Outcomes in Patients with a Calipered Kinematically Aligned TKA That Already Had a Contralateral Mechanically Aligned TKA

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Abstract

Prior studies suggest kinematically aligned (KA) total knee arthroplasty (TKA) provides some clinical benefits. There are no reports of self-reported outcome measures in patients treated with a calipered KA TKA that already had a contralateral mechanically aligned (MA) TKA. We performed a retrospective study and asked the following questions: (1) Were you satisfied with your MA TKA when you were treated with the KA TKA? (2) What are the Forgotten Joint Scores (FJS) and Oxford Knee Scores (OKS) in each of your knees? (3) Do you favor one knee? and (4) Did one knee recover faster? From January 2013 to January 2017, 2,378 consecutive primary TKAs were performed of which all were treated with calipered KA that uses serial verification checks incorporating measurements of bone resections and positions to restore the prearthritic or native joint lines accurately. A records review identified patients with a prior primary MA TKA in the contralateral limb. Excluded were those with a history of fracture, osteotomy, infection, or revision knee surgery in either limb. In September 2018, 78 patients (57 females) with a mean age of 73 years (range, 50–91 years) completed a follow-up evaluation consisting of the FJS and OKS questionnaires and three anchor questions. A total of 83% of patients were satisfied with the MA TKA and 92% were satisfied with the KA TKA. The KA TKA had a 15 point higher median FJS and a comparable OKS to that of the MA TKA. Also, 56% of patients favored the KA TKA, and 8% favored the MA TKA. Seventy four percent of patients favored the recovery of the KA TKA, and 6% favored the recovery of the MA TKA. Accordingly, a patient considering a contralateral KA TKA can expect that more often than not the KA TKA will have a higher FJS, a similar OKS, be their favorite knee, and recover faster. Present study is therapeutic and reflects level IV evidence.

Keywords
- ► knee arthroplasty
- ► kinematic alignment
- ► Oxford knee score

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Patients considering a total knee arthroplasty (TKA) often ask the surgeon for an explanation of the expectations, advantages, and disadvantages of a new or innovative procedure as they consider alternatives to the standard procedure. Providing thoughtful counseling is especially challenging when the patient has already experienced the standard procedure in one knee. Studying responses to clinical outcome questionnaires and the experiences of patients with the standard procedure in one knee followed by the innovative procedure in the contralateral knee could reveal expectations for use when counseling patients.

Kinematic alignment (KA) is an innovative TKA procedure that patients might consider as an alternative to mechanical alignment (MA). Patient interest stems from results of three randomized trials and a national multicenter study that showed patients treated with KA TKA performed with patient-specific instrumentation reported better pain relief, function, and flexion, than patients treated with MA TKA[1–4]; whereas two randomized trials reported that both procedures resulted in high-functioning clinical outcomes as determined by validated patient-reported outcome questionnaires.[5,6]

KA coaligns the joint lines and axes of the femoral and tibial components with the joint lines and three "kinematic" axes of the prearthritic or native knee, without placing limits on the preoperative deformity and postoperative correction, and without soft tissue release. The "caliper" KA technique uses manual instruments and a series of verification checks that incorporate caliper measurements of bone resections and positions (►Fig. 1).[7,8] These verification checks restore the prearthritic or native left-to-right symmetry of the distal lateral femoral angle and proximal medial tibial angle, and native tibial compartment forces without ligament release.[9,10]

There are no reports of self-reported outcome measures in patients treated with a calipered KA TKA that already had a contralateral mechanically aligned (MA) TKA. Accordingly, we performed a retrospective review of 2,378 consecutive primary TKA of which all were performed with calipered KA of which 87 patients had been treated with a prior contralateral primary MA TKA. Responses to an evaluation consisting of patient-reported outcome questionnaires and three anchor questions were analyzed from 78 available patients that were mentally competent and physically active. The evaluations asked: (1) Were you satisfied with your MA TKA when you were treated with the KA TKA? (2) What are the Forgotten Joint Scores (FJS) and Oxford Knee Scores (OKS) in each of your knees? (3) Do you favor one knee? and (4) Did one knee recover faster?

Methods and Materials

An institutional review board approved this retrospective study of patients (IRB 1347338–1). From January 2013 to January 2017, 2,378 consecutive primary TKAs were performed of which all were treated with KA using verification checks that recorded eight caliper measurements to accurately restore the native joint lines.[9,10] The indications for TKA included disabling symptoms that had not resolved after conservative knee treatment, radiographic evidence of Kellgren–Lawrence grade 2 to 4 arthritic changes or osteonecrosis, any severity of flexion, varus, and valgus deformity as measured when nonweightbearing with a goniometer. Preoperatively, each patient completed the OKS (48 = best, 0 = worst) for the knee scheduled for treatment.

Briefly, the calipered KA was performed using sequential caliper measurements and a series of verification checks with manual instruments through a midvastus approach using a previously described technique by a single surgeon (►Fig. 1).[10–12] For the femoral component, the varus–valgus orientation and proximal-distal location were set coincident with the native joint line by adjusting the thickness of the distal medial and distal lateral femoral resections as measured with a caliper to within 0 ± 0.5 mm of the thickness of the femoral component condyles after compensating for cartilage wear and kerf of the saw blade. The internal–external orientation and anterior–posterior (AP) location were set based on the native joint line by adjusting the thickness of the posterior medial and posterior lateral femoral resections as measured with a caliper to within 0 ± 0.5 mm of the thickness of the femoral component condyles after compensating for cartilage wear and kerf. These steps set the femoral component with a bias of 0.3 degrees and precision of ± 1.1 degrees with respect to the flexion–extension plane of the knee and reliably aligned the cylindrical axis of the femoral condyle to the flexion–extension axis of the knee.[13,14]

The knee was balanced by adjusting the proximal–distal position, and varus–valgus rotation, and the slope of the tibial resection according to six options in a decision-tree (►Fig. 2). The varus–valgus orientation was set coincident with the native joint line using the following two verification checks. First, the thicknesses of the medial and lateral tibial resections were measured at the base of the tibial spines with a caliper and adjusted to within 0 ± 0.5 mm. Second, with the knee in full extension, the varus–valgus angle of the tibial resection was adjusted, working in 1 to 2 degrees increments, until the varus–valgus liftoff of the trial tibial component on the femoral component was negligible. These verification checks closely restore the native rectangular extension space, laxities, tibial compartment forces, and alignments of the limb and femoral and tibial joint lines.[9,10,15,16] The internal–external rotation of the tibial component was set using a kinematic tibial template with a negligible bias of 0.1° external and a precision of ± 3.9 degrees.[17] The slope was set coincident with the native joint line, working in 1 to 2 degrees increments. The slope and insert thickness were adjusted until: (1) the caliper measurement of the offset of the anterior tibia from the distal medial femoral condyle with trial components with the knee in 90 degrees of flexion matched that of the knee at exposure after adjusting for cartilage wear on the femur, and (2) the passive internal-external rotation of the tibia on the femur approximated ± 14degrees, which restores the mean range of native laxity.[12,18] No ligament releases were performed. Alignment references, such as the femoral and tibial mechanical axes, transepicondylar axis, and tibial tubercle border were not used when performing kinematic alignment.[10,11] A posterior cruciate ligament-retaining femoral and tibial component and

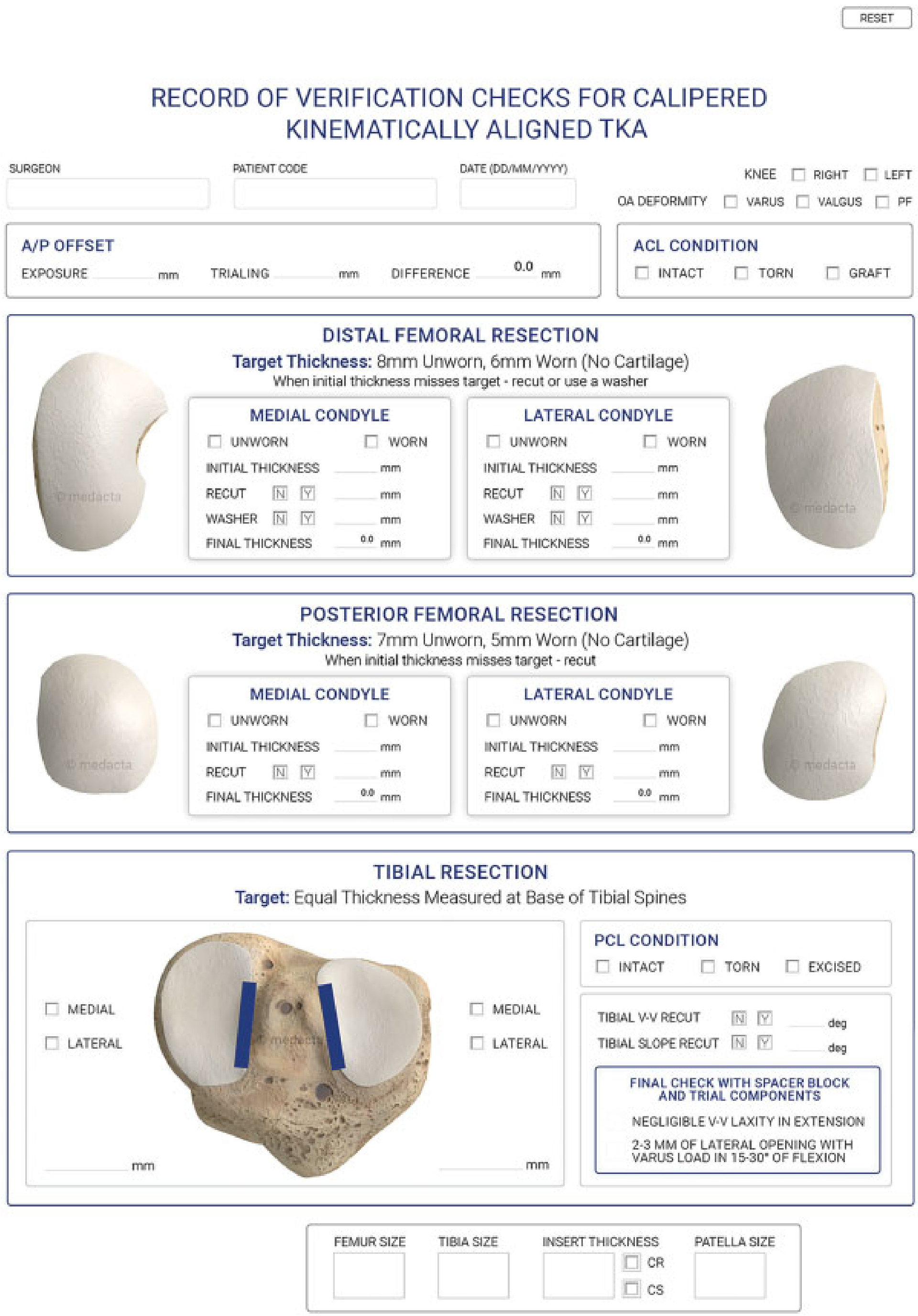

Fig. 1 Current worksheet for intraoperatively recording serial verification checks based on caliper measurements of bone resections and positions for a femoral component with a 9 mm thick distal femoral condyles and 8 mm thick posterior femoral condyles. The order of the bone cuts progress from distal femoral, posterior femoral, anterior femoral, chamfer femoral, and tibial resection. The thickness of the distal and posterior femoral resections is adjusted so they equal the thickness of the implant within 0 ± 0.5 mm after compensating for approximately 1 mm kerf from the saw cut and 2 mm of cartilage wear when present.[24]

patella button were implanted with cement (Persona; Zimmer Biomet, Warsaw, IN).

A record review identified those patients with a prior primary MA TKA in the contralateral limb. Excluded were those with a history of fracture, osteotomy, infection, or revision knee surgery in either limb. In September 2018, a follow-up evaluation consisting of three anchor questions: (1) Were you satisfied with your MA TKA when you were treated with the KA TKA? (2) Do you favor one knee? (3) Did one knee recover faster?; and the validated FJS (best = 100, worst = 0) and the OKS (best = 48, worst = 0 points) questionnaires were emailed and postal mailed to 87 patients. A phone call and an evaluation were resent to remind patients when they did not return the evaluation within 2 weeks.

Statistical Analysis

Data were recorded and analyzed using statistical software (JMP Pro 14.1.0, www.jmp.com, SAS, Cary, NC). The mean,

DECISION-TREE FOR BALANCING A CALIPERED KINEMATICALLY ALIGNED **CR** TKA					
Tight in Flexion & Extension	Tight in Flexion Well-Balanced in Extension	Tight in Extension Well-Balanced in Flexion	Well-Balanced in Extension and Loose in Flexion	Tight Medial & Loose Lateral in Extension	Tight Lateral and Loose Medial in Extension
Recut tibia and remove 1-2mm more bone.	Increase posterior slope until exposure A-P offset is restored at 90° of flexion.	Remove posterior osteophytes. Strip posterior capsule. Insert trial components & gently manipulate knee into extension.	Add thicker insert and recheck knee extends fully. When knee does not fully extend check PCL tension. When PCL is incompetent use **CS** Insert.	Remove medial osteophytes. Reassess. Recut tibia in 1-2° more varus. Insert 1 mm thicker insert.	Remove lateral osteophytes. Reassess. Recut tibia in 1-2° more valgus. Insert 1 mm thicker insert.

Fig. 2 The decision-tree provides six options to balance the cruciate-retaining (CR) component by adjusting insert thickness and proximal-distal position, and varus–valgus rotation, and the slope of the tibial resection without a ligament release. A cruciate-substituting (CS) insert or posterior stabilized components are used when the posterior cruciate ligament is incompetent.

standard deviation (SD), and 95% confidence interval (CI) described the distribution of continuous variables. As the Shapiro-Wilk test showed the distribution of the FJS and OKS values were not normal, so we reported nonparametric median and interquartile range (IQR) values. A Wilcoxon signed-rank test determined whether the FJS and OKS were different between the KA TKA and MA TKA. For the anchor questions, a Chi-squared test determined whether the observed number of "favor KA TKA" and "favor MA TKA" responses were different from the "expected response" of each procedure receiving an equal number of "favor" responses. Significance was $p < 0.05$.

Results

Nine of 87 patients were excluded: three were deceased, three were demented, two were physically inactive from either cancer or a neurologic disorder, and one non-English speaker moved to another continent. Of the 78 patients available for study, the mean age at final follow-up was 73 ± 8.2 years (range, 50–92 years), and 73% (range, 57–78%) were female. ►**Table 1** summarizes preoperative patient demographics, motion, the range of knee deformities, and function. Eighty-three percent ($n = 65$) of patients reported satisfaction with the MA TKA when they were treated with the KA TKA. The mean time between each primary TKA and the final evaluation was 3 ± 1.4 years for the KA TKA and 10 ± 4.6 years for the MA TKA.

For the patient response to the question "were you satisfied with your MA TKA when you were treated with the KA TKA?" 83% of patients were satisfied with the MA TKA when they were treated with the KA TKA and 92% were satisfied with the KA TKA at final follow-up.

For the FJS, the median value for the KA TKA (75 [IQR = 51–92]) was higher than that for the MA TKA (60 [IQR = 29–80]) with a difference of 15 points ($p = 0.006$) (►**Fig. 3**). For the OKS, the median value for the KA TKA (43 [IQR = 39–47]) was higher than that for the MA TKA (42 [IQR = 33–45]) with a difference of 1 point ($p = 0.019$).

For the patient response to the question "do you favor one knee?" 56% favored the KA TKA ($n = 44$), 8% favored the MA TKA ($n = 6$), and 36% rated both knees the same ($n = 28$; $p < 0.001$). For the patient response to the question "did one knee recover faster?" 74% indicated the KA TKA ($n = 58$), 6% indicated the MA TKA ($n = 7$), and 17% rated both knees the same ($n = 13$; $p < 0.001$).

Table 1 Average preoperative characteristics of patients prior to their kinematically aligned total knee arthroplasty

Preoperative characteristics of patients and knee treated with kinematically aligned TKA	Values
Demographics	
Age (y)	70 ± 8
Number of female patients (%)	57 of 78 (73)
Body mass index (kg/m^2)	31 ± 6
Preoperative motion and deformity of KA TKA	
Extension (degrees)	12 ± 8
Flexion (degrees)	112 ± 9
Valgus (+)/varus (–) deformity (degrees)	–3 ± 11
Preoperative clinical outcome scores of KA TKA	
Oxford knee score (48 = best, 0 = worst)	20 ± 7
Knee Society score (100 = best, 0 = worst)	34 ± 15

Abbreviations: KA, kinematically aligned; TKA, total knee arthroplasty.

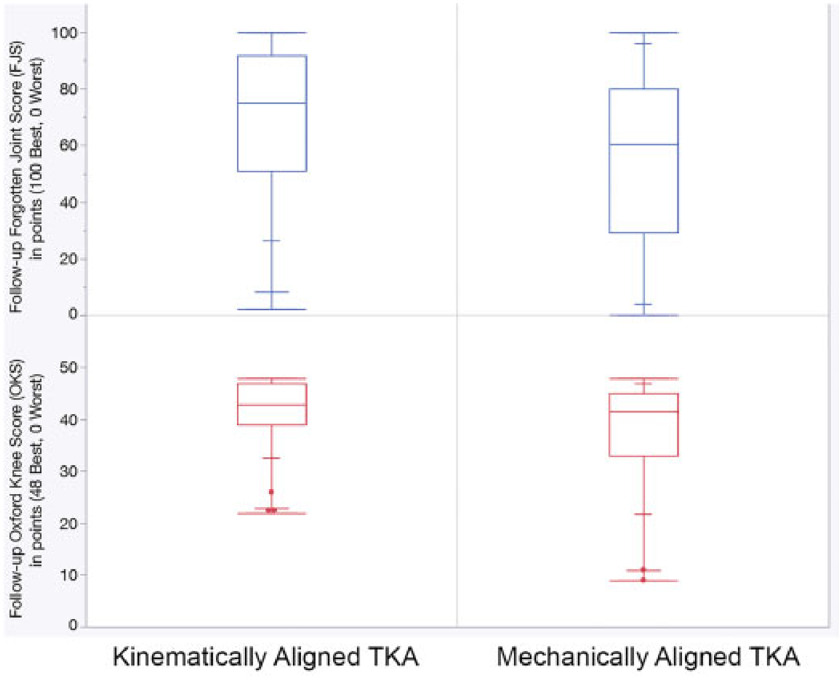

Fig. 3 Quantile box and whisker plots give a pictorial representation of the nonparametric descriptive statistics of the Forgotten Joint Score (FJS) and Oxford Knee Score (OKS) patient-reported outcomes for the kinematically aligned TKA and mechanically aligned TKA. The "box" represents the distance between the first and third quartiles, the line between these quartiles represents the median, and the "whiskers" represent the minimum and maximum value excluding outliers. The median value for the KA TKA is 15 points higher for the FJS and 1 point higher for the OKS than the MA TKA ($p < 0.006$ and $p < 0.019$, respectively). KA, kinematically aligned; TKA, total knee arthroplasty.

Discussion

This retrospective study formulated expectations from differences in the patient-reported responses to questionnaires and anchor questions between the KA TKA and MA TKA for use when counseling a patient that has a MA TKA and is considering a contralateral KA TKA. The most important findings of the present study were: (1) a total 83% of patients were satisfied with the MA TKA when they were treated with the KA TKA and 92% were satisfied with the KA TKA at final follow-up, (2) the KA TKA had a 15 point higher median FJS and a comparable OKS to that of the MA TKA, (3) 56% of patients favored the KA TKA and 8% favored the MA TKA, and (4) 74% of patients favored the recovery of the KA TKA, and 6% favored the recovery of the MA TKA.

Several limitations might affect the generalization of the findings. First, the impact of a (1) selection bias if the percentage of MA TKA that satisfied the patient in the present study was lower than the reported percentage of MA TKA that satisfied the patient in the general population, (2) transfer bias from the performance of the MA TKA with different implant brands and designs by different surgeons, (3) chronology bias from performing the KA TKA on an average of 7 years after the MA TKA, (4) performance bias from a difference in the level of surgical expertise between those that performed the MA TKA and KA TKA, and (5) a recall bias must be considered. In the present study, 83% of patients that reported satisfaction with their MA TKA and 92% reported satisfaction with their KA TKA at final follow-up. The 83% of patients that reported satisfaction with their MA TKA was comparable to a national registry that reported 82% of patients were satisfied with their MA TKA.[19] The high median OKS of the KA TKA and MA TKA at final follow-up were comparable to those reported by a randomized control trial.[6] Hence, the outcomes of the MA TKA in the present study are comparable to those well-respected studies of MA TKA, which makes the results from the present study generalizable. Second, the responses for the KA TKA in the present study were from a procedure that relies on serial verification checks based on caliper measurements of bone resections and positions to coalign the axes and joint lines of the components with the three "kinematic" axes and joint lines of the prearthritic or native knee without placing restrictions on the preoperative deformity and postoperative correction.[7] The outcome scores of other methods of kinematic alignment (i.e., patient-specific instrumentation, navigation, and robotics) that do not use intraoperative verification checks, and that restrict treatment based on the level of preoperative deformity and postoperative correction might not be comparable.[2,5,6]

With respect to the two outcome questionnaires, patients tended to favor the KA TKA over the MA TKA. The median FJS was 15 points higher for the KA TKA, whereas the OKS was comparable to the MA TKA. A ceiling effect explains this inconsistency as the proportion of patients reporting scores within 15% of the maximum value was 2.5 times more for the OKS than the FJS (62 vs. 26%).[20] In the present study, the median FJS of 75 points for the KA TKA and 60 points for the MA TKA were comparable if not higher than the mean FJS of 69 points for the KA TKA and comparable if not lower than the mean FJS of 66 points for the MA TKA reported by a randomized trial.[6] These differences might be explained by the randomized trial excluding knees with severe preoperative varus–valgus and flexion deformities, restricting the postoperative coronal alignment by changing the preoperative plan, setting implants positions with patient-specific instrumentation that is likely less accurate and reliable than the caliper technique (►**Fig. 1**).[2,5] Hence, when patients have high OKS the FJS should be the primary clinical outcome measure.[21,22]

Normative values for the FJS for the United States population for men > 70 years of age are 97 points for the median and 79 points for the mean, and for women > 70 years of age are 85 points for the median and 73 points for the mean.[23] The mean age at final follow-up in the present study was 73 years. For the KA TKA, the FJS values in men were 75 points for the median and 76 points for the mean, and in women were 73 points for the median and 66 points for the mean. Whereas for the MA TKA, the FJS values in men were 67 points for the median and 59 points for the mean, and in women were 57 points for the median, and 53 points for the mean. Hence, the KA TKA median and mean values of the FJS for men and women were closer to normative values than the MA TKA values.

With respect to the three anchor questions, although a proportion of patients reported no difference, more patients tended to favor the KA TKA over the MA TKA with 83% of patients were satisfied with the MA TKA when they were treated with the KA TKA and 92% were satisfied with the KA TKA at final follow-up. When a patient was asked whether they favored one knee, 56% favored the KA TKA, whereas 36% of patients did not pick a favorite. When a patient was asked whether one knee recovered faster, 74% of patients favored the recovery of the KA TKA, whereas only 20% did not pick a favorite.

In summary, a patient considering a contralateral KA TKA can expect that more often than not the KA TKA will have a higher FJS, a similar OKS, be their favorite knee, and recover faster.

Note

The study was approved by our ethical committee.

Funding

None.

Conflict of Interest

S.M.H. reports personal fees from Zimmer-Biomet, personal fees from ThinkSurgical, personal fees from Medacta, outside the submitted work.

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