated outcomes following a structured three-phase rehabilitation programme in patients undergoing primary unilateral TKA using kinematic alignment. Significant pre–post improvements were reported in pain, knee function, ROM, muscle strength, and quality-of-life scores. Mean VAS decreased from 7.55 to 2.94, mean OKS increased from 22.49 to 38.63, mean ROM improved by 27.15°, mean muscle strength increased by 2.32 grades, and mean quality-of-life score increased by 29.72 points.

These findings support the clinical relevance of organised postoperative rehabilitation incorporating early mobilisation, progressive strengthening, gait training, balance, and functional activities.

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