Influence of Kinematic Alignment on Soft Tissue Releasing and Manipulation Under Anesthesia Rates in Primary Total Knee Arthroplasty

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ABSTRACT

Introduction: Total knee arthroplasty (TKA) is typically performed to restore a neutral mechanical alignment. Recently, there has been increased interest in kinematic alignment to restore the patient's individual alignment. The purpose of this study is to determine if kinematic balancing reduces the need for intraoperative soft tissue releases and rates of manipulation under anesthesia compared to mechanical alignment.

Materials and Methods: A query was performed between January 2021 and July 2022 to identify all patients who underwent a primary TKA that was performed with kinematic alignment (KA), which revealed 97 patients (107 TKAs). A cohort of consecutive patients from the preceding six months was gathered of patients who underwent primary TKA with mechanical alignment (MA). This cohort consisted of 199 patients (223 TKAs), yielding a total study cohort of 296 patients (330 knees). Mean age was 64.7 years, mean body mass index (BMI) was 33.1 kg/m2, and 57.1% of patients were female. Rates of manipulation under anesthesia and intraoperative release status were analyzed.

Results: Average range of motion preoperatively improved from 108.9° to 114.4° in the KA group but decreased from 112.3° to 109.9° in the MA group at six weeks (p<0.0001). Three of 107 knees (2.8%) required an additional pie-crusting of the superficial MCL in the KA group, whereas 58 of 223 knees (26.0%) did in the MA group (p<0.0001). Three of 107 knees (2.8%) in the KA group and 24 of 223 knees (10.8%) in the MA group required MUA (p<0.0001).

Conclusion: Kinematic alignment significantly reduced the need for intraoperative soft tissue releases and postoperative manipulation under anesthesia. Further studies of the influence of kinematic alignment on these outcomes across multiple surgeons should be performed and/or compared to mechanical alignment.

INTRODUCTION

Total knee arthroplasty (TKA) has rapidly evolved from what was originally considered a "poor operation" in the 1970s to one of the most successful procedures today.[1] Research over this time has tasked the industry with fine tuning every element of this surgery to improve patient outcomes. Although this research continues to improve upon itself, there still exists a significant contingent of TKA patients that are not satisfied with their overall outcome. It is believed that this may be in part a result of the method by which their operative knee is aligned.[2]

Traditionally, TKA is performed to achieve a set mechanical alignment using either a measured resection or gap balancing technique. In mechanical alignment (MA), the femoral and tibial prostheses are placed perpendicularly to the coronal mechanical axis of the femur[3]—the goal being to recreate a neutral alignment of the lower limb and balance the load distribution between the medial and lateral compartments.[4] This notion is problematic because only 0.1% of patients have a neutral mechanical axis thereby axiomatically modifying nearly every patient's native anatomy.[5] Furthermore, rotational alignment of the femoral component and sagittal alignment of both components are set to relatively fixed parameters. The result of standardized component alignments across various types of patient anatomy is that soft tissue releases may need to be performed to achieve balance of the knee. Doing so, however, can be technically challenging, resulting in overcorrection and further altering the natural kinematics of the knee.[6]

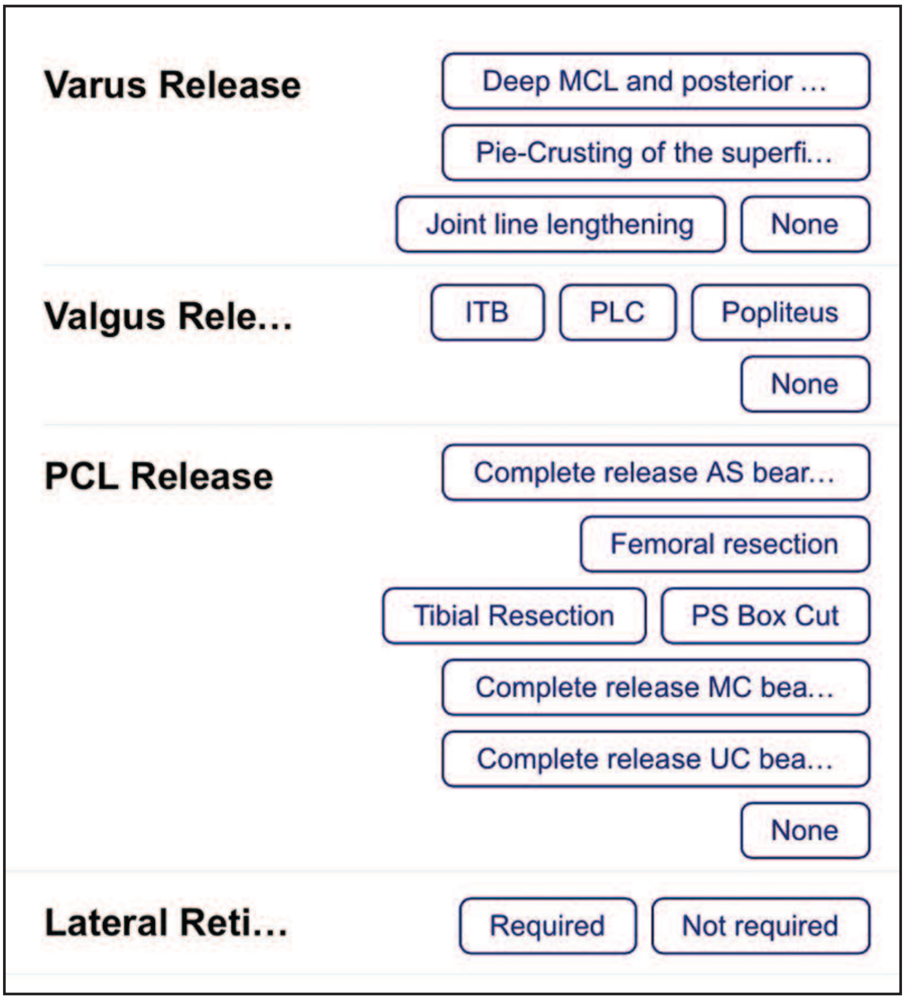

Figure 1. Digital operative report.

In kinematic alignment (KA), the goal is to restore the pre-arthritic alignment of the knee by positioning both components in a way that restores the native joint lines.[4,7,8] This technique is a "pure bone procedure" and "true knee resurfacing" in which the thickness of the bone cuts is rather predictable.[9] Assuming that the femur is precisely resurfaced, balancing via KA is accomplished by removing osteophytes and resecting the tibia.[6] A potential pitfall of this technique is its risk of malalignment in the coronal and sagittal planes.[10]

In a similar vein to differing techniques to align a knee, differing implants may also play a significant role in patient outcomes. Since the turn of the century, implant design has been aimed at replicating the physiological medial-pivoting movement of the knee. Medial-pivot (MP) implants are asymmetrical, with decreased lateral congruence when compared to the medial side.[11] In theory, the goal of this design is to resemble the true kinematic relationship between the tibia and femur during knee flexion by restricting anterior sliding movement and avoiding paradoxical anterior rollback of the femoral condyles.[12] Ultracongruent (UC) implants, however, have a high congruence between the surfaces of the femur and insert [11] in order to increase anteroposterior (AP) stability.[13] Putame et al. found that the MP design better simulated true physiological tibial rotation in early knee flexion when compared to UC implants, thus implying a lower wear rate, which leads to improved implant survivorship.[11] However, Dalton et al. found that there was no increased rate of revision due to polyethylene wear with UC inserts.[13]

The debate involving knee alignment[2] and sacrifice or retention of the PCL in a TKA has been highlighted due to its potential to influence the need for manipulation under anesthesia (MUA) postoperatively.[14] MUA offers physicians a method to intervene in patients suffering from a lack of range of motion (ROM) and/or stiffness in the early postoperative period.[15] Daluga et al. demonstrated that MUA is indicated when the patient is unable to flex more than 90° at six weeks postoperatively, and if performed earlier, the results were far more promising.[16] Doing so too early, however, such as within three weeks of the procedure, could result in damage to the skin and soft tissue.[17] Several studies utilizing kinematic alignment showed a low rate of MUA, specifically between 3.6% and 4.6%, which may be attributed to the technique with which the TKAs were performed.[7,18-20]

The purpose of this study is to compare rates of intraoperative soft tissue release and manipulation under anesthesia between anterior-stabilized mechanically aligned TKA and medial congruent kinematically balanced TKA performed by one surgeon.

MATERIALS AND METHODS

A query of a single surgeon's arthroplasty registry was performed between January 2021 and July 2022 to identify all patients who underwent a primary TKA that was performed with kinematic alignment and medial pivot knee design. This query revealed 97 patients (107 TKAs). A cohort of consecutive patients who underwent primary TKA with mechanical alignment and an anterior-stabilized bearing from the preceding six months was gathered. This cohort consisted of 199 patients (223 TKAs), yielding a total study cohort of 296 patients (330 knees).

Data collected on patients at the time of TKA included basic demographics, such as age, height, weight, and body mass index (BMI). Operative notes were reviewed to identify type of balancing performed, implants utilized, and what releases were performed on the medial collateral ligament (MCL) and lateral knee structures. A digital operative report was utilized for all patients with detailed description of soft tissue releases (Fig. 1). Medical records were further reviewed for six-week postoperative knee range of motion (ROM) and whether patients underwent a manipulation under anesthesia and/or revision.

For all procedures, a medial parapatellar approach was performed to expose the knee joint. The deep MCL was released as part of the exposure, and the femur was addressed first. The anterior cruciate and posterior cruciate ligaments were released in all cases. The patella was resurfaced in select cases per the surgeon's discretion. All TKA components were cemented in both cohorts.

MECHANICAL ALIGNMENT

An intramedullary femoral guide was utilized for the distal femoral resection with a set 5° of valgus and a resection depth of 9mm based on a medial femoral condyle and neutral flexion. Femoral component rotation and sizing was based on a posterior referencing guide with 3° of external rotation. Tibial resection was performed with an extramedullary guide with neutral coronal alignment, 3° of posterior slope, and a 10mm resection depth off the most intact cartilage height. Once osteophytes and menisci were removed, trialing proceeded. Soft tissue releases were utilized to address asymmetrical imbalance in the medial and lateral compartments with superficial pie-crusting of the MCL for tightness in the medial compartment and progressive lateral releases as needed for tightness in the lateral compartment in valgus knees. Once the surgeon felt there was appropriate balance, the patella was resurfaced, if deemed appropriate, and final components were cemented.

KINEMATIC ALIGNMENT

All osseous resections using kinematic technique were measured with a manual caliper to match the appropriate resection depth accounting for any cartilage wear and the kerf of the saw blade. Distal femoral resection was performed first with an intramedullary femoral rod and paddles to articulate with the distal femur based on wear pattern. Intact cartilage used a standard paddle "no wear," and a worn condyle had an additional 2mm build-up to account for articular cartilage loss. Both medial and lateral paddles were flush with the distal femur, and a 9mm distal femoral resection was performed. Adjustments were made to the resection as needed to meet the 9mm resection accounting for worn cartilage and the kerf of the saw blade. Femoral rotation and sizing were determined by a matched resection from the posterior condyles accounting for any cartilage loss as described above. Sizing was posterior referenced with the goal being matched resection from the posterior condyles as described, and the anterior flange sitting flush with the anterior cortex of the femur. Posterior condyles were resected first and measured with a target of 8mm accounting for any worn cartilage and the kerf of the saw blade. Adjustments were made as needed to achieve the appropriate resection, followed by completion of the remaining femoral cuts.

Tibial resection alignment was dictated by the patient's anatomy with an estimated 10mm resection accounting for the kerf of the saw blade and cartilage loss from the worn side. Following tibial resection, spacer blocks were placed in both flexion and extension, and adjustments to the tibial resection were made as needed. For example, if the medial compartment was 2mm tighter than the lateral compartment, a 2° varus guide was added to the previous cut. Once osteophytes and menisci were removed, trialing proceeded. Any imbalance was addressed with recutting of the appropriate bony structures. Once the surgeon felt there was appropriate balance, the patella was resurfaced, if deemed appropriate, and final components were cemented.

Postoperative follow-up visits were scheduled for patients at six weeks and 12 months. Knee range of motion was recorded at all visits. Patients who presented with less than 90° of ROM and/or had significantly less knee ROM than preoperatively were offered a manipulation under anesthesia (MUA). All MUAs were performed before 12 weeks postoperatively.

RESULTS

Of the 296 patients (330 knees), 97 patients (107 knees) received a Medacta GMK Sphere® prosthesis (Medacta International, Castel San Pietro, Switzerland) with kinematic alignment. The remaining 199 patients (223 knees) received a Vanguard® anterior stabilized (AS) prosthesis (Zimmer Biomet, Warsaw, Indiana) with mechanical alignment. The former group had 54 females (55.7), and the latter had 115 females (57.8%) (p=0.09).

The average age, BMI, height, and weight of the kinematic alignment (KA) group was 65 years, 34.2 kg/m^2, 67.3 inches, and 211.9 pounds, respectively. For the mechanical alignment (MA) group, these same figures were 64.5 years, 32.5 kg/m^2, 67.4 inches, and

Table I
Patient demographics

Alignment	Mechanical		Kinematic		p-value
Category	Mean ± standard deviation	Range	Mean ± standard deviation	Range	
Age (years)	64.5 ± 8.5	34–84	65.0 ± 8.6	42–85	0.57
Height (inches)	67.4 ± 4.1	58–77	67.3 ± 4.6	60–76	0.78
Weight (pounds)	210.4 ± 46.6	120–352	211.9 ± 53.0	116–378	0.79
BMI (kg/m²)	32.5 ± 6.6	21–55	34.2 ± 8.0	17–58	0.05

Table II
Patient demographics and perioperative characteristics

Alignment / Category	Mechanical	Kinematic	p-value
Gender by knee			0.81
Male (%)	92 (41.3)	46 (43.0)	
Female (%)	131 (58.7)	61 (57.0)	
Gender by patient			0.80
Male (%)	84 (42.2)	43 (44.3)	
Female (%)	115 (57.8)	54 (55.7)	
Operative side			0.48
Left (%)	106 (47.5)	46 (43.0)	
Right (%)	117 (52.5)	61 (57.0)	

Table III
Patient demographics and perioperative characteristics

Alignment	Mechanical	Kinematic	p-value
Category	N (%)		
Deep MCL and posterior medial corner, pie-crusting of superficial MCL	58 (26.0)	3 (2.8)	<0.0001

Table IV
Valgus releases

Alignment	Mechanical	Kinematic	p-value
Valgus releases	N (%)		
None	192 (86.1)	104 (97.2)	0.002
ITB	17 (7.6)	0 (0)	
ITB, popliteus	2 (0.9)	0 (0)	
ITB, PLC	11 (4.9)	0 (0)	
Popliteus	1 (0.4)	3 (2.8)	

ITB: Iliotibial band; PLC: posterolateral corner

210.4 pounds (Tables I and II). The patella was resurfaced in 219 of 223 (98.2%) MA cases and 106 of 107 (99.1%) KA cases (p=0.68).

The surgeon studied (KRB) performs a medial parapatellar approach with elevation of the medial soft tissue sleeve to allow subluxation of the tibia forward in all cases. In the KA group, three of the 107 knees (2.8%) required an additional pie-crusting of the superficial MCL, whereas 58 of 223 knees (26.0%) did in the MA group (Table III) (p<0.0001). Valgus releases were required in 31 of 223 cases in the MA group (13.9%) and in three of 107 cases in the KA group (2.8%) (Table IV) (p=0.002). A tight popliteus tendon was released in these three cases in the KA group.

Average preoperative range of motion was 112.3° in the MA group and 108.9° in the KA group (p=0.03). At six weeks postoperatively, average range of motion had decreased to 109.9° in the MA group but improved to 114.4° in the KA group (Table V) (p<0.0001), a decrease of 2.4° and increase of 5.5°, respectively (p<0.0001). Manipulations under anesthesia (MUA) were performed in three of 107 knees (2.8%) in the KA group but in 24 of 223 knees (10.8%) in the MA group (p=0.014). In the latter group, one arthroscopic lysis of adhesions was performed during the MUA (Table VI).

DISCUSSION

The dispute between mechanical and kinematic alignment of TKA is an ever-present debate in the orthopedic community that will likely continue for quite some time. The principal findings of this study show that the kinematically aligned knees had significantly less need for intraoperative soft tissue releasing, better range of motion at six weeks, and a far lower rate of manipulation under anesthesia.

The two cohorts had a statistically significant difference in BMI, as the MA group had an average BMI in kg/m² of 32.5 ± 6.6, while the KA group was 34.2 ± 8.0 (p=0.05). It is important to make note of this, as patients with a higher BMI typically have a lower ROM.[17] ROM in the MA group decreased on average 2.4° from 112.3° to 109.9°, while the KA group saw an average increase of 5.5° from 108.9° to 114.4°.

The findings of Nam et al. showed that across nearly 700 patients, those whose knee was replaced via KA were three times more likely to report a more normal-feeling knee nearly 30 months postoperatively, on average, than those whose knee was replaced via MA.[21] Elbuluk et al. demonstrated that both pain improvement and knee function were superior in KA TKA when compared to MA TKA, as KOOS JR scores were significantly higher in the KA group at six weeks, one year, and two years. Their study only focused on varus knees, however, whereas the current study included both varus and valgus knees.[22] Both Dossett et al. and Calliess et al. reported similar findings, showing that Knee Society Scores were greater in KA TKA.[7,23]

One of the most important steps of a TKA is the trialing of implant components prior to cementation. Soft tissue releasing to allow for adequate balancing of the knee is performed at the discretion of the surgeon. Several studies analyzing KA TKA tend to show a need for soft tissue releasing in the range of 5–17% of cases,[24,25] with more so occurring via valgus releases,[25] as was the case in the current study. The findings of Sapper-Marinier et al. showed a significant increase in the number of releases necessary to produce the target laxity values in MA knees as compared to KA knees.[26] An et al. found that statistically significantly more soft tissue releasing was also needed in MA knees when compared to KA knees in 210 TKAs performed by one surgeon.[27] A decreased need for soft tissue releasing is beneficial for the patient, as limiting such intraoperatively allows for optimization of joint function, pain control, and rehabilitation.[28]

In a cohort of 121 TKAs performed via KA, Abhari et al. found that MUA was required in seven knees (5.8%) as opposed to nine knees (7.8%) in a matched cohort of 115 separate TKAs performed via MA.[29] These findings are corroborated by Shekhar et al., who reported that only 82 of 3,558 (2.3%) TKAs performed via KA required MUA from 2010 to 2017. Thirty of these 82 patients (36.6%) had MUA performed within three months.[18] Other studies substantiate these findings, as seen in Table VII. The results of the present study show slightly higher rates of manipulation under anesthesia than those mentioned above. In the entire cohort, 27 of 330 knees (8.2%) required MUA, although this figure was far greater for those who had mechanical alignment. The need for soft tissue releasing was also greater in the mechanical alignment cohort.

There are several limitations to this study. First, this study is retrospective in nature. Secondly, the cases of only one surgeon were utilized, which may not allow for generalizability of the results. The discretion when deciding to increase the amount of varus releasing needed may differ from other surgeons. The decision to proceed with MUA was not steered by any algorithm or standardized definition of postoperative stiffness but rather by input from the surgical team. The cohort utilized in the present study is not as large a sample as other similar studies mentioned in the text. The authors acknowledge that radiographs were not used pre- or postoperatively to address exact alignment. However, this finding would have had little to no bearing on outcomes, as the goal of this study was to investigate the need for intraoperative releases and subsequent MUA. Two different implants were used in each cohort, with all patients of each group receiving the same implant. This was done for continuity; however, the focus of this study is on alignment technique as opposed to the implants used. A confounding variable may be that a medial pivot design was used in the KA group while an anterior stabilized bearing was

Table V
Range of motion (ROM)

Alignment	Mechanical		Kinematic		p-value
Category	Mean* ± standard deviation	Range*	Mean* ± standard deviation	Range*	
Preoperative	112.3 ± 11.9	80–130	108.9 ± 12.8	80–130	0.03
Six weeks postoperatively	109.9 ± 11.9	60–130	114.4 ± 10.1	85–133	<0.0001
Δ	-2.4		+5.5		<0.0001

*Measured in degrees

Table VI
Manipulation under anesthesia (MUA) rates

Alignment / Category	Mechanical	Kinematic	p-value
Number of TKA	223	107	
Number of MUA	24	3	<0.0001
MUA rate (%)	10.8	2.8	

Table VII
Documented studies of TKA performed via kinematic alignment

Study	Year	TKA	MUA	MUA Rate
Newman et al.[29]	2018	1729	62	3.6%
Knapp et al.[30]	2020	3556	164	4.6%
Dossett et al.[7]	2014	44	2	4.5%
Young et al.[31]	2017	49	2	4.1%

used in the MA group. Investigating the principles of alignment across additional implant and polyethylene insert types may be of interest in further studies. Lastly, these procedures were based on kinematic principles and thus cannot directly be compared to outcomes of mechanically aligned TKA.[31] It should be noted that this study is not concerned with patient satisfaction or clinical outcomes postoperatively and thus does not assess such outcomes.

CONCLUSION

Kinematic alignment significantly reduced the need for intraoperative soft tissue releases and postoperative manipulation under anesthesia. Further studies of the influence of kinematic alignment on these outcomes across multiple surgeons should be performed and/or compared to mechanical alignment.

AUTHORS' DISCLOSURES

No direct funding was received in support of this study. Dr. Crawford is a consultant to DePuy Orthopedics and Medacta. Dr. Lombardi is a consultant to Zimmer Biomet, receives IP royalties from Zimmer Biomet and Innomed, and has minority investment interests in SPR Therapeutics, Joint Development Corporation, Elute Inc., VuMedi, Prescribe Fit, and Parvizi Surgical Innovation.

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