

Is there a difference in the outcome of primary total knee arthroplasty performed using kinematic versus mechanical alignment?

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Response/Recommendation: Kinematic alignment appears to result in improved patient-reported outcome measurements (PROMs) in the early period after total knee arthroplasty (TKA). However, several randomized controlled trials (RCTs) and systematic reviews fail to identify a significant clinical difference between the two methods in the medium and long term.

Level of Evidence: Moderate/high

Rationale

Total knee arthroplasty (TKA) is an effective surgical procedure that aims to alleviate pain and restore function to patients with end-stage arthritis of the knee. However, achieving optimal long-term outcomes remains challenging, as factors such as implant malalignment can lead to complications like pain, instability, and stiffness after TKA [1]. Traditionally, surgeons have utilized mechanical alignment (MA) techniques in TKA, striving for a neutral lower limb alignment to enhance implant stability and longevity [2]. However, the conventional mechanical alignment technique does not consider individual variations in pre-arthritic knee anatomy, while the persistence of pain and patient dissatisfaction is not uncommon [3].

Kinematic alignment (KA) is a newer than MA surgical philosophy that seeks to replicate the patient's pre-disease joint alignment during TKA [4]. This method aims to restore the natural biomechanics of the knee, potentially resulting in improved implant kinematics, patellar tracking, and overall patient satisfaction[5]. The debate between KA and MA in TKA continues, with ongoing research exploring the clinical outcomes and potential benefits of each technique. The purpose of this review is to summarize the results and present the pros and cons of RCTs comparing the results of KA and MA in total knee arthroplasty.

Methods

A comprehensive search was conducted in different scientific databases (Scopus, Pubmed and Cochrane Library) to identify relevant literature. The following MeSH Terms were utilized : ("Total Knee Arthroplasty"[MeSH] OR "Total Knee Arthroplasty" OR "Knee Replacement"[MeSH] OR "Knee Replacement" OR "Knee Prosthesis"[MeSH] OR "Knee Prosthesis" OR "Arthroplasty, Replacement, Knee"[MeSH] OR "Arthroplasty, Replacement, Knee") AND ("Kinematic Alignment"[MeSH] OR "Kinematic Alignment") AND ("Mechanical

Alignment"[MeSH] OR "Mechanical Alignment") AND ("Outcome Assessment (Health Care)"[MeSH] OR "Outcome Assessment (Health Care)" OR "Treatment Outcome"[MeSH] OR "Treatment Outcome" OR "Outcome"[MeSH] OR "Outcome"). Duplicates were removed, and all the summaries were read to identify the included articles. Only RCTs published before May 2024 were included. The evaluated parameters included PROMs, radiological evaluation, and survival rate and complications. The most common scores used in the trials were the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Oxford Knee Score (OKS), and Forgotten Joint Score (FJS).

Results

There were finally 11 RCTs analyzed comparing KA with MA total knee replacements. Of note, the three of them were part of the same research study in different follow-up periods (six months – two years and 13 years). In one of the initial studies comparing mechanical and kinematic alignment, Dossett et al. presented better clinical outcomes and flexion with KA at an early post-op period of six months [6]. WOMAC, OKS, Knee Society Score (KSS), and Knee Function were utilized. Operative time was significantly shorter in the KA group by 21 minutes. Despite both alignment methods achieving similar overall limb alignment (hip–knee–ankle angle), KA better replicated the natural joint line obliquity. In a subsequent RCT from the same group, reporting the results in a two-year postoperative period, kinematically aligned TKA seemed to offer significant advantages over mechanically aligned TKRs in terms of pain relief, function, and range of motion (ROM) [7]. Patients with KA walked further before discharge and had higher flexion with better clinical scores. However, there were no significant differences in blood loss, length of hospital stay, or rates of further surgeries between the two groups. In their last report from this study group at a mean follow-up of 13 years the results remained more or less the same with similar survival rates between the two groups and a trend for higher satisfaction in the KA group [8].

Calliess et al. demonstrated that kinematic alignment using patient-specific instrumentation (PSI) can achieve comparable and in some cases superior, outcomes to conventional mechanical alignment [9]. At the 12-month follow-up, the KA group showed a statistically significant improvement in both the Knee Society Score and WOMAC score compared to the MA group. However, the KA group also experienced complications, including two patients requiring revision surgery due to severe multidirectional instability. Radiologically, the KA group had an average post-operative alignment deviation of $1^\circ \pm 3^\circ$ valgus compared to the targeted mechanical axis in the MA group, which was $1^\circ \pm 1^\circ$ varus. KA group had a negative correlation between alignment deviation and KSS, while excessive femoral component flexion correlated with higher WOMAC scores. Overall, while KA showed promising functional outcomes, it also presented challenges related to alignment accuracy and complication rates when using PSI techniques.

On the contrary, another RCT found no significant differences between the two methods in mean OKS at two years [10]. KA did not show improved pain and function outcomes as expected. It was concluded that KA does not offer significant short-term functional advantages over MA in TKA, and the long-term impact on implant durability remains uncertain. The same

conclusion was also derived from Waterson et al. who indicated that KA may offer some early benefits, but longer-term follow-up is necessary to fully understand its impact on function and implant survivorship [11]. No significant differences between the two methods were also reported in a longer follow-up period of five years [12]. In this period, the survivorship rates from reoperation or revision were similar, with KA at 95.9% and MA at 94.1%.

In a clinical and radiological evaluation, Matsumoto et al. showed that the mean hip-knee-ankle (HKA) angles showed greater varus alignment in the kinematic group, while joint line orientation (JLO) angles in double-leg and single-leg positions were significantly different, with the kinematic group exhibiting less valgus. The mechanical axis passing positions also differed significantly, with the kinematic group having more centrally aligned axes. Clinically, the kinematic group had better flexion and higher objective and functional KSS scores [5]. In terms of tibial component migration, this do not significantly differ between the two methods and seems to be independent from alignment [2]. MA and KA appear to have similar tibial component migration patterns.

Mechanical and kinematic alignment have also been compared in the setting of computer-assisted bilateral TKAs [13]. No significant differences in flexion range and functional scores were observed. Notably, more participants preferred kinematic alignment TKA and fewer releases were needed in KA group. In one of the most recent RCT MacDessi et al. highlighted the superiority of KA in knee balancing [14]. Moreover, KA also reduced the need for additional bony resections and soft tissue balancing procedures, with significantly fewer resections required compared to the MA group. The incidence of lift-off, indicating pathological knee imbalance, was notably lower in the KA group.

Discussion

The debate surrounding the efficacy of KA versus MA in TKA has generated significant interest and varied results across several studies. The existing literature presents a mixed picture regarding the benefits of KA versus MA in TKA. Several studies suggest that KA may offer superior early and mid-term clinical outcomes and better restoration of natural knee kinematics, offering value to patients undergoing TKA. However, other studies report comparable outcomes between the two techniques at longer-term follow-up.

Some studies have highlighted the benefits of KA in TKA, suggesting it may offer superior early and mid-term clinical outcomes compared to MA [5–7,9,14]. These studies have shown superior clinical outcomes, including better WOMAC, OKS Knee Society, and Knee Function scores, alongside greater knee flexion, earlier functional recovery, and better knee balancing. KA may achieve a more natural joint line position compared to MA [5]. This could potentially improve patellar tracking and reduce the risk of patellofemoral complications.

Contrastingly, several published data indicate that KA and MA result in similar clinical and functional outcomes, particularly in the short to mid-term follow-up periods [2,11,13]. Clinical outcomes, survivorship rates, and radiographic evaluations appear to be comparable in KA and

MA. KA does not show clear benefits in terms of radiographic precision and reduction of radiographic outliers.

This review is not without limitations. Firstly, there is a heterogeneous level of technology used in the KA and MA groups. Some studies used patient-specific instrumentation, navigation, and robotic technology to achieve precision in hitting KA targets, while others used manual techniques. Second, the term KA encompasses a heterogeneous set of techniques in the literature, including for example unrestricted KA, restricted KA, and inverse KA. We recommend authors specify the KA technique in future publications for more granular comparisons.

Conclusion

KA has emerged as a promising alternative to traditional MA in TKA. Published data suggest that KA might lead to improved functional outcomes, especially in the early postoperative period, a more natural joint line position, and potentially better soft-tissue balance. However, long-term data is still scarce. Further research is essential to determine the definitive role of KA in TKA surgery and establish its long-term benefits compared to MA.

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