



Kinematic alignment is bone and soft tissue preserving compared to mechanical alignment in total knee arthroplasty



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ABSTRACT

Background: Kinematically aligned (KA) total knee arthroplasty (TKA) has emerged as an alternative approach to the intraoperative alignment targets of mechanically aligned (MA) TKA. While the clinical outcomes of the two philosophies have been investigated, further investigation is required to quantify exactly how the two philosophies differ in their approach to correcting the deformities encountered in osteoarthritic knees such as fixed flexion deformities (FFD) and coronal malalignment. The aim of this paper was to compare MA and KA philosophies in TKA in terms of the intra-operative correction of FFD and coronal malalignment and quantify the way in which each philosophy achieves a well-balanced knee that can reach full extension.

Methods: A retrospective review of prospective data collected from 210 consecutive TKAs performed by a single surgeon between March 2015 and May 2017 was undertaken. MA and KA cases were compared in terms of pre-operative patient deformity and characteristics, intraoperative steps taken to correct FFD (including bony resections, soft tissue releases and components used) and postoperative alignment achieved.

Results: One hundred twenty MA and 90 KA TKAs were analysed. There was no significant difference in terms of patient age, gender and preoperative coronal and sagittal deformity between the two cohorts. KA TKAs were able to achieve the same degree of sagittal correction as MA TKAs with less total bony resection (16.7 mm vs. 18.9 mm, $p < 0.0001$), less soft tissue releases (10% vs. 49.2%, $p < 0.0001$). This was achieved with a difference in component alignment. The femur was in more valgus (-2.5 vs. -0.03° , $p < 0.0001$), the tibia in more varus (2.3 vs. 0.3° , $p < 0.0001$), and the overall alignment slightly more varus in the KA group (1.1 vs. 0.4° , $p = 0.007$), without significant difference in the proportion of patients within three degrees of a neutral axis.

Conclusion: This study shows that using a kinematic alignment philosophy in total knee arthroplasty results in the achievement of extension range-of-motion and soft tissue balance goals with less bone resection and less soft tissue release. This allows for bone stock preservation and minimization of trauma due to soft tissue release. Further study is required to correlate these results with patient reported outcomes and determine their clinical significance.

Level of evidence: III – retrospective cohort study.

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Abbreviations: TKA, Total knee arthroplasty; KA, Kinematic alignment; MA, Mechanical alignment; FFD, Fixed flexion deformity.

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1. Introduction/purpose

While there are several philosophies for performing total knee arthroplasty (TKA), historically the prevailing approach has been to create a neutral mechanical axis. This is created by performing bony cuts perpendicular to the long axis of the femur and tibia and adding soft tissue release of the surrounding ligaments to balance the knee where required [1]. This mechanical alignment (MA) technique has been considered well performed when the overall limb alignment is within three degrees of neutral, however at least 10–12% of patients remain dissatisfied with the resulting outcome using this technique [2,3], with older papers reporting higher rates of dissatisfaction at about 20% [4–6].

Kinematic alignment (KA) has recently emerged as an alternative to this traditional philosophy of mechanically aligned total knee replacement. In KA TKA, the aim is to restore the native joint line anatomy and orientation, preserving the patients' native soft tissue envelope by balancing the knee with bony resection rather than soft tissue releases. Early studies comparing MA and KA TKA have demonstrated either equivalent or better clinical outcomes for KA TKA [7–12]. This may be because KA TKA produces more neutral weight bearing positions and decreased knee adduction moment, a surrogate for medial tibiofemoral joint loading and thus implant durability when compared to MA TKA [13,14], or it may result from less disruption of the native soft tissue envelope [15–17]. The KA technique attempts to modify implant position in order to recreate the anatomy of the prearthritic articular surface for the individual patient. This would theoretically improve ligament balancing and minimise the need for releases, because component alignment will more closely match each individual patient's anatomy and the corresponding soft tissue envelope of their knee. However, there is a lack of published data regarding how KA total knee replacement can effectively achieve sagittal plane correction of fixed flexion deformities (FFD) with less soft tissue release and bone resection in comparison to MA patients. While the clinical outcomes of the two philosophies have been investigated, there is a gap in the literature around quantifying exactly how the two philosophies differ in their approach to correcting the deformities encountered in osteoarthritic knees such as fixed flexion deformities and coronal malalignment.

Fixed flexion deformity is an inability to achieve complete extension of the knee in the sagittal plane. As the native knee degenerates this loss of full extension tends to develop, and increase as the disease advances. Without the ability to fully extend the knee there is an increased energy requirement for standing and gait, increased incidence of anterior knee pain and overall poorer knee function [12,18,19]. As a result, restoring full extension is one of the primary objectives when patients undergo total knee replacement. Traditionally, FFD is addressed via a combination of soft tissue releases and if needed, increased bony resection, generally from the distal femur [20–27]. In KA TKA, recreating the joint line may allow soft tissues to remain at their “native” orientations, decreasing the need for direct intervention (i.e. bony resection and soft tissue releases) to achieve full range of motion.

The aim of this paper was to quantify the different implant positions that result from using the KA and MA philosophies, and compare the amount of bone resection and soft tissue releases required with each respective technique to achieve intra-operative correction of FFD and thus achieve the primary goal of a well-balanced knee that can reach full extension.

This was undertaken via a retrospective review of prospectively collected data from a single surgeon. We hypothesised that there would be a difference between the amount and orientation of bone resection from the distal femur and proximal tibia and degree of soft tissue release required to achieve the same amount of FFD correction and a balanced knee using the KA and MA alignment philosophies.

2. Methods

This project was approved by the local ethics board (Approval number: LNR/15/HAWKE/478).

2.1. Patient population

A retrospective review of prospective data collected from 210 consecutive TKAs performed by a single surgeon between March 2015 and May 2017 was undertaken. Included patients were those undergoing either mechanically aligned (MA) or kinematically aligned (KA) robotically assisted total knee arthroplasty performed with computer navigation (Global Orthopaedics, Australia) who demonstrated preoperative fixed flexion deformity as measured with computer navigation, with any degree of coronal deformity. These cases were performed as a consecutive series, with the vast majority of the mechanically aligned knees being performed before the surgeon changed to the kinematic philosophy.

2.2. Surgical technique

All total knee arthroplasties were performed by a single surgeon and all patients received the Omni Apex (Global Orthopaedics, Australia) cruciate retaining implant, a single radius implant with spherical posterior condyles. The Omni computer navigation system was used for all cases, including the Omnibot robotic delivery system for all femoral cuts. Preoperative alignment was measured with a standardised computed tomography (CT) protocol in all cases. The depth of every femoral cut (posteromedial, posterolateral, distal medial and distal-lateral) was either validated with a navigation check block (distal and anterior cut) or measured using a calliper device (posterior cut). Soft tissue releases were recorded in a database by the operating surgeon and classified by their location: i.e. lateral (iliotibial Band, popliteus, fibular collateral ligament), medial compartment (superficial medial collateral ligament), posterior (posterior capsule, popliteus tendon) or lateral patellar retinaculum.

2.2.1. Kinematic alignment technique

A medial parapatellar approach was performed to expose the knee joint and osteophytes were removed. Navigation trackers were placed, anatomical landmarks registered, and the articular surfaces of the tibia and femur mapped to generate a three dimensional (3D) reconstruction of the bony morphology. This reconstruction was used for virtual planning of the desired implant position in real time. Femoral bony resection was performed first with distal and posterior resections made to match the native joint line prior to disease by accounting for cartilage loss and implant thickness and making a matched resection. It was assumed that full thickness cartilage amounted to two millimetres [28,29]. The Apex implant used is nine millimetres thick distally and 11 mm thick posteriorly, and the respective resections were made to account for this. The femoral component coronal alignment was driven by this matched resection philosophy to a maximum of six degrees of valgus in the coronal plane. Femoral rotation was driven by a matched resection from the posterior condyles accounting for any cartilage loss as described above (parallel to the posterior condylar axis when there was no posterior cartilage loss). 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 (no notching). The component was flexed between 0 and four degrees as needed to achieve this, or if necessary upsized to the next size. In those cases where this KA philosophy would have resulted in the femoral component being in more than six degrees of valgus, a modification to the philosophy was made to not exceed this value and make a suitable adjustment to the tibial cut (this was necessary in only one case).

Tibial resection followed femoral resection. The initial tibial resection was made to match the estimated native joint line. This was generally between 0 and three degrees varus to the long axis of the tibia. Depth of the tibial resection was matched to the implant thickness (including the thinnest polyethylene insert) removed from the high side except where this would result in more than seven millimetres from the medial side. In this circumstance the resection depth would be reduced to take a maximum of seven millimetres from the medial side. Tibial slope was set to match the preoperative slope measured in the preoperative CT scan. Tibial rotation was set parallel to the long axis of the ellipse of the lateral tibial plateau [30]. In cases where there was significant bone loss from the worn side, a point of reference was used that could best approximate the point where that bone loss began to pass beyond the native bony joint line position.

Posterior tibial slope and coronal and sagittal alignment were confirmed intraoperatively using the navigation system and then recorded by the surgeon.

Finally trial components were inserted and computer navigation was used to assess the range of motion and laxity throughout range. Sagittal plane balance was carefully assessed. The goal was full extension under gravity, and a matched flexion gap. Where full extension was not achieved a posterior capsular release was performed. If the capsular release was not enough to acquire full extension with the smallest polyethylene insert, a re-resection of the distal femur would be performed (not required in any KA cases). Any releases or extra resections were recorded. Where the knee was hyperextending thicker polyethylene inserts were used until this corrected. Tightness in flexion was assessed by the surgeon intra-operatively and addressed by changing the tibial slope angle (too tight in flexion leading to recutting the tibia with greater slope, and vice-versa). Coronal plane balance was assessed throughout the range of motion and any imbalance was addressed via recutting the tibia into more varus or valgus as required (up to a maximum of five degrees tibial varus or three degrees tibial valgus), rather than soft tissue releases wherever possible. In essence, this KA TKA technique is a kinematically resected femur with a gap balanced tibia with tibial recuts used to replace ligamentous releases in order to achieve coronal and sagittal balance.

All final resection angles and depths were recorded via the navigation system along with final limb alignment, laxity curves, releases performed and implants used.

2.2.2. Mechanical alignment technique

The same approach and initial preparation with osteophyte removal, navigation pin placement, and anatomic registration were performed. Virtual planning was performed on the computer generated model but with mechanical alignment parameters (perpendicular to the mechanical axis).

The distal femoral cut was performed first, oriented perpendicular to the mechanical axis of the femur. Resection depth was referenced against the most distal femoral condyle (“high side”), taking the same thickness as the distal implant (nine millimetres), with the low side resection being driven by the combination of the high side reference and 0° mechanical alignment. The posterior cut was positioned to take implant thickness (11 mm) from the medial femoral condyle and lateral posterior condyle resection depth being driven by rotation of the component three degrees external to the posterior condylar axis and parallel to the transepicondylar axis (where these did not match, the surgeon made a best fit between them). Sizing was performed in the same fashion as described for KA.

Following femoral resection, tibial resection was performed perpendicular to the mechanical axis of the tibia, with resection depth from the high side made to match the implant thickness.

Trial components were inserted, with laxity and range of motion testing performed. Incomplete extension was addressed via posterior capsular release and then further distal femoral resection as required to achieve full extension. Any tightness in flexion was addressed via a posterior cruciate ligament (PCL) release and then increased tibial slope if required. Coronal plane imbalances were addressed via release of either the medial or lateral capsular and ligamentous structures depending on which side was too tight and in which part of the flexion–extension cycle. The coronal plane cut of the femur and tibia was not deviated from perpendicular to the mechanical axis of each bone and balance was achieved by soft tissue releases and/or more femoral bone resection as described.

2.3. Data collection and analysis

Pre-operative patient characteristics (e.g. age, sex, date of surgery) were collected from the clinical patient files. Intraoperative data (e.g. pre- and post-operative range of motion and alignment, resection depths and alignment) was collected from the intra-operative reports and screenshots taken from the navigation system intra-operatively and cross referenced against the log files generated by the navigation system. Pre- and post-operative laxity was calculated by subtracting end coronal range of motion on varus and valgus stress (performed by the senior surgeon) at 0, 30 and 90° of flexion. This measurement was used as a measure of soft tissue tension.

The amount of implant placed in the joint was compared to the amount of bone resected from each of the medial and lateral compartments. This was calculated by the formula below:

$$\text{Difference} = 9 \text{ mm (Femoral component thickness)} + \text{Poly Thickness in mm} - (\text{Femoral resection} + \text{Tibial Resection})$$

A positive difference would indicate that on a net level, more implant was placed in the knee than bone resected, and a negative difference the opposite. The joint line may move depending on where this net difference was most pronounced (femur or tibia).

Statistical analysis was performed using R (R Core Team, New Zealand) and MiniTab Express (Minitab Inc., United States of America). Continuous variables were presented as means with standard deviations. Comparisons between the MA and KA TKA groups were made using unpaired Student's T-test with alpha set at 0.05. Proportions between these groups were made using the chi-squared test with alpha set at 0.05. Population variances were compared using the multiple comparison test with alpha set at 0.05.

3. Results

3.1. Preoperative patient characteristics

A total of 210 consecutive total knee arthroplasties were analysed consisting of 120 mechanically aligned and 90 kinematically aligned TKA cases. These were done as a consecutive series, with the vast majority of the mechanically aligned knees being performed before the surgeon changed to the kinematic philosophy.

There was no significant difference between MA and KA groups in terms of age (67.9 ± 10.7 vs. 67.0 ± 12.0 , $p = 0.58$) (Standard Deviation), proportion of male sex (37.5% vs. 38.9%, $p = 0.67$) and left side cases (52.5% vs. 62.2%, $p = 0.16$). There was also no significant difference between mechanical vs. kinematic alignment in terms of pre-operative coronal deformity (5.3 vs. 5.2°) (Figure 1), or fixed-flexion deformity (7.3 vs. 8.1°) (See Table 1). The proportion with a significant coronal ($>3^\circ$, 30.8% vs. 31.1%) or sagittal malalignment ($>15^\circ$, 5.8% vs. 8.9%) was also the same between the two groups. Pre-operative laxity on varus–valgus stress testing was similar between the two groups at 0 (1.8 vs. 2.3°) and 30° (4.6 vs. 5.3°). At 90°, knees in the KA group were more lax (2.7 vs. 4.7° , $p < 0.001$).

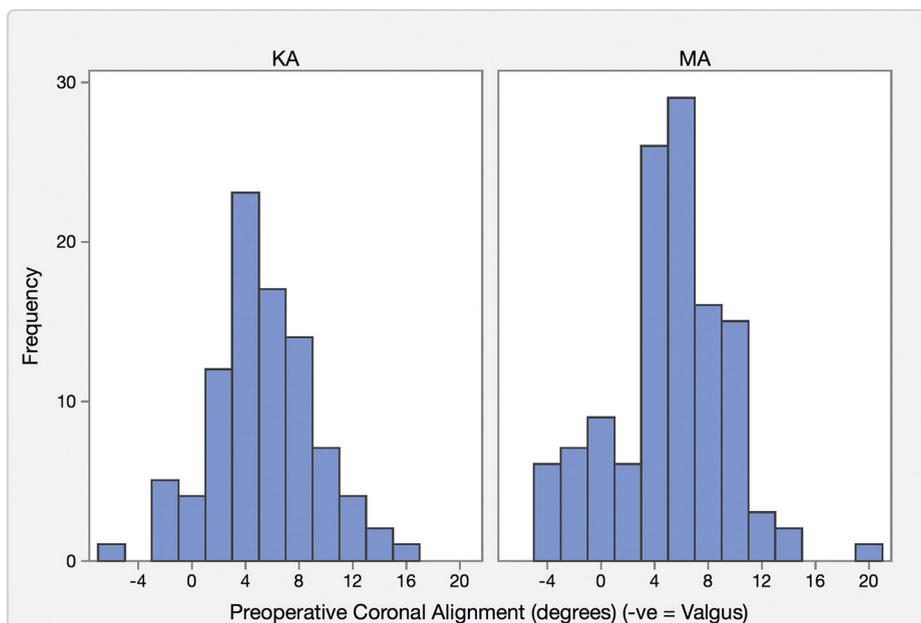


Figure 1. Histogram of preoperative alignment between mechanically aligned and kinematically aligned knees.

Table 1

Comparison of preoperative patient alignment between mechanically and kinematically aligned total knee arthroplasty (95% confidence intervals in brackets).

n	MA	KA	p-Value
	120	90	
<i>Pre-op alignment</i>			
Coronal deformity (absolute)	5.3 (0.6)	5.2 (0.7)	0.82
Coronal (varus + ve, valgus – ve)	4.3 (0.8)	4.8 (0.8)	0.77
Pre-op within 3°	30.8% (8.2)	31.1% (8.3)	0.97
Max extension	7.3 (0.9)	8.1 (0.5)	0.1
Pre-op more than 15° of FFD	5.8% (4.2)	8.9% (5.0)	0.41
<i>Pre-op laxity on stress testing</i>			
0°	2.8 (0.4)	3.0 (0.3)	0.16
30°	7.4 (0.5)	7.9 (0.5)	0.13
90°	4.5 (0.5)	4.98 (0.5)	0.17

Statistically significant result.

Table 2

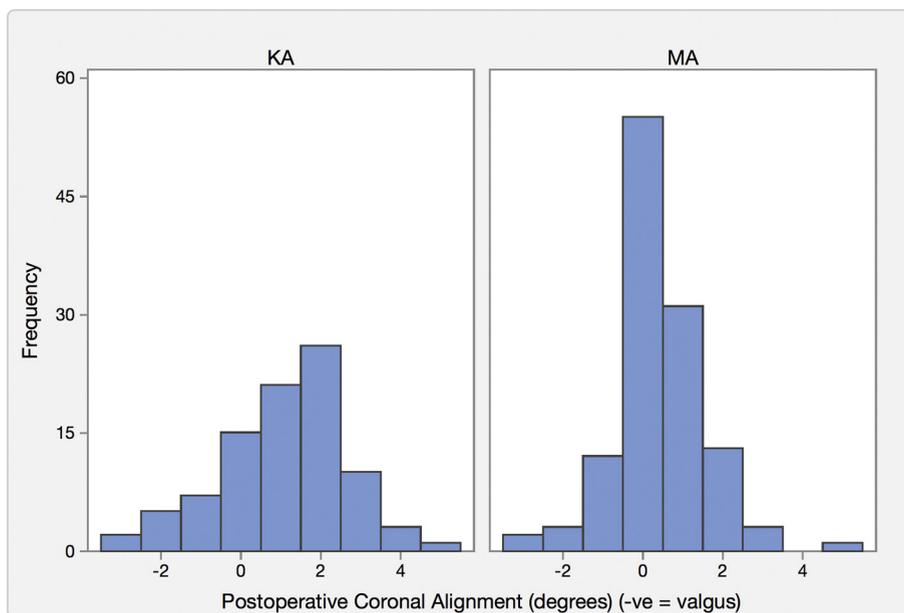
Comparison of post-operative patient alignment between mechanically and kinematically aligned total knee arthroplasty (95% confidence intervals in brackets).

Post-op alignment	MA	KA	p-Value
Coronal deformity (absolute) ^a	0.8 (0.2)	1.5 (0.2)	<0.0001
Coronal ^a	0.4 (0.2)	1.1 (0.3)	0.0007
Post-op within 3°	99.2% (2.0)	95.6% (0.2)	0.16
Max extension	–0.1 (0.3)	–0.1 (0.3)	0.99

^a Statistically significant result.

3.2. Post-operative alignment

While there was a tendency for final limb alignment to be slightly more varus in the KA group (1.5 vs. 0.8°), there was no significant difference between the two groups for the proportion having a final alignment within three degrees of neutral (95.6% vs. 99.2%) (Table 2, Figure 2). There was no significant difference between the MA and KA knees in terms of post-operative extension achieved (–0.1 vs. –0.1°) (see Table 2, Figure 3).

**Figure 2.** Histogram of post-operative alignment between mechanically aligned and kinematically aligned knees.

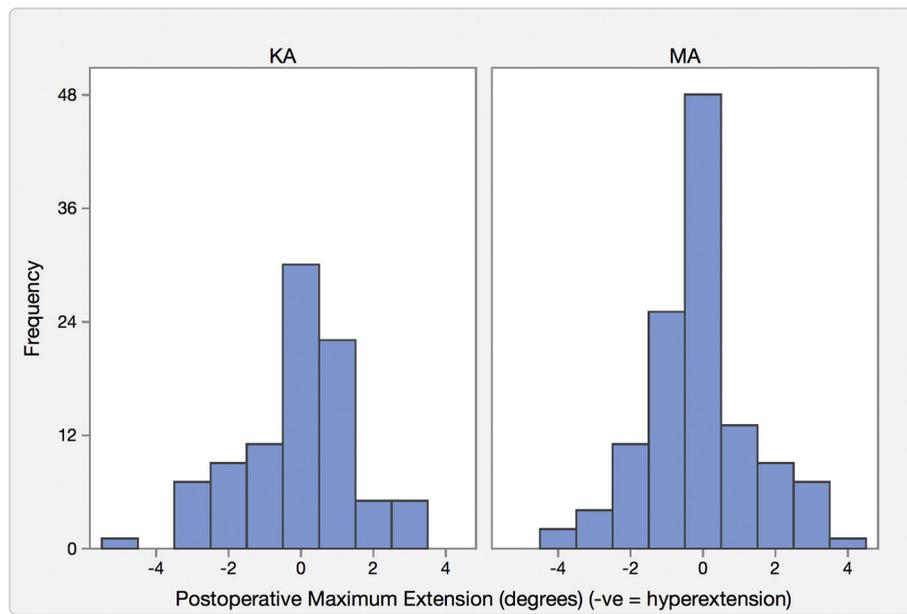


Figure 3. Histogram of post-operative maximum extension between mechanically and kinematically aligned knees.

3.3. Bony resection and soft tissue releases

In KA knees the distal femoral resection was significantly more valgus (-2.5° vs. -0.03° , $p < 0.0001$) (Figure 4) with less overall resection depth but no difference in flexion while the tibial resection was in more varus (2.3 vs. 0.3° , $p < 0.0001$) with less posterior slope (2.8 vs. 3.3° , $p = 0.01$) and less overall resection depth (8.1 vs. 9.1 mm, $p < 0.0001$) (Figure 5). The total bone resection was less for KA than for MA knees (16.7 vs. 18.9 mm, $p < 0.0001$).

There were less bony recuts of the distal femur required in KA compared to MA knees, but this was not statistically significant (0% vs. 1.7%). In the KA group, 4.4% (four) of cases required a tibial recut to allow for appropriate balancing, while there were no tibial recuts in the MA group. Significantly more soft tissue releases were performed in MA knees compared to KA (49.2% vs. 3.3% , $p < 0.0001$). This was the case for medial (35.8% vs. 3.3% , $p < 0.0001$), posterior (18.3% vs. 3.3% , $p < 0.0001$) and lateral releases

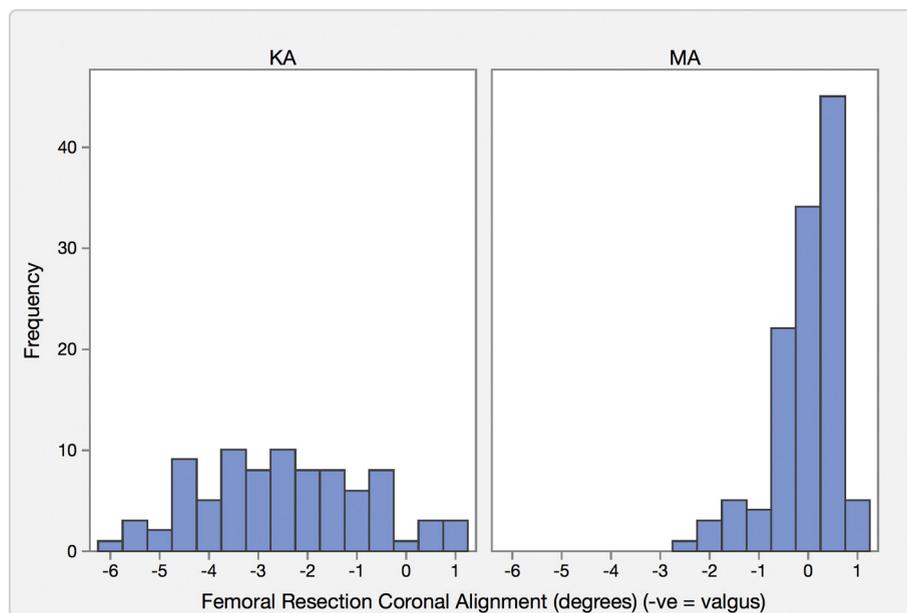


Figure 4. Histogram of coronal alignment of femoral resection between mechanically aligned and kinematically aligned knees.

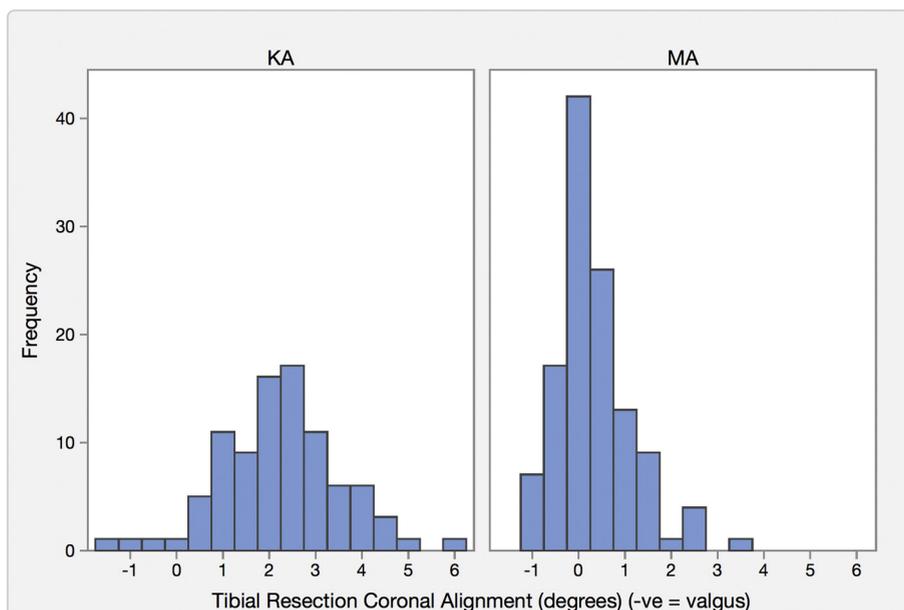


Figure 5. Histogram of coronal alignment of tibial resection between mechanically aligned and kinematically aligned knees.

(5.8% vs. 0%, $p = 0.02$) respectively (see Table 3). To make a measure of total intervention required to balance the knee after the primary cuts via combined soft tissue recuts, we see 10% in the KA group and 49.2% in the MA group ($p < 0.0001$).

There was no significant difference between MA and KA knees in terms of polyethylene insert thickness (11.1 vs. 10.9 mm), or proportion of inserts above 10 mm in thickness (43.3% vs. 37.8%).

3.4. Compartmental changes

In both groups the net result tended to be more positive but compared to MA knees, more implant was added to KA knees in both the medial and lateral compartments (Figure 6). The variance of the lateral gap change was significantly greater in MA knees compared to KA knees ($p = 0.02$). The same was observed in the medial compartment ($p < 0.0001$).

Table 3

Comparison of intraoperative steps performed between mechanically and kinematically aligned total knee arthroplasty (95% confidence intervals in brackets).

	MA	KA	p-Value
<i>Tibial cuts</i>			
Primary resection ^a	9.1 (0.2)	8.1 (0.3)	<0.0001
Varus/valgus ^a	0.3 (0.1)	2.3 (0.4)	<0.0001
Posterior slope ^a	3.3 (0.2)	2.8 (0.4)	0.01
<i>Femoral cuts</i>			
Distal resection ^a	9.95 (0.3)	8.6 (0.3)	<0.0001
Varus/valgus ^a	-0.03 (0.1)	-2.5 (0.4)	<0.0001
Flexion	1.6 (0.3)	1.2 (0.3)	0.052
Distal femoral recut	1.7% (n = 2) (0.3)	0% (0)	0.51
Sum of high tibial + high distal femoral resection	18.9 (0.5)	16.7 (0.4)	<0.0001
<i>Releases</i>			
Release performed at all? ^a	49.2% (8.9)	3.3% (3.2)	<0.0001
Balancing release/recut performed at all? ^a	49.2% (8.9)	10.1% (5.4)	<0.0001
Medial release ^a	35.8% (8.5)	3.3% (3.2)	<0.0001
Posterior release ^a	18.3% (6.9)	3.3% (3.2)	0.002
Lateral release ^a	5.8% (4.2)	0.0% (0)	0.02
Tibial recuts	N/A	4.4% (3.7)	-
<i>Poly insert</i>			
Poly thickness	11.1 (0.3)	10.9 (0.3)	0.25
Poly greater than 10 mm used	43.3% (8.9)	37.8% (8.6)	0.42
Medial difference (in vs. out) ^a	5.1 (0.6)	6.9 (0.6)	0.0001
Lateral difference (in vs. out) ^a	2.7 (0.7)	3.8 (0.6)	0.03

^a Statistically significant result.

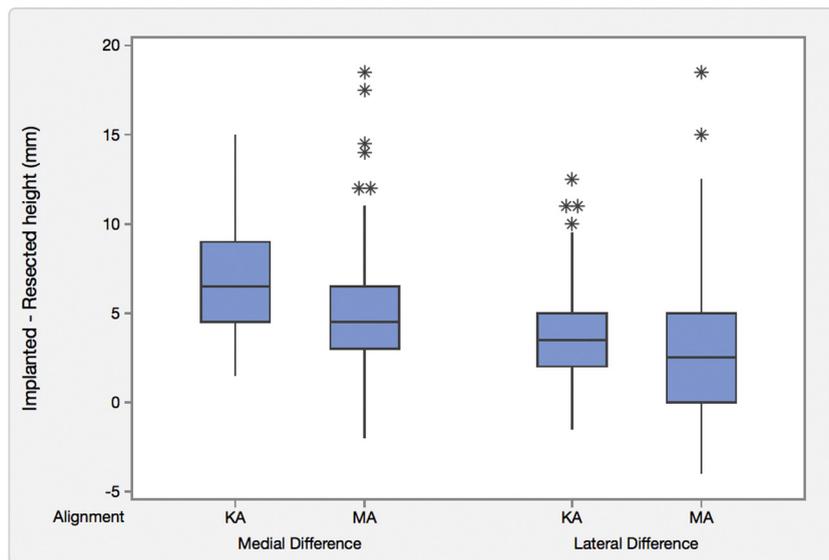


Figure 6. Comparison of compartmental change between mechanically aligned and kinematically aligned knees.

3.5. Pre- and post-operative laxity

MA TKA resulted in significant difference between pre- and postoperative laxity at 0 (2.8 vs. 1.8°), 30 (7.4 vs. 4.6°) and 90° (4.5 vs. 2.7°) of flexion on varus–valgus stress testing. On the other hand, pre- and postoperative laxity was not significantly different for KA TKA group at 0 and 90°, but was different at 30° (Table 4).

4. Discussion

This study examined the differences in component orientation, amount of bone resection, and need for soft tissue releases or bony recuts to achieve the goal of a well-balanced knee that can fully extend, using the mechanical and kinematic philosophies. We found that in the absence of any difference in preoperative deformity, age, gender and side, KA TKA was able to achieve a similar level of correction in sagittal range of motion with less distal femoral and tibial resection, and much less soft tissue releases, and required a greater net increase in joint space to avoid hyperextension compared to MA TKA. On average, there was greater increase in terms of difference in implanted and resected joint surface in both the medial and lateral compartments in KA TKA than MA TKA. KA TKA employed femoral resections placed in a more valgus position and tibial resections placed in a more varus position compared to MA TKA. However, while KA TKA knees had slightly greater varus final limb alignment compared to MA TKA knees, overall there was no significant difference between them, and more than 95% were within three degrees of neutral even in the KA group.

KA TKA has been shown to be a viable alternative to MA TKA, with equivalent if not slightly better outcomes published in the literature overall. Specifically, KA TKA has been shown to result in better functional outcomes and shorter operative times compared to MA TKA [15,31]. The results of our study add to this body of work, showing that KA TKA is able to correct sagittal deformities with less bony resection and soft tissue releases to achieve the same amount of correction to full extension compared to MA TKA.

A lesser requirement for soft tissue release is advantageous for a number of reasons. As the soft tissues around the knee joint are integral in proprioceptive function and to maintain balance [32], avoiding releasing or interfering with these structures could

Table 4

Comparison of pre- and post-operative laxity on varus–valgus stress testing at 0, 30 and 90° of flexion in mechanically and kinematically aligned knees.

	Pre-operative laxity (degrees, SD in brackets)	Post-operative laxity (degrees, SD in brackets)	p-Value
<i>Mechanical alignment</i>			
0° ^a	2.8 (2.3)	1.8 (1.6)	0.01
30° ^a	7.4 (2.6)	4.6 (2.1)	<0.0001
90° ^a	4.5 (2.7)	2.7 (1.6)	<0.0001
<i>Kinematic alignment</i>			
0°	3.0 (1.6)	2.3 (2.0)	0.06
30° ^a	7.9 (2.2)	5.3 (2.4)	<0.0001
90°	4.98 (2.3)	4.7 (3.2)	0.49

^a Statistically significant result.

optimise joint function, accelerate patient rehabilitation and result in a more normal feeling knee with higher patient satisfaction. Avoiding soft tissue releases is beneficial as the lesser degree of trauma may result in less pain and swelling experienced post-operatively by the patient, allowing for faster recovery and better outcomes. Additionally, soft tissue releases are difficult to quantify compared to measured bone resections, and therefore minimising soft tissue releases could lead to a more standardised approach to TKA, with the potential to develop quantified predictive models to guide intraoperative decision making.

The second advantage of the KA philosophy identified by this study is less bone resection being required to achieve the same goals of full extension and a balanced knee. This results in greater bone stock preservation, which would be advantageous in case future revision is required. Lesser bony resection would mean a lower risk of changing the native joint line, thereby optimising range of motion and reducing component wear and postoperative patient pain [33]. Excessive distal femoral resection has also been associated with dysfunction of the patellofemoral and tibiofemoral articulations and poorer clinical scores, all of which would be avoided with minimised bony resection [34]. A lower requirement for bony resection would suggest a minimised need for distal femoral re-cuts required to achieve full extension, which, although not statistically significant, was indeed the case in this study. This combined with the avoidance of soft tissue releases to balance the knee may have resulted in the decreased intraoperative time, which was not studied in this paper but has previously been demonstrated in the literature [15].

In our cohort, KA reduces the need for soft tissue release from 49% to 10% and decreases the amount of bony resection. This minimises the potential for errors to be made performing releases, which are difficult to perform in a reproducible, quantifiable fashion, and are associated with instability [35]. We hypothesise KA TKA is able to achieve this due to the greater degree of preservation of the patients' pre-operative anatomy, including the soft tissue envelope, which may be similar to their native, disease-free state. MA TKA may distort more of the native soft tissues, placing them on stretch or at maximum excursion (tight) in various positions short of full extension. This is necessary with MA philosophy because of the forced positioning of the implant perpendicular to the mechanical axis even when the patients' native joint line does not share this orientation. A natively valgus knee with bony resections performed as per mechanical alignment would relatively under-resect the lateral compartment, resulting in a tight lateral ligament complex (as well as disturbing the physiological laxity of the medial compartment) [36]. This not only causes coronal imbalance, but also prevents the joint from achieving full extension, therefore necessitating a lateral release [37]. By maintaining pre-operative articular surface alignment, KA TKA produces conditions which allow the patients' native soft tissues to maintain tension at a level close to that of their disease-free state and achieve full extension before becoming fully taut, as well as allowing for native coronal balance.

The rates of soft tissue release encountered in this study in the MA TKA group are higher than other reported rates employing MA TKA and computer navigation. Previous studies quote collateral ligament release rates in MA TKA of two to 25% [38–40], with reported rates of 50 to 100% also postulated [39]. This variation may result from the fact that most of these studies, including our own, were small case series, but may also result due to surgeon preference and practice in fine tuning knee balance. Our study investigated soft tissue release in a single surgeon's cohort, with a demonstrable reduction in soft tissue release required.

Our comparison of pre- and post-operative laxity on varus–valgus stress of the knee preliminarily supports the notion that KA TKA preserves the pre-disease soft tissue envelope. We demonstrated that MA TKA significantly alters soft tissue balance at the 0 and 90 degree mark (while KA TKA does not significantly alter laxity at this range), overall resulting in a tighter varus/valgus envelope. However, both MA and KA TKAs were associated with less laxity postoperatively at 30°. Future study should further elucidate and validate our findings, preferably with *in vivo* testing using soft tissue tensometers.

4.1. Limitations

There are a number of limitations which may hinder the validity of our results. Our study was retrospective, and so the identified relationships in this study need to be further evaluated, preferably in the setting of a randomised controlled trial comparing MA and KA TKA. We used laxity of the knee on varus/valgus stress as a measure of soft-tissue tension – this is a non-quantified technique which will have different results depending upon how much force is applied. While we could not measure this force, having all cases performed by a single surgeon goes some way to standardising this measure across patients, but further studies may benefit from tensometers or pressure measurements. Furthermore operative time was not available for analysis and would be useful when comparing MA vs. KA in future study. Future study should aim to quantify soft tissue balance with tensometers. As only a small proportion of patients had more extreme FFD ($>15^\circ$), we should be cautious in extrapolating our findings to this population. Finally, it remains unclear as to whether our findings translate into improved clinical outcome, due to limited patient follow-up with regard to patient reported outcome measures. However, the main goal of this study was comparing the efficacy and efficiency of MA and KA philosophies in TKA on the intra-operative correction of FFD. The relationship between these differences and their effect on patient reported outcome measures (PROMs) needs to be investigated in further study.

5. Conclusions

This study shows that using a kinematic alignment philosophy results in the achievement of full extension with less bone resection, less soft tissue release, and no difference in final overall limb alignment compared to mechanical alignment. Future study should verify this relationship with prospective data and a larger dataset, and should link this relationship to patient reported outcome measures.

Conflicts of interest/funding statement

There were no direct conflicts of interest to report with regard to this study. There was no funding for this study. The other potential conflicts of interests are declared below:

Vincent VG An – None

Joshua Twiggs – Is a paid employee of 360 Knee Systems

Murilo Leie – None

Brett Fritsch

- Holds shares in 360 Knee Systems and Arthrex
- Has not received any royalties
- Has done consulting work for Arthrex.

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