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Primary Knee

Head-to-Head Comparison of Kinematic Alignment Versus Mechanical Alignment for Total Knee Arthroplasty

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ABSTRACT

Background: Seeing as there are many alignment strategies for total knee arthroplasty (TKA), we need to determine differences between them in a rigorous scientific way. Therefore, we sought to compare perioperative and postoperative functional outcomes in patients undergoing TKA for varus osteoarthritis with a mechanical alignment target vs a kinematic alignment target, both executed with the same implant and same technological guidance.

Methods: One hundred consecutive patients who underwent TKA using a mechanical alignment technique were 1:1 matched to 100 patients who underwent TKA using a kinematic alignment (KA) technique, using the same implant and robotic technology. Patient-reported outcomes were measured postoperatively at 1 and 2 years. Power analysis revealed 94 patients to detect a significant difference.

Results: Mean Visual Analog Scale scores were higher in the mechanical alignment group during the first 6 weeks ($P = .04$), but statistically similar at 1 year. Six-week Veterans RAND 12 Item Health Survey mental and physical components were statistically similar ($P = .1$). Patients did not differ in 6-week or 1-year knee range of motion ($P > .43$). Knee Injury and Osteoarthritis Outcome Score Joint Replacement was significantly better in the KA group at 6 weeks, 1 year, and 2 years ($P = .09$). Forgotten Joint Score at 1 and 2 years postoperatively were significantly higher in the KA group ($P < .001$).

Conclusion: Patients undergoing TKA with KA experienced less pain in 6 weeks after surgery, and higher Forgotten Joint Scores at 1 and 2 years postoperatively. Alternative TKA alignment and balancing strategies should be considered to increase patient satisfaction.

Although total knee arthroplasty (TKA) remains a widely successful procedure for pain relief and functional recovery, recent studies suggest that nearly 20% of patients with a TKA were dissatisfied with their clinical outcome [1,2]. Some experts argue that one explanation is that contemporary TKA techniques fail to restore the natural knee kinematics [2]. Thus, there has been increasing debate regarding alternative and optimal alignment strategies in TKA [3].

Restoration of neutral knee alignment is a fundamental principle of a successful TKA. Standard surgical techniques for TKA use 2 different alignment methods for prosthesis implantation: mechanical alignment (MA) and kinematic alignment (KA). MA TKA aims to position femoral and tibial components perpendicular to the mechanical axis of each bone, aligning the hip-knee-ankle angle of the limb to neutral under static weight-bearing conditions [4]. This allows for a more balanced load distribution within the medial and lateral compartments, which minimizes wear and component loosening. Although the mean of the population as a whole is neutral, only 0.1% of patients have a neutral mechanical axis, and therefore MA TKA inevitably alters almost every patient's native anatomy. Thus, the KA technique, which attempts to maintain the natural kinematic axis and ligament balance of the individual knee, has increased in popularity.

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Table 1
Mechanical Alignment vs Kinematic Alignment: FJS.

FJS	MA	KA	*P*-Value
6 wk	57.2 ± 8.9	53.4 ± 6.4	NS
1 y	72.4 ± 5.8	88.2 ± 6.9	<.001
2 y	77.6 ± 7.1	92.0 ± 5.3	<.001

FJS, Forgotten Joint Score; MA, mechanical alignment; KA, kinematic alignment; NS, not significant.

Table 3
Mechanical Alignment vs Kinematic Alignment: KOOS JR.

KOOS JR	MA	KA	*P*-Value
6 wk	60 ± 4	71 ± 3	<.05
1 y	73 ± 5	88 ± 6	<.05
2 y	84 ± 4	91 ± 5	<.05

KOOS JR, Knee Injury and Osteoarthritis Outcome Score Joint Replacement; MA, mechanical alignment; KA, kinematic alignment.

Proponents of KA argue that anatomic component position will improve clinical results compared to MA technique by reducing the need for ligament releases and improve soft tissue balancing [5,6]. However, it is known that increasing the physiological tibial varus or slope might lead to an overload of the bone interface or early implant loosening [3]. Previous comparisons of alignment strategy cite several outliers as being attributed to the inaccuracy of current surgical techniques to achieve KA or MA [5]. Recent literature has shown that computer navigation and robotic-assisted surgery result in higher accuracy and precision in component positioning compared to manual instrumentation [7,8]. However, comparative data are lacking with regards to MA vs KA TKA using technology. Increased accuracy in obtaining either alignment strategy with robotic assistance allows for more rigorous critique of the current clinical evidence surrounding this debate.

The aim of this study is to determine if clinical and patient-reported outcome measures (PROMs) differ in patients undergoing robotic-assisted TKA with KA compared with an MA technique, using a matched-cohort analysis.

Methods

Patient Selection

In our prospectively maintained institutional TKA database, we reviewed 936 consecutive patients who underwent unilateral TKA using robotic-assistance system (MAKO; Stryker, Inc, Mahwah, NJ) from 2016 to 2019. Inclusion criteria included a primary diagnosis of varus knee OA suitable for a posterior-stabilized knee replacement. All procedures were performed by 1 senior surgeon with extensive experience in robotic-assisted TKA, including using KA and MA techniques. We excluded patients with post-traumatic, septic, or inflammatory arthritis of the knee, body mass index (BMI) >40 kg/m^2, patients with valgus knee, patients with contralateral TKA or ipsilateral total hip arthroplasty, and those without a minimum follow-up of 2 years. After the aforementioned exclusion, 100 patients undergoing MA technique were identified, and subsequently 1:1 matched (age, gender, BMI, and varus OA) in the final analysis.

Surgical Techniques

All TKAs were performed using a cruciate-sacrificing, cemented, fixed-bearing implant placed through a medial parapatellar approach. Both patients and independent outcome assessors collecting PROMs were blinded to the intervention. To maintain blinding, all patients underwent identical preoperative assessment, and perioperative analgesia protocols.

Table 2
Mechanical Alignment vs Kinematic Alignment: VAS at Rest.

VAS	MA	KA	*P*-Value
6 wk	6	2	NS
1 y	2	1	>.05
2 y	1	1	>.05

MA, mechanical alignment; KA, kinematic alignment; VAS, Visual Analog Scale; NS, not significant.

In the KA group, surgery was carried out according to the manufacturer-supplied surgical protocol. The cuts were manufactured to match the patient anatomy of the preoperative computed tomography (CT) scan, which determined guide positioning. In accordance with KA principles, ligamentous release was avoided but was performed if necessary to achieve symmetric ligament balance in both flexion and extension. Trial components were then positioned, and range of motion (ROM), stability, and patellar tracking were checked before definitive components were cemented in situ.

In the MA group, computer navigation was used according to the manufacturer's surgical protocol to guide measured resection of bone with the goal of achieving overall neutral coronal limb alignment with tibial and femoral bony cuts perpendicular to the mechanical axis of each bone. Posterior and anterior femoral cuts were then made with navigation assistance parallel to the surgical epicondylar axis with Whiteside's line and 3° external rotation relative to the posterior condylar axis used as additional references. Tibial rotation was aligned to the junction of the medial and middle thirds of the tibial tubercle. Ligament releases when performed were required to achieve symmetric ligament balance in both flexion and extension. Trial components were positioned and final checks of stability performed as described before cementation of the definitive components.

Postoperative management was identical between the 2 groups with physical therapists blinded to the intervention. Patient-reported outcomes were assessed using Visual Analog Scales (VASs) measuring pain at rest and when mobilizing (0-10 none to worst), Veterans RAND 12-item Health Survey [9], Knee Injury and Osteoarthritis Outcome Score Joint Replacement (KOOS JR) [10], and the Forgotten Joint Score (FJS, 0-100 worst to best) [11,12]. Scores were measured preoperatively and at 6 weeks, 12 months, and 24 months postoperatively.

Statistical Analysis

Statistical analysis was performed using the statistical software package R (http://www.R-project.org). Student's *t*-test was used to compare continuous variables of the normal distribution, and baseline surgery and alignment data were evaluated using a chi-squared test. The change from preoperative to the 2-year time point for PROMs was analyzed with analysis of covariance for repeated measurements. A *P*-value of <.05 was considered significant.

Results

A total of 200 consecutive patients were included in our study. There were 100 patients in the KA and 100 patients in the MA group with 1:1 matched age, gender, BMI, and varus OA. There were no significant preoperative differences between groups.

Primary Outcome

The FJS was significantly higher in the KA group compared to the MA group at 1 and 2 years postoperatively ($P < .001$; Table 1). At 6 months, the FJS was statistically similar between the MA and KA groups ($P = .5$; Table 1).

Secondary Outcome

VAS scores were significantly lower in the KA group at week 6 postoperative compared to the MA group (2 vs 6; $P = .04$). There is, however, no statistical difference in VAS scores between groups at 1-year (2 vs 1, $P \geq .05$; Table 2) and 2-year follow-up (1 vs 1, $P \geq .05$; Table 2). KOOS JR score, which represents the level of function and pain, was significantly higher in the KA group at 6 weeks, 1 year, and 2 years ($P \geq .05$; Table 3). There is no statistically significant difference in knee ROM between the KA and MA group (126 vs 122; $P = .55$). The 6-week Veterans RAND 12-Item Health Survey mental and physical components were also statistically similar between the MA and KA group (57.6 vs 54.3; $P = .32$).

Discussion

Our study found that patients undergoing TKA with KA experienced less pain in 6 weeks after surgery, and higher FJSs at 1 and 2 years postoperatively. Restoration of appropriate mechanical axis has been shown to be one of the most important factors influencing long-term survivorship of TKA [13] and malalignment has been shown to be one of the main risk factors for revision surgery [14]. Compared to the traditional MA where the femoral and tibial components are all placed perpendicular to their corresponding mechanical axis, KA aims to position TKA implants to match the native anatomy of each patient [15,16]. The goal of KA is to produce anatomic component position, as well as more physiological joint line obliquity and knee kinematics [17]. In this study, we found that KA is associated with better pain improvement and knee function after TKA compared to MA. Functional improvement and pain relief was observed as early as 6 weeks postoperative and continued for at least 2 years. Our finding is in line with prior clinical studies comparing clinical outcomes of TKA using KA vs MA. Dossett et al [18,19] found higher Western Ontario and McMaster Universities Osteoarthritis Index, Oxford Knee Score, combined Knee Society Score, and ROM in the KA group compared to the MA group at 6 months and 2-year follow-up. Calliess et al [20] found improvement in the Knee Society Score and Western Ontario and McMaster Universities Osteoarthritis Index score in the KA group compared to the MA group.

Although our findings suggest that KA results in higher PROMs, the current study has several limitations. First, we have only used 1 knee prosthesis with a posterior-stabilized design, and therefore, the results of this study might not be applicable to other implant designs. Second, although there are statistically significant differences in the FJS, VAS, KOOS JR score, these differences might be less than the minimal clinically important differences. Third, in this study we focused on varus knee, thus findings of this study may not be translatable to valgus knee. Finally, we did not record granular data regarding ligament releases in the MA group, which should be included in future studies.

Conclusion

In summary, TKA patients with KA experienced less pain in the first 6 weeks after surgery and improved function as demonstrated by higher FJSs at 1 and 2 years postoperatively. Therefore, KA should be considered as a strategy in select patients when implanting a TKA.

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