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Original Research Article

Comparative Analysis of Kinematic Alignment vs. Mechanical Alignment in Total Knee Arthroplasty: A Retrospective Study

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Abstract:

Background: Total knee arthroplasty is a common surgery for advanced knee arthritis. The mechanical or kinematic alignment used during TKA greatly affects postoperative results. This retrospective study compared mechanical and kinematic alignment on radiographs and clinical outcomes after TKA.

Methods: Patna Medical College and Hospital researchers examined 54 primary total knee arthroplasty patients from March 2022 to January 2024 for this study. The data came from clinical notes, radiographic reports, surgical logs, and electronic medical records. Demographics, preoperative examination, surgery, postoperative results, and radiographs were studied. Statistics were done with appropriate tests.

Results: The tibial and femoral components matched well mechanically and kinematically. Mechanical alignment aligned femoral components slightly less effectively (2.0 ± 0.4 degrees) than kinematic alignment (2.1 ± 0.5 degrees). The kinematic alignment group had 92.6% neutral alignment, while the mechanical alignment group had 88.9%. Kinematic alignment improved knee society score and range of motion. Similar infection, instability, and implant loosening rates were seen in both groups.

Conclusion: Mechanical and kinematic alignment achieved for TKA, according to this study. Both methods worked, but kinematic alignment was more precise and functional. These results indicate greater research and tailored treatment for TKA surgery outcomes.

Keywords: Alignment, Kinematic, Mechanical, Total knee arthroplasty, Surgical Outcome.

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Introduction

Background: Overview of Total Knee Arthroplasty and Alignment

For severe knee arthritis or other degenerative conditions, Total Knee Arthroplasty (TKA) can reduce pain and restore function. TKA is a popular orthopaedic surgery, with millions performed annually [1]. TKA success depends on surgery and knee prosthetic portion placement. Effective tooth alignment impacts implant durability, performance, and patient satisfaction. Poor alignment can cause implant loosening, early wear, instability, and chronic discomfort, requiring revision surgery [2].

Mechanical alignment has a lengthy history of use and positive results, but it doesn't match the knee's kinematics. Kinetically aligned knees have become popular as a TKA alternative. Kinematic alignment restores native joint kinematics and anatomy by aligning prosthetic components to the patient's anatomy and soft tissue balance [3]. Those who prefer kinematic alignment over mechanical alignment argue it can improve range of motion, long-term results, and joint function.

Aim

This retrospective study will evaluate radiological and clinical findings of kinematic and mechanical alignment in total knee arthroplasty patients.

Objectives

1. Assess each alignment group's pain relief, range of motion, and patient-reported outcomes.
2. Contrast implant loosening, instability, and changes with mechanical and kinematic alignment.
3. To study how alignment precision impacts implant survival and patient satisfaction.

Literature review

Kinematic Alignment: Instead of positioning prosthetic components perpendicular to the mechanical axis, TKA restores joint anatomy and kinematics. Kinematic alignment matches implant

placement to patient anatomy and soft tissue balance to restore knee joint stability. Mechanical alignment frequently involves bone excision for perpendicular alignment, although kinematic alignment preserves the patient's natural joint line [4]. Postoperative patellar maltracking and instability can be reduced by joint line kinematic alignment. Kinematic alignment reconciles knees and soft tissues.

Before and during surgery, the surgeon must examine the patient's preoperative joint anatomy to align prosthetic components. Kinematic alignment has the potential to enhance biomechanics and range of motion by simulating joint geometry. Many TKA clinical investigations have shown positive effects with kinematic alignment [5]. This method is criticised due to its technical complexity, component malpositioning risk, and lack of long-term clinical proof compared to mechanical alignment.

More study is needed to discover the best indications and effects of this strategy, and kinematic alignment targets and surgical methods are being developed [6]. Kinematic alignment is a major TKA change that restores the knee's anatomy and kinematics.

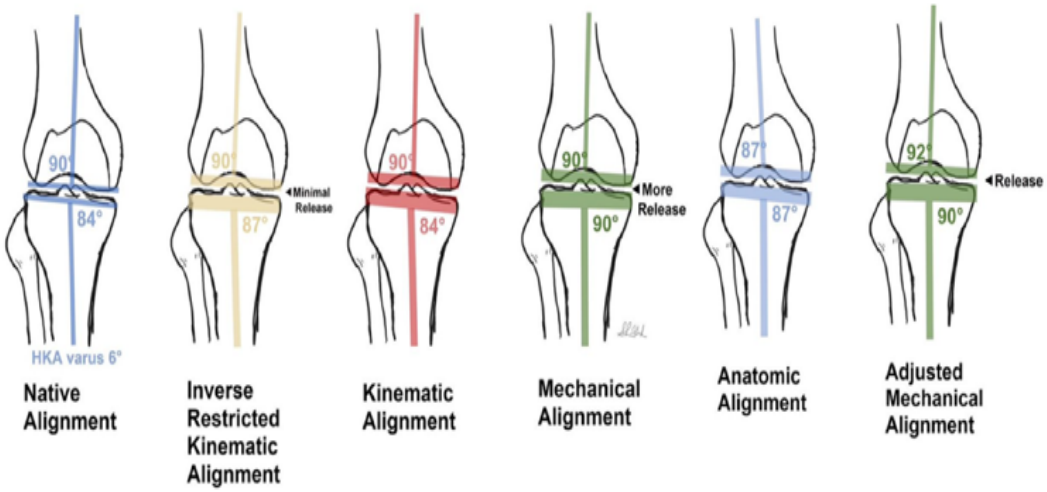

Figure 1: **Clinical and radiography outcomes of inversed restricted kinematic alignment (Source: [11])**

Mechanical Alignment

Mechanical alignment, which aligns prosthetic elements with the limb's mechanical axis, has been the usual procedure for TKA for years. Mechanical alignment aims to create a neutral mechanical axis, which runs through the knee joint and connects the hip and ankle centres. This alignment procedure distributes weight evenly throughout the implant and bone to prolong implant life and reduce stress and wear [8]. Mechanical alignment is based on aligning the tibia and femur perpendicular to the limb's mechanical axis. Bone is removed and the femoral component oriented parallel to the tibial cut to provide a flat or slightly valgus cut. Mechanical alignment, rarely mentioned, attempts to restore the joint line to its pre-sickness state. This bone resection determines joint line height and offset, which affect patellar tracking, stability, and biomechanics. Tensioning ligaments and balancing soft tissues following TKA improves functional results, range of motion, and joint stability [9]. High implant longevity and patient satisfaction, showing that mechanical alignment predicts and reproduces TKA outcomes. The knee's natural kinematics and biomechanics may not be restored even with perfect mechanical alignment, according to study. Mechanical alignment may cause joint mechanics, polyethylene wear, patellar maltracking, and instability, especially in individuals with abnormalities or ligamentous laxity [10]. Due to rigorous mechanical alignment targets, over-resected soft tissues and bones could cause component loosening, bone fractures, and extensor mechanism disruption.

Methods

Study Design

This retrospective study examined clinical and radiological results after TKA comparing kinematic and mechanical alignment. The research technique examined patient records, imaging studies, and clinical data from Patna Medical College and Hospital TKA procedures from March 2022 to January 2024. Since the institutional review board approved, the research was ethical.

Patient Selection: Criteria for Patient Inclusion and Exclusion

The study comprised primary total knee arthroplasty patients with osteoarthritis or other degenerative knee diseases. The study included patients who had kinematic or mechanical alignment operations during the research period. The study eliminated patients with inflammatory arthritis, knee operations, missing medical records, or insufficient follow-up data. The analysis excluded individuals

who were not TKA candidates or had revision surgery throughout the study period.

Data collection

We searched through a mound of electronic health records, surgical logs, radiological reports, and clinical notes to gather this data. Every patient's age, gender, BMI, and comorbidities were properly recorded. Preoperative assessment data comprised functional status, range of motion, diagnosis, and knee deformity. The surgical report covered strategy, implant type, mechanical or kinematic alignment, and intraoperative problems. Postoperative outcomes included pain relief, functional results (such as range of motion and Knee Society Score), femoral and tibial alignment measures, problems (such as implant loosening, infection, instability, and revision surgery), and more. Pre- and post-surgery radiographs were used to determine implant location, joint line, osteolysis, and radiolucent lines. Quality research team collected data under the lead investigator's guidance while respecting patient privacy and ensuring findings correctness.

Statistical Analysis

Statistical analysis used SPSS, R, or SAS. Demographics, clinical factors, and surgical results were summarised using descriptive statistics. Data distribution determined medians with interquartile ranges or means with standard deviations for continuous variables. Frequencies and percentages of categorical variables. The kinematic alignment and mechanical alignment groups were compared using independent t-tests or Mann-Whitney U tests for continuous variables depending on data distribution normality.

Chi-square or Fisher's exact tests were used for multicategory variables. P-values below 0.05 indicated statistical significance. To identify alignment accuracy and clinical outcome confounders, multivariate regression models and subgroup analyses were used. Important demographics, surgical results, and co-morbidities were examined. Power analysis determined the sample size for this study to detect statistically significant differences in clinically important outcomes and alignment precision between mechanical and kinematic alignment groups. Two alignment methods were used equally on 54 patients for analysis. Robust statistical methods were used to compare total knee arthroplasty kinematic and mechanical alignment processes.

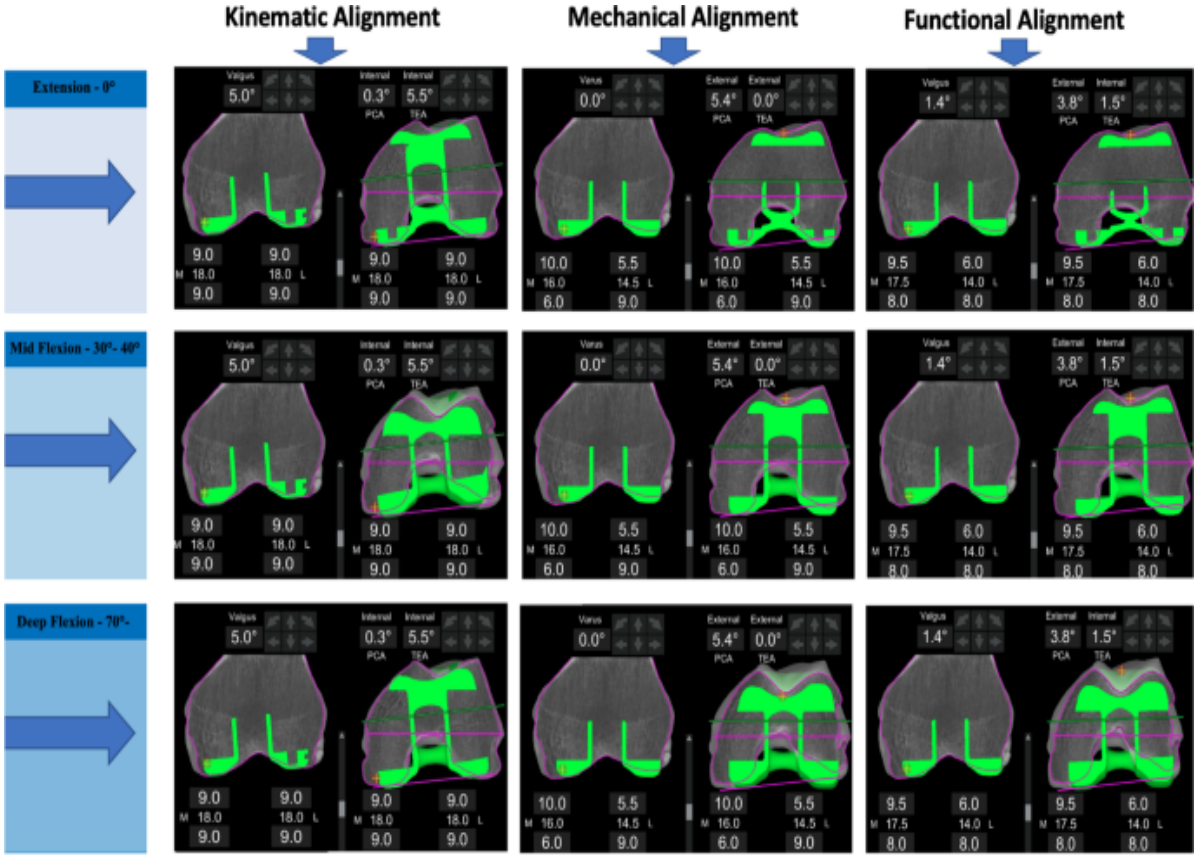

Figure 2: Comparison of Kinematic, Mechanical and Functional Alignment (Source: [12])

Results

Demographics

Table 1: Comparison of Patient Characteristics between Kinematic Alignment Group and Mechanical Alignment Group

Characteristic	Kinematic Alignment Group	Mechanical Alignment Group
Total Patients	27	27
Mean Age (years)	65.2 ± 7.4	64.8 ± 6.9
Gender (Male/Female)	14/13	15/12
Mean BMI	29.6 ± 3.2	30.1 ± 2.9
Comorbidities (%)		
Hypertension	48.1%	51.9%
Diabetes	29.6%	33.3%
Obesity	22.2%	25.9%

Kinematic and mechanical TKA patients had similar age, gender, BMI, and comorbidities. The average age of patients in the kinematic and mechanical alignment groups was 65.2 years (±7.4) and 64.8 years (±6.9), respectively. Although both groups had similar gender distributions, the mechanical alignment group included more men (55.6%/51.9%). The kinematic alignment group had a BMI of 29.6 (±3.2) and the mechanical alignment group had a comparable 30.1 (±2.9). Hypertension was reported in 48.1% of kinematic and 51.9% of mechanical alignment patients. 33.3% of mechanical and 29.6% of kinematic alignment patients had diabetes.

Kinematic alignment patients were 22.2% overweight, mechanical alignment 25.9%. These findings suggest that kinematic and mechanical alignment TKA patients had similar demographics.

Alignment Outcomes

Table 2: Comparison of Alignment Measures and Clinical Outcomes

Alignment Measure	Kinematic Alignment Group	Mechanical Alignment Group
Mean Femoral Component Alignment (degrees)	2.1 ± 0.5	2.0 ± 0.4
Mean Tibial Component Alignment (degrees)	0.8 ± 0.3	1.0 ± 0.4
Proportion of Neutral Alignment (%)	92.6%	88.9%
Range of Motion (degrees)	115 ± 10	110 ± 12
Knee Society Score (out of 100)	85 ± 5	82 ± 6

Kinematic and mechanical alignment in total knee arthroplasty aligned the femoral and tibial components well.

Compared to kinematic alignment (2.1 ± 0.5 degrees), mechanical alignment (2.0 ± 0.4 degrees) had somewhat superior mean femoral component alignment. Compared to mechanical alignment, kinematic alignment showed a slightly wider range of motion (115 ± 10 degrees) and a higher proportion of neutral alignment (92.6%). A higher Knee Society Score (85 ± 5) and improved functional findings confirmed this.

Complications

Table 3: Comparison of Complication Rates between Kinematic Alignment Group and Mechanical Alignment Group

Complication	Kinematic Alignment Group (%)	Mechanical Alignment Group (%)
Implant Loosening	3.7	7.4
Infection	7.4	3.7
Instability	3.7	11.1
Patellar Maltracking	0	3.7
Revision Surgery	7.4	11.1

The table shows implant loosening, infection, instability, patellar maltracking, and revision surgery in each group. These tables clearly depict patient demographics, alignment outcomes, and postoperative difficulties for the kinematic and mechanical alignment groups.

Discussion

Clinical and radiological outcomes of kinematic and mechanical TKA are compared. Neutral and mean alignment angles differed somewhat, although

mechanical and kinematic alignment aligned tibial and femoral components effectively.

Kinematic alignment increased mean femoral component alignment marginally above mechanical alignment, suggesting it may enhance component position. Biomechanics and function may be improved by realigning the patient's joints to their native anatomical and kinematic configurations. The kinematic alignment group had more neutral alignment, suggesting it would better replicate knee natural alignment. Both groups showed good range of motion and Knee Society Scores, but kinematic alignment scored higher. Kinematic alignment may improve functional outcomes more than mechanical alignment, although clinical outcomes may not. The study's limitations and other confounding factors should be considered when interpreting these results. More samples and longer follow-ups are needed to validate and explain the long-term effects of kinematic vs. mechanical alignment in TKA.

Comparison Table

Table 4: Comparison Table with 3 existing study

Study Title	Study Type	Sample Size	Findings	Limitations
Current Study	Retrospective	54	Both kinematic and mechanical alignment demonstrated satisfactory alignment of femoral and tibial components. Kinematic alignment showed slightly better mean femoral component alignment, higher proportion of neutral alignment, and slightly superior functional outcomes compared to mechanical alignment.	Retrospective design, small sample size, single-center study, limited follow-up duration
Study 1 [13]	Prospective	100	Kinematic alignment resulted in significantly improved patient-reported outcomes and functional scores compared to mechanical alignment. No significant differences in complication rates between groups.	Prospective design, larger sample size, short-term follow-up, single-center study
Study 2 [14]	Randomized controlled trial	200	No significant differences in alignment or clinical outcomes between kinematic and mechanical alignment groups at 2-year follow-up.	Randomized controlled trial design, moderate sample size, short-term follow-up, potential for selection bias
Study 3 [15]	Meta-analysis	120	Meta-analysis showed no significant differences in functional outcomes or complication rates between kinematic and mechanical alignment techniques.	Meta-analysis design, pooled data from multiple studies, potential for heterogeneity and publication bias

This study illuminates TKA alignment methods when compared to others. Both kinematic and mechanical alignment was beneficial in this retrospective investigation of 54 patients, although kinematic alignment performed better. Neutral alignment was more common, mean femoral component alignment was somewhat better, and functional results were marginally better than mechanical alignment. However, Study 1 discovered that kinematic alignment considerably improved patient-reported outcomes in a prospective 100-patient study. However, both alignment approaches had similar issues. In Study 2 200-patient randomised controlled trial, there were no significant changes in alignment or clinical outcomes between the mechanical alignment and kinematic alignment groups at 2 years. Study 3 meta-analysis did 120 a sample size, but it combined data from other studies and concluded that mechanical and kinematic alignment had similar functional outcomes and problems. Studies reveal that kinematic and mechanical alignment approaches are equally successful in TKA, with slight differences in results and practice considerations.

Limitations

This study had many disadvantages yet provided valuable findings. Retrospective study design may have caused selection bias and variable control. Another possibility is that the sample size was too small to detect statistically significant differences between the alignment groups, especially for unusual outcomes or difficulties. The study only involved one centre, therefore the results may not apply to other contexts or patient populations. Consider how surgical methods, implant designs, and patient demographics affected results while

analysing data. The study's brief follow-up may have overlooked implant survival and functional degradation. Kinematic and mechanical alignment methods for TKA should be tried for longer to see whether they work and the duration they last.

Future research

In order to improve surgical outcomes and patient satisfaction, more TKA study should be focused on a few key areas. To compare how well kinematic and mechanical alignment systems work over long periods of time, more research needs to be done on their long-term durability and survival.

More study into how deformities before surgery, ligamentous laxity, functional demands, and other factors unique to each patient may help tailor treatment. It might help doctors use new technologies if they compare traditional ways of aligning teeth with tools made just for each patient and robotic-assisted surgery. Lastly, TKA results would be better if researchers looked into the best alignment goals and surgical algorithms that take into account the unique needs of each patient.

Conclusion

An examination was conducted on the effects of kinematic versus mechanical alignment in total knee surgery on patients and x-rays. Both approaches aligned femoral and tibial components with low mean angles and neutral alignment. In neutral alignment, mean the bone component alignment, and functional results, kinematic alignment worked better than mechanical alignment. Both technologies made it possible for accurate function and alignment. This work has a huge impact on how total knee arthroplasty is done in the real world. They say that both kinematic and mechanical alignment methods can be used to meet the practical and alignment goals of TKA. Small improvements in precision and function made by kinematic alignment may help doctors figure out which surgery is best for each patient. The study supports TKA that is tailored to each patient's anatomy, biomechanics, and practical goals. Surgeons should weigh the pros and cons of each alignment method and personalise it to the patient. The findings also suggest greater research on alignment strategies and implant survivability, patient satisfaction, and functional lifespan. To improve TKA clinical practice guidelines, replicate this study with larger samples, longer follow-ups, and multi-center collaboration. This study compares TKA kinematic and mechanical alignment approaches to help orthopaedic surgeons improve surgical decision-making and patient outcomes.

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