1. **LUO Z, ZHOU K, PENG L, SHANG Q, PEI F, ZHOU Z.**

**SIMILAR RESULTS WITH KINEMATIC AND MECHANICAL ALIGNMENT APPLIED IN TOTAL KNEE ARTHROPLASTY. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2019 JUN 27.**

**Abstract**

**PURPOSE:**

This meta-analysis compared the results of kinematic alignment (KA) and mechanical alignment (MA) applied in total knee arthroplasty (TKA).

**METHODS:**

Randomized controlled trials and cohort studies comparing functional, radiological, and perioperative results and complications in TKA with KA and MA were collected from databases and included in the analysis.

**RESULTS:**

Nine trials were included. KA showed a better performance in terms of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (mean difference [MD] =  - 9.06, 95% confidence interval [CI] - 14.69, - 3.42) and Oxford knee score (OKS) (MD = 4.72, 95% CI 0.24, 9.21); however, the Knee Society score (KSS), knee injury and osteoarthritis outcome score (KOOS), EuroQoL 5-dimension questionnaire (ED-5D), range of motion, and complications were similar for KA and MA (n.s.). KA resulted in slightly more varus alignment in the tibia [mechanical medial proximal tibial angle (mMPTA) MD = - 2.45, 95% CI - 2.89, - 2.01) and more valgus alignment in the femur (mLDFA MD = - 2.06, 95% CI - 2.48, - 1.65) than MA (P < 0.05), but showed similar results in terms of the joint line orientation angle (JLOA) (MD = 0.54, 95% CI - 2.59, 3.66), hip-knee-ankle angle (HKA), anatomical knee angle (AKA), femoral flexion-extension angle (FFA), and tibial slope (TS). The preoperative results, including the incision length, hospital stay, and changes in hemoglobin, were also similar.

**CONCLUSION:**

KA achieved functional, radiological, and perioperative results similar to those of MA and did not increase the complication rate. KA is an acceptable and satisfactory method for application in TKA.

**LEVEL OF EVIDENCE:**

III.

1. **TAKAHASHI T, ANSARI J, PANDIT HG.**

**KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY OR MECHANICALLY ALIGNED TOTAL KNEE ARTHROPLASTY. J KNEE SURG. 2018 NOV;31(10):999-1006.**

**Abstract**

Kinematically aligned total knee arthroplasty (KATKA) was developed to more anatomically align the knee prosthesis to restore the native alignment of the knee and promote physiological kinematics. Even though there are concerns with implant survival, and follow-up at 10 years or more after KATKA has not been reported, there is a negligible incidence of failure of a tibial component at 2 to 9 years. Early clinical results with this technique are encouraging and demonstrate better functional outcomes compared with mechanically aligned TKA (MATKA). The purpose of this study is to perform a systematic review and meta-analysis of the literature to determine whether there are any clinical differences between KATKA and MATKA. The authors conducted a systematic review of the English literature. Five randomized controlled trials (RCTs) which compared clinical outcomes of KATKA and MATKA were finally included. Four RCTs used patient-specific instrument, and one RCT used navigation. Data were extracted and meta-analysis was conducted. KATKA patients had better outcomes: Mean difference between KATKA and MATKA and p-value are presented in brackets after each variable: the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (-12.5; p < 0.0001), Oxford Knee Score (OKS) (2.3; p = 0.030), combined Knee Society Score (C-KSS) (13.1; p < 0.0001), Knee Function Score (KFS) (6.4; p = 0.0070), and postoperative range of motion (ROM) (4.1°; p = 0.0010). There was no significant difference concerning the complication rates which needed reoperations or revision surgery (odds ratio, 1.01; p = 0.99). KATKA components had a more femoral valgus (-1.8°; p < 0.0001), more tibial varus (1.2°; p = 0.0001), and more tibial slope (1.2°; p = 0.0001), all being statistically significantly different. Better clinical outcomes were obtained in KATKA and component placement in KATKA is significantly different from that in MATKA. There was no increase of patients with poor clinical results due to implant position especially for varus placement of tibial component. This systematic review of five RCTs suggests that KATKA is of potential alternative method to MATKA since the risk of revision for tibial loosening is negligible compared with MATKA for the same follow-up period.

1. **RIVIÈRE C, LAZIC S, VILLET L, WIART Y, ALLWOOD SM, COBB J.**

**KINEMATIC ALIGNMENT TECHNIQUE FOR TOTAL HIP AND KNEE ARTHROPLASTY: THE PERSONALIZED IMPLANT POSITIONING SURGERY. EFORT OPEN REV. 2018 MAR 29;3(3):98-105.**

**Introduction**

In the 20th century, Sir John Charnley and Sir John Insall successfully introduced modern total joint replacements for hips (THA) and knees (TKA), respectively. In order to prevent implant fixation failure and accelerated polyethylene wear, it was initially recommended that implants were positioned in a ‘biomechanically friendly’ way, which disregarded most of the individual patient anatomy.1-5 Therefore, knee implants were aligned perpendicular to the femoral and tibial mechanical axes2,3 and the acetabular cup component was medialized as much as possible.1,4,5 A few years later, Lewinnek et al6 recommended that the acetabular cup was radiographically positioned with 40° inclination and 20° anteversion, as they found it reduced the risk of prosthetic hip dislocation. While those initial surgical techniques made for popular and clinically successful total joint replacements, many complications have remained, most notably the functional limitations after TKA7 and the persistence of frequent instability after THA.8 In response to those complications, many improvements were developed in the field of joint replacement over the last few decades, moving away from these conventional methods of positioning to more personalized techniques, namely kinematically aligned (KA) THA9 and TKA.10

This instructional review aims, in the first half, to outline the rationale and clinical outcomes of conventional implant-positioning surgical techniques for TKA and THA and then, in the second half, to describe the newly promoted more personalized techniques (kinematic alignment).

Conventional techniques for hip and knee replacement: rationale and limitations

Conventional technique for TKA

For decades, knee components have been positioned following the concept of mechanical alignment (MA), where implants are aligned perpendicular to the femoral and tibial mechanical axes in order to create a straight lower limb with a prosthetic tibio-femoral joint line (TFJL) perpendicular to the overall limb mechanical axis. Also, the femoral component is expected to be frontally and axially aligned with the trans-epicondylar axis, which then becomes the prosthetic flexion-extension axis, and the flexion and extension gaps are made, sometimes through the need for soft-tissue release, rectangular and identical in every knee2,3.Every patient implanted with a MA TKA receives similar implant positioning, despite the fact that each patient has different constitutional knee anatomy (obliquity of the native TFJL, alignment of the native knee). This technique enables protection of each implant’s fixation and surface bearing by reducing the knee adduction moment and by more evenly sharing the loading between medial and lateral tibial plateaus.1 All of these things aim to optimize long-term implant survivorship. Also, it aligns the extensor mechanism, which reduces the risk of patella instability.2,3

Comparison between KA TKA and MA TKA. In KA TKA, the posterior femoral cut (red) is made parallel to the posterior condylar line (dotted blue). In comparison, in MA TKA, the femoral cut is made with 3° external rotation relative to the posterior condylar line (measured resection) or parallel to the tibial cut (dotted red – gap balancing) which is perpendicular to the mechanical axis of the tibia (solid blue).

Besides these biomechanical advantages, there remain some inconveniences related to the disregard for individual knee anatomy: first, changing the lower limb and joint line alignment often leads to the need for technically demanding, and therefore poorly reliable, soft-tissue balancing;2,11 second, a high rate of lateral trochlea facet and distal condyle overstuffing, potentially responsible for clinically deleterious lateral retinacular stretching and patella mal-tracking;12 and third, abnormal tibiofemoral (TF) and patella-femoral joint (PFJ) kinematics.13 These drawbacks might explain why MA TKAs have remained overall functionally disappointing with high rates of residual symptoms (an average of 50%)7 despite the many improvements in surgical precision and knee implant design.14-17.

For decades, it was recommended that the prosthetic hip centre of rotation be medialized relative to the native centre of rotation by medialization of the acetabular component and a compensatory increase of femoral offset.4,5 The rotation is mainly biomechanical, as this reduces the joint reaction force secondary to a reduction of the abduction moment from the abductors,4,18 thus reducing the risk of early implant loosening and accelerated polyethylene liner wear. This concept has generated good long-term implant survivorship.19

Since 1978, the prosthetic cup orientation has been recommended to be at 40° inclination and 20° anteversion (Lewinnek box) relative to the anterior pelvic plane (Lewinnek plane), as this was shown to reduce the risk of prosthetic dislocation.6 Because the native acetabular orientation varies in the population,20,21 a similar prosthetic orientation for all patients is rarely likely to reproduce their constitutional acetabular anteversion, either anatomical or functional, and their functional cone of hip mobility (Fig. 2). As the soft tissues around the hip tend to limit the motion of the hip within its physiological cone of mobility,22,23 this positioning (disregarding the individual acetabular anteversion) is likely not to be optimal and therefore sometimes generates complications such as articular impingement and prosthetic instability.24,25

Personalized techniques for total joint replacement: the kinematic revolution

Kinematic alignment technique for TKA

Following the results of a few studies suggesting that the standing post-operative limb alignment was of poor predictive value for clinical outcomes for patients with MA TKA,26 the idea of preserving the constitutional knee alignment arose.

Since 2007, Howell et al have promoted the KA technique for TKA,10 which aims at restoring the native three-dimensional (or constitutional) anatomy of the TFJL and at aligning the implants with the kinematic axis of the knee, namely the cylindrical (or trans-condylar) axis,13 around which the tibia flexes and extends around the femur. In simplistic terms, the KA technique is almost a true resurfacing of the TFJL, where implant thickness aims to replace the exact same amount of ‘bone cartilage’ removed and therefore to restore the highly variable individual native pre-arthritic (or constitutional) TFJL orientation27,28 and soft-tissue laxity.28-30 It is important to understand that the KA technique is not a modification of the MA technique, but rather a new surgical technique for TKA, with only the sagittal positioning of the femoral component shared with the MA technique. The KA technique, like the MA technique, can be performed with the use of navigation31 or patient-specific instrumentation32 or manual instrumentation.33

Current evidence has shown this personalized technique performs better early on than the MA technique for TKA. Five randomized studies32,34-38 have shown the KA TKA to provide faster recovery than MA TKA, and a meta-analysis39 concluded that KA TKAs provide better functional outcomes and similar complication rates compared with MA TKA at two-year follow-up. Also, a prospective cohort study40 and a systematic review41 found the KA technique to generate excellent overall outcomes up until six years of follow-up. Longer-term outcomes are needed in order to define the best indication for the KA technique, as it is likely some patients would not benefit from restoration of their constitutionally extreme ‘patho-anatomy’.42

Kinematic alignment technique for THA

Technological developments enabling more precise surgery (computer-assisted surgery, robotics43) and improvement in implant design and quality (wear-resistant surface bearings,44 biological implant fixation) have enabled the progressive evolution of THA towards a more anatomical technique aiming to better restore the native hip centre of rotation5 and acetabular anteversion (Fig. 2).45,46 A technique for aligning the prosthetic cup parallel to the transverse acetabular ligament (TAL), and therefore allowing a personalized cup position, has recently been promoted with high safety and efficacy regarding dislocation risk.45,46 However, despite more personalized cup positioning and improvements in implant tolerance (larger head-neck ratio design to prevent articular impingement, larger head to increase the jumping distance), prosthetic instability remains a concerning complication and one of the main causes of early revision after THA.8,45

There are two types of abnormal lumbopelvic sagittal kinematics which may influence complications after THA.9 The first one is related to insufficient pelvic retroversion when sitting or squatting (type 1)9,47-51,61 and the second is a consequence of ageing of the spine where the pelvis becomes progressively more retroverted when standing (type 2).52,53 Patients with one of these aforementioned abnormal types of pelvic kinematics or an abnormally low pelvic incidence (< 35°) are therefore affected by a clinically deleterious lumbopelvic stiffness.54-60 This generates aberrant functional acetabular orientation in sitting/squatting9,47-51,61 or standing positions.59,62 A compensatory effect by the use of a larger hip range of motion makes these patients ‘hip users’9. With THA, this lumbopelvic stiffness might be responsible for some complications such as prosthetic instability9,55,57 and/or edge-loading.50 Sagittal pelvic kinematics can be estimated in daily practice through standing and sitting lateral lumbopelvic images, either with conventional radiographs or EOS images63-65 (EOS imaging system®, Biospace®, Paris, France).

The concept of KA THA9 consists of restoring the constitutional hip anatomy (proximal femur anatomy and acetabular centre of rotation) and taking into account the individual sagittal lumbopelvic kinematics in order to plan the implant design (cup and head size), the acetabular cup orientation (using the TAL19,46) and the need for spinal surgery to correct a severe sagittal imbalance .The more stiff a lumbopelvic complex is, the more it seems sensible firstly to use a large diameter femoral head24,25,66,67 or dual mobility cup with a mobile liner68,69 which are more tolerant to articular impingement and edge loading, and second to adjust cup positioning relative to the TAL19,46 in order to partially correct the abnormal functional cup positioning that would have resulted in anatomic positioning9,58,59,61 (Table 2). To illustrate, it might be sensible to implant an elderly patient with severe abnormal type 2 pelvic kinematics with a dual mobility cup implanted with anatomic anteversion (parallel to the TAL) or maybe slightly reduced (Table 2). If the same type 2 kinematic abnormality was seen in a younger patient, it might be more reasonable to use a 36 mm diameter head and to adjust the cup using the TAL19,46 with reduced anteversion and inclination (Table 2). Although more high-quality randomized controlled trials are needed to establish the safety and effectiveness of KA THA, in the author’s (CR’s) experience with > 150 KA THAs, no adverse clinical or aberrant radiographic features in this cohort have been observed.

**Conclusion**

Both KA and conventional implant positioning have different advantages and disadvantages. The main advantage of conventional positioning is that it has a well-established, large evidence base regarding complications such as polyethylene wear in TKA1,3 and dislocation in THA,6 for example. However, the main disadvantage with conventional positioning is that it ignores individual variation in anatomy/kinematics, although it remains unclear whether restoring extreme native ‘patho-anatomy’ would be of benefit for every patient.42 Even though KA TKA has shown promising early outcomes so far,32,34-41 further research is still needed (for KA THA and KA TKA) to determine the true value and role of ‘personalized’ implant positioning.

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1. **RIVIÈRE C, LAZIC S, BOUGHTON O, WIART Y, VÏLLET L, COBB J.**

**CURRENT CONCEPTS FOR ALIGNING KNEE IMPLANTS: PATIENT-SPECIFIC OR SYSTEMATIC? EFORT OPEN REV. 2018 JAN 8;3(1):1-6.**

**Introduction**

Knee arthroplasty surgery is becoming more common with an increasing prevalence of osteoarthritis (OA) and increasing life expectancy.1 Knee arthroplasty can be either partial (PKA) or total (TKA), depending on the extent of joint disease, with both approaches having shown favourable long-term survivorship and functional outcomes.2,3 However, by comparison with total hip arthroplasty, TKA provides overall inferior functional outcomes with a high prevalence of residual symptoms and lower patient satisfaction.4-6 Technological advances leading to better implant design and surgical precision have unfortunately not helped to significantly improve TKA patients’ functional outcomes.7,8 Considering this and other improvements such as better wear-resistance with modern polyethylene and better cementation, some authors have started to challenge the basics of the mechanical alignment (MA) technique and recently developed and tested more anatomy-friendly techniques for TKA.9 Because the optimal knee soft-tissue tension10 and component alignment in TKA remain a matter of debate,9 this instructional review aims to classify the multiple techniques (systematic, patient-specific and hybrid alignment techniques) for knee implant positioning (Fig. 1) and to summarize the evidence behind each one.

Systematic alignment techniques for knee arthroplasty

A systematic implant positioning results in implants being always positioned in the same way for every patient, which disregards patient-specific knee joint anatomy. This has been described as ‘biomechanically-friendly’. In order to optimize implant survivorship by reducing the risk of accelerated polyethylene wear, early implant loosening and patella instability, the recommended positioning for TKA implants has been to create a straight limb with a perpendicular tibiofemoral joint line (TFJL). In order to do so, as initially described by Insall et al, implants were systematically positioned perpendicular to the mechanical axis of the femur and tibia in the frontal plane.11,12 This systematic positioning, the MA technique, does not take into account patient-specific knee anatomy and generated a similar biomechanically-friendly but non-physiological prosthetic knee geometry for almost every patient. Traditionally, the axial rotational alignment of the femoral component was suggested to be systematically externally rotated 3° relative to the posterior condylar line (measured resection technique) in order to compensate for the frequent varus orientation (3° on average in the Caucasian population) of the proximal tibia joint line.12 However, because the proximal tibia joint line orientation varies between patients, this frequently resulted in the necessity for balancing a non-rectangular flexion gap. However, the technical demands of properly balancing a TKA and the frequently observed post-operative clinically deleterious knee imbalances generated by this conventional technique3,13 led to the development of the gap-balancing technique to adjust the axial rotational alignment of the femoral component.14

Patient-specific femoral implant rotation enables adjustment of the flexion gap to equal the extension gap and therefore significantly improves the prosthetic knee balance. Unfortunately this technique does not respect the physiological lateral knee laxity, which seems to be beneficial for knee biomechanics and potentially for clinical TKA outcomes.15

Because the average TFJL frontal orientation in the population is 3° valgus,16,17 a technique for positioning TKA implants trying to create a systematic 3° valgus orientated TFJL, namely the anatomical alignment (AA) technique,18 was developed in parallel with the MA technique. The goal of this technique is to simplify human anatomy by aiming at the mean value for all patients with the theoretical advantage (compared with the MA technique) of reducing the risk of stretching the lateral retinaculum during deep flexion and therefore potentially reducing the risk of anterior knee pain and abnormal patellar tracking by optimizing the patella biomechanics.19 Hungerford, Kenna and Krackow18 promoted this philosophy in the 1980s; however, the poor precision of initial instrumentation, which risked ending up with supposedly clinically deleterious excessive varus orientation of the tibial implant,20,21 limited its widespread use. Over the last decade, new implant designs with a built-in oblique TFJL have been developed, and their mechanical positioning enables the creation of a systematic oblique TFJL, reproducing the effect of the AA technique.22-24 The MA of those new implants therefore generated an AA-like technique with MA bone cuts. Published results using the AA and AA-like techniques have shown good mid- to long-term results.18,23,24 However, there is still no definitive scientific evidence that the AA technique provides improvement compared with the traditional MA technique.25,26

As the recommended frontal alignment with MA technique is neutral (0°+/-3°)27 and constitutional limb alignment in the population varies from valgus to varus,17 the idea of aligning the TKA to slightly reproduce the constitutional limb deformity was promoted.28-31 To achieve this goal, an adjustment relative to the frontal mechanical axis of the femur with the femoral component positioning in slight (2° to 3°) varus (patient with constitutional varus limb) or slight valgus (patient with constitutional valgus limb) while keeping the tibial component perpendicularly aligned to the frontal mechanical axis of the tibia has been proposed.28-31 This approach could be thought of as a hybrid technique, as it is an adjusted version of the MA technique (aMA) aiming at respecting more of the patient’s anatomy and therefore at helping to obtain ligamentous balance in extension. One study reported excellent functional outcomes with aMA-TKAs for patients with constitutionally varus knees,30 and another has shown good long-term clinical outcomes for patients with constitutionally valgus knees.31

Kinematic alignment (KA) technique for TKA

Following the results of a couple of studies suggesting that the standing post-operative limb alignment was of poor value in predicting clinical outcomes for patients with prosthetic knees,27,28 the idea of preserving the constitutional knee alignment has arisen. The concept of preserving the entire constitutional knee alignment has been developed by Howell and Hull32 since 2007 with the KA technique. KA aims to respect the 3D anatomy of the TFJL and aims at aligning the implants with the kinematic axis of the knee around which the tibia moves around the femur. Put simply, the KA technique is a true resurfacing of the femorotibial joint aiming at restoring its pre-arthritic (or constitutional) articular surfaces and soft-tissue laxity.32 It is important to understand that the KA technique is not an adjustment of the MA or AA techniques, but rather a new surgical technique for TKA, with nothing in common with the MA technique except the sagittal positioning of the femoral component. The KA technique can be performed with the use of navigation33 or patient-specific instrumentation,34 or manual instrumentation using the measured resection technique.35 Recently, implant manufacturers have developed specific KA manual instrumentation.35 A prospective cohort study36 and a systematic review37 found that the KA technique generated excellent overall outcomes up until six years follow-up. Randomized controlled trials comparing MA and KA TKA have shown faster recovery with KA TKA,34,42 no significant difference in complications38-40 and significant early (one to two years average follow-up) clinical improvements with KA TKA using patient-reported outcomes such as Oxford Knee Scores and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) Scores.34,38,40,42 A meta-analysis43 also concluded that KA TKAs provide a better functional outcome (Oxford Knee Score and Knee Society Score) and a similar complication rate compared with MA TKA at two years of follow-up. Longer-term outcomes are needed in order to define the best indication for the KA technique as it is likely that some patients with extreme variation in constitutional knee anatomy (severe pathoanatomy) may not benefit from restoring it.44

UKA – another way of restoring constitutional knee anatomy and kinematics

Although it is widely accepted that generalized (tricompartmental) OA is best treated with TKA, OA localized to one or two compartments can be treated with either PKA or TKA.2,45 For varus patients with medial TF OA, replacing the disease-free lateral TF and patellofemoral compartments, and potentially removing the anterior and posterior cruciate ligaments, alter the knee kinematics and proprioception.46 Therefore, partial knee resurfacing techniques confined to the damaged and symptomatic compartments have been suggested.47,48 These ligament- and bone-sparing methods attempt to restore the constitutional knee anatomy (like KA TKA), improve knee stability and preserve joint proprioception.49

Studies have shown excellent functional outcomes and long-term survival after medial UKA with minimal wear, even in the context of constitutional deformity.45,50,51-54 Therefore, indications for medial UKA have been progressively widened, with constitutional frontal limb deformity no longer being considered a contraindication, and UKA is now being estimated to be a valuable treatment option for 30% to 80% of patients requiring a knee arthroplasty.45 However, the reality is that PKA usually represents less than 10% of a surgeon’s knee arthroplasties, mostly due to the surgeon’s preference,55 their fear of having an increased revision rate50,56 and the different ways of interpreting the current literature.50 Surprisingly, although medial UKA results in better clinical outcomes compared with MA TKA, with better efficacy (faster recovery, better functional scores, higher satisfaction) and safety (lower rates of morbidity and mortality and fewer complications),38,39,45,50,53 national joint registries still show a substantially higher revision rate for medial UKA compared with MA TKA.5,56,57 This is mainly because UKA fixation may be more challenging (small implant surface), because of disease progression in other native compartments and because a medial UKA is easier to revise compared with a TKA, and therefore surgeons have a lower threshold for revising a UKA (for a similar disappointing functional outcome, UKAs are more likely to be revised than TKAs).50,57

Hybrid alignment techniques for knee arthroplasty

Patients can have wide-ranging variation in knee anatomy and performing KA TKA can lead to a high rate of limb alignment and implant positioning which would traditionally be considered as at risk of failure.39 Therefore, some cautious authors33 have described performing a KA TKA when there was no significant pathoanatomy (constitutional limb and TFJL alignments) while slightly correcting in more severe cases, by adjusting the position of either the tibial or femoral component and following a specific algorithm.58 In doing so, it is hoped that a patient’s supposed safe range of alignment will be achieved; a hip-knee-ankle angle within 3° (varus or valgus) and frontal implants positioning within 5° of femoral or tibial mechanical axis.33,58 This technique has been referred to as restricted KA (rKA) (as authors restrict the indication of a full KA technique)58 and has been shown to generate good early clinical outcomes.33 Surgeons willing to do the rKA technique need to assess the patient’s anatomy (limb alignment, joint line obliquity) pre- or intraoperatively, in order to adjust the positioning of implants if needed. The rKA technique is therefore best performed with the use of intraoperative computer-assisted navigation or with the use of preoperative planning and the subsequent generation of patient-specific instruments.33

**Conclusions**

The positioning of knee implants and the ‘systematic approach’ (patient’s anatomy adapted to a fixed implant orientation) versus the ‘patient-specific approach’ (implant positioning to replicate the pre-arthritic patient’s anatomy) is currently largely debated. Systematic and biomechanically-friendly alignment techniques such as the MA and AA techniques have successfully demonstrated good long-term survival but with some functional limitations. The patient-specific and anatomically-friendly KA technique has emerged and has shown promising results; however, this technique might not be suitable for extreme anatomical variants which may be considered as pathoanatomies. In the latter situation, the hybrid rKA technique seems to be an attractive option. However, alignment and implant orientation probably only explain in part some of our unsatisfactory TKA results, as patient’s preoperative disease status and chronic pain syndrome installation may also play a significant role. Also, in all TKAs, whatever the technique of positioning, significant anatomical and kinematic modifications are made secondary to meniscus removal, changing the conforming cartilaginous surface to a rigid polyethylene, removal of cruciate ligament(s) with compensatory implant design(s) (central post, polyethylene lips and congruency, etc), which make it very challenging to restore normal knee function. Further research is needed to improve functional outcomes of TKA by defining the true value and best indications for each alignment technique and implant design.

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1. **WOON JTK, ZENG ISL, CALLIESS T, WINDHAGEN H, ETTINGER M, WATERSON HB, TOMS AD,YOUNG SW.**

**OUTCOME OF KINEMATIC ALIGNMENT USING PATIENT-SPECIFIC INSTRUMENTATION VERSUS MECHANICAL ALIGNMENT IN TKA: A META-ANALYSIS AND SUBGROUP ANALYSIS OF RANDOMISED TRIALS. ARCH ORTHOP TRAUMA SURG. 2018 SEP;138(9):1293-1303.**

**Abstract**

**INTRODUCTION:**

Kinematic alignment (KA) in total knee arthroplasty (TKA) matches component position to the pre-arthritic anatomy of an individual patient, with the aim of improving functional outcomes. Recent randomised controlled trials (RCTs) comparing KA to traditional neutral mechanical alignment (MA) have been mixed. This collaborative study combined raw data from RCTs, aiming to compare functional outcomes between KA using patient-specific instrumentation (PSI) and MA, and whether any patient subgroups may benefit more from KA technique.

**MATERIALS AND METHODS:**

A literature search in PubMed, EMBASE and Cochrane databases identified four randomised controlled trials comparing patients undergoing TKA using PSI-KA and MA. Unpublished data including Western Ontario McMaster Universities Arthritis Index (WOMAC) and Knee Society Score (KSS) were obtained from study authors. Meta-analysis compared MA to KA change (post-op minus pre-op) scores. Subgroup-analysis on KA patients looked for subgroups more likely to benefit from KA and the impact of PSI accuracy.

**RESULTS:**

Meta-analyses of change scores in 229 KA patients versus 229 MA patients were no different from WOMAC (mean difference 3.4; 95% confidence interval - 0.5 to 7.3), KSS function (1.3, - 3.9 to 6.4) or KSS combined (7.2, - 0.8 to 15.2). A small advantage was seen for KSS pain in the KA group (3.6, 95% CI 0.2-7.1). Subgroup-analysis showed no difference between varus, valgus and neutral pre-operative alignment groups, and those who did and did not achieve KA plans. Pain-free patients at 1-year were more likely to achieve KA plans.

**CONCLUSION:**

Patient-reported outcome scores following TKA using PSI-KA are similar to MA. No identifiable subgroups benefited more from KA, and long-term results remain unknown. Inaccuracy of the PSI system used in KA patients could potentially affect outcome.

1. **XU J, CAO JY, LUONG JK, NEGUS JJ.**

**KINEMATIC VERSUS MECHANICAL ALIGNMENT FOR PRIMARY TOTAL KNEE REPLACEMENT: A SYSTEMATIC REVIEW AND META-ANALYSIS. J ORTHOP. 2019 FEB 28;16(2):151-157.**

**NO ABSTRACT AVAILABLE**

1. **YOON JR, HAN SB, JEE MK, SHIN YS.**

**COMPARISON OF KINEMATIC AND MECHANICAL ALIGNMENT TECHNIQUES IN PRIMARY TOTAL KNEE ARTHROPLASTY: A META-ANALYSIS. MEDICINE (BALTIMORE). 2017 SEP;96(39):E8157.**

**Abstract**

**BACKGROUND:**

This meta-analysis compared clinical and radiographic outcomes and complications of kinematic alignment (KA) and mechanical alignment (MA) techniques in primary total knee arthroplasty (TKA).

**METHODS:**

All studies comparing the operation time, change in hemoglobin, length of hospital stay, postoperative complications, and clinical and radiographic outcomes as assessed with various measurement tools, from direct interview to imaging methods, in patients who underwent primary TKA through the KA or MA technique were included.

**RESULTS:**

Six studies were included in the meta-analysis. The proportion of patients who developed postoperative complications (OR: 1.10, 95% CI: 0.49-2.46; P = .69) did not differ significantly between the KA and MA techniques. The 2 groups were also similar in terms of change in hemoglobin (95% CI: -0.38 to 0.34; P = .91), length of hospital stay (95% CI: -0.04 to 0.55; P = .10), hip-knee-ankle angle (95% CI: -1.76 to 0.75; P = .43), joint line orientation angle (95% CI: -4.27 to 4.23; P = .99), tibial component slope (95% CI: -0.53 to 3.56; P = .15), and femoral component flexion (95% CI: -2.61 to 7.57; P = .34). In contrast, operation time (95% CI: -27.16 to -3.71; P = .01), overall functional outcome (95% CI: 6.59-11.51; P < .0001), knee anatomical axis (95% CI: -1.38 to -0.01; P = .05), femoral component relative to the mechanical axis (95% CI: -2.47 to -1.40; P < .0001), and tibial component relative to the mechanical axis (95% CI: 1.56-2.95; P < .0001) were significantly different between the 2 groups.

**CONCLUSIONS:**

There were no significant differences in postoperative complications, change in hemoglobin, length of hospital stay, hip-knee-ankle angle, joint line orientation angle, tibial component slope, or femoral component flexion between the KA and MA techniquesfor primary TKA. However, the KA technique resulted in a significantly shorter operation time and better overall functional outcome than the MA technique, even though the femoral component was placed in a slightly more valgus position relative to the mechanical axis and the tibial component in a slightly more varus position with the KA technique.

1. **RIVIÈRE C, IRANPOUR F, AUVINET E, HOWELL S, VENDITTOLI PA, COBB J, PARRATTE S.**

**ALIGNMENT OPTIONS FOR TOTAL KNEE ARTHROPLASTY: A SYSTEMATIC REVIEW. ORTHOP TRAUMATOL SURG RES. 2017 NOV;103(7):1047-1056.**

### Abstract

In spite of improvements in implant designs and surgical precision, functional outcomes of mechanically aligned total knee arthroplasty(MA TKA) have plateaued. This suggests probable technical intrinsic limitations that few alternate more anatomical recently promoted surgical techniques are trying to solve. This review aims at (1) classifying the different options to frontally align TKA implants, (2) at comparing their safety and efficacy with the one from MA TKAs, therefore answering the following questions: does alternative techniques to position TKA improve functional outcomes of TKA (question 1)? Is there any pathoanatomy not suitable for kinematic implantation of a TKA (question 2)? A systematic review of the existing literature utilizing PubMed and Google Scholar search engines was performed in February 2017. Only studies published in peer-reviewed journals over the last ten years in either English or French were reviewed. We identified 569 reports, of which 13 met our eligibility criteria. Four alternative techniques to position a TKA are challenging the traditional MA technique: anatomic (AA), adjusted mechanical (aMA), kinematic (KA), and restricted kinematic (rKA) alignment techniques. Regarding osteoarthritic patients with slight to mid constitutional knee frontal deformity, the KA technique enables a faster recovery and generally generates higher functional TKA outcomes than the MA technique. Kinematic alignment for TKA is a new attractive technique for TKA at early to mid-term, but need longer follow-up in order to assess its true value. It is probable that some forms of pathoanatomy might affect longer-term clinical outcomes of KA TKA and make the rKA technique or additional surgical corrections (realignment osteotomy, retinacular ligament reconstruction etc.) relevant for this sub-group of patients. Longer follow-up is needed to define the best indication of each alternative surgical technique for TKA. Level I for question 1 (systematic review of Level I studies), level 4 for question 2.

1. **COURTNEY PM, LEE GC.**

**EARLY OUTCOMES OF KINEMATIC ALIGNMENT IN PRIMARY TOTAL KNEE ARTHROPLASTY: A META-ANALYSIS OF THE LITERATURE. J ARTHROPLASTY. 2017 JUN;32(6):2028-2032.E1.**

### Abstract

#### BACKGROUND:

Kinematic alignment in total knee arthroplasty (TKA) seeks to more anatomically align the knee prosthesis to promote more physiological kinematics. However, there are questions about the durability, function, and complication rate of a non-mechanically aligned TKA. Therefore, the purpose of this study is to perform a systematic review and meta-analysis to evaluate early outcomes after kinematic alignment.

#### METHODS:

Two independent reviewers performed a systematic review of the English literature using both the MEDLINE and Embase databases searching for studies on kinematic TKA. Of the initial 839 published reports, 9 studies were included in the review. Four randomized, controlled trials comparing outcomes of kinematic and conventional alignment TKA were identified. Data were extracted and aggregated using inverse variance and Mantel-Haenszel fixed effects meta-analysis.

#### RESULTS:

Of an aggregated 877 kinematic TKAs, the cumulative survivorship was 97.4% at a weighted mean follow-up of 37.9 months. The most common reasons for revision were patellofemoral problems in 8 patients (1.2%). We found no difference in the complication rate between the 229 kinematic and 229 conventional TKA patients (3.9% vs 4.4%; P = .83). The kinematic TKA group had a higher combined postoperative Knee Society Score than the conventional TKA group (mean difference, 9.1 points; 95% confidence interval, 5.2-13.0 points; P < .001).

#### CONCLUSION:

Small deviations from the traditional mechanical axis alignment in TKA do not appear to impact overall survivorship or complication rates at short-term follow-up. Functional outcome as measured by the Knee Society Score favored kinematic alignment. These preliminary results illustrate the concept that there may be more than a single alignment target for all patients undergoing primary TKA.

1. **LEE YS, HOWELL SM, WON YY, LEE OS, LEE SH, VAHEDI H, TEO SH.**

**KINEMATIC ALIGNMENT IS A POSSIBLE ALTERNATIVE TO MECHANICAL ALIGNMENT IN TOTAL KNEE ARTHROPLASTY. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2017 NOV;25(11):3467-3479.**

**Abstract**

**PURPOSE:**

A systematic review was conducted to answer the following questions: (1) Does kinematically aligned (KA) total kneearthroplasty (TKA) achieve clinical outcomes comparable to those of mechanically aligned (MA) TKA? (2) How do the limb, knee, and component alignments differ between KA and MA TKA? (3) How is joint line orientation angle (JLOA) changed from the native knee in KA TKA compared to that in MA TKA?

**METHODS:**

Nine full-text articles in English that reported the clinical and radiological outcomes of KA TKA were included. Five studies had a control group of patients who underwent MA TKA. Data on patient demographics, clinical scores, and radiological results were extracted. There were two level I, one level II, three level III, and three level IV studies. Six of the nine studies used patient-specific instrumentation, one study used computer navigation, and two studies used manual instrumentation.

**RESULTS:**

The clinical outcomes of KA TKA were comparable or superior to those of MA TKA with a minimum 2-year follow-up. Limb and knee alignment in KA TKA was similar to those in MA TKA, and component alignment showed slightly more varus in the tibial component and slightly more valgus in the femoral component. The JLOA in KA TKA was relatively parallel to the floor compared to that in the native knee and not oblique (medial side up and lateral side down) compared to that in MA TKA. The implant survivorship and complication rate of the KA TKA were similar to those of the MA TKA.

**CONCLUSION:**

Similar or better clinical outcomes were produced by using a KA TKA at early-term follow-up and the component alignment differed from that of MA TKA. KA TKA seemed to restore function without catastrophic failure regardless of the alignmentcategory up to midterm follow-up. The JLOA in KA TKA was relatively parallel to the floor similar to the native knee compared to that in MA TKA. The present review of nine published studies suggests that relatively new kinematic alignment is an acceptable and alternativealignment to mechanical alignment, which is better understood. Further validation of these findings requires more randomized clinical trials with longer follow-up.

**LEVEL OF EVIDENCE:**

Level II.

1. **LI Y, WANG S, WANG Y, YANG M.**

**DOES KINEMATIC ALIGNMENT IMPROVE SHORT-TERM FUNCTIONAL OUTCOMES AFTER TOTAL KNEE ARTHROPLASTY COMPARED WITH MECHANICAL ALIGNMENT? A SYSTEMATIC REVIEW AND META-ANALYSIS. J KNEE SURG. 2018 JAN;31(1):78-86.**

### Abstract

This meta-analysis was conducted to study whether kinematically aligned total knee arthroplasty (TKA) improves short-term functionaloutcomes compared with mechanical alignment without changing the hip-knee-ankle angle. Prospective cohort studies were searched from electronic literature databases, including PubMed, Web of Science, Embase (Ovid interface), and Cochrane Library (Ovid interface). Total 1,159 records were identified. Six trials involving 561 patients were eligible for data extraction and meta-analysis. The included studies recorded outcomes in the follow-up range from 6 to 34 months. Primary outcomes were to assess the functionaloutcomes in follow-up, and KA group achieved better performance on WOMAC score (mean difference [MD] = -18.82, 95% CI: -16.06 to -5.58), knee function score (MD = 7.23, 95% CI: 0.52-13.94), Oxford knee score (MD = 4.76, 95% CI: 0.40-9.12), and knee range of flexion (MD = 4.48, 95% CI: 2.09-6.86), whereas other parameters including Knee Society score, knee range of extension, VAS pain score, and the occurrence of the complications were without significant difference (*p* > 0.05). Second outcomes evaluated the perioperative clinic indexes. Our meta-analysis showed that KA group had a shorter time of operation (MD = -15.44, 95% CI: -27.47 to -3.71) and a longer walk distance before discharge (MD = 53.24, 95% CI: 21.32-85.15) when compared with the MA group, whereas the change in hemoglobin, incision length, knee range of flexion before discharge, and length of stays were without significant difference (*p* > 0.05). Third outcomes were used to analyze the alignment data. Our study showed that KA had larger angles of femoral component and mechanical axis of the femur (MD = -1.95,95% CI: -2.77 to -1.13), tibial component and mechanical axis of tibia (MD = 2.06, 95% CI: 1.43-2.70), anatomic knee angle (MD = -0.72, 95% CI: -1.33 to -0.11), and operative limb alignment (MD = -1.97, 95% CI: -2.50 to -1.45,) compared with the MA group, but the hip-knee-ankle angles between the two groups were similar. KA provided better functionaloutcomes and better flexion following short-term follow-up of TKA. However, longer-term follow-up and larger sample studies are needed to put into research in the future.

1. **MCEWEN P, BALENDRA G, DOMA K.**

**MEDIAL AND LATERAL GAP LAXITY DIFFERENTIAL IN COMPUTER-ASSISTED KINEMATIC TOTAL KNEE ARTHROPLASTY. BONE JOINT J. 2019 MAR;101-B(3):331-339.**

**Abstract**

**AIMS:**

The results of kinematic total knee arthroplasty (KTKA) have been reported in terms of limb and component alignment parameters but not in terms of gap laxities and differentials. In kinematic alignment (KA), balance should reflect the asymmetrical balance of the normal knee, not the classic rectangular flexion and extension gaps sought with gap-balanced mechanical axis total knee arthroplasty(MATKA). This paper aims to address the following questions: 1) what factors determine coronal joint congruence as measured on standing radiographs?; 2) is flexion gap asymmetry produced with KA?; 3) does lateral flexion gap laxity affect outcomes?; 4) is lateralflexion gap laxity associated with lateral extension gap laxity?; and 5) can consistent ligament balance be produced without releases?

**PATIENTS AND METHODS:**

A total of 192 KTKAs completed by a single surgeon using a computer-assisted technique were followed for a mean of 3.5 years (2 to 5). There were 116 male patients (60%) and 76 female patients (40%) with a mean age of 65 years (48 to 88). Outcome measures included intraoperative gap laxity measurements and component positions, as well as joint angles from postoperative three-foot standing radiographs. Patient-reported outcome measures (PROMs) were analyzed in terms of alignment and balance: EuroQol (EQ)-5D visual analogue scale (VAS), Knee Injury and Osteoarthritis Outcome Score (KOOS), KOOS Joint Replacement (JR), and Oxford Knee Score (OKS).

**RESULTS:**

Postoperative limb alignment did not affect outcomes. The standing hip-knee-ankle (HKA) angle was the sole positive predictor of the joint line convergence angle (JLCA) (p < 0.001). Increasing lateral flexion gap laxity was consistently associated with better outcomes. Lateral flexion gap laxity did not correlate with HKA angle, the JLCA, or lateral extension gap laxity. Minor releases were required in one third of cases.

**CONCLUSION:**

The standing HKA angle is the primary determinant of the JLCA in KTKA. A rectangular flexion gap is produced in only 11% of cases. Lateral flexion gap laxity is consistently associated with better outcomes and does not affect balance in extension. Minor releases are sometimes required as well, particularly in limbs with larger preoperative deformities. Cite this article: Bone Joint J 2019;101-B:331-339.

1. **CHERIAN JJ, KAPADIA BH, BANERJEE S, JAUREGUI JJ, ISSA K, MONT MA.**

**MECHANICAL, ANATOMICAL, AND KINEMATIC AXIS IN TKA: CONCEPTS AND PRACTICAL APPLICATIONS. CURR REV MUSCULOSKELET MED. 2014 JUN;7(2):89-95.**

**Introduction**

One aim for total knee arthroplasty is to achieve excellent alignment of the femoral, tibial, and patellar components, with ultimate restoration of the patient’s lower extremity to neutral [1]. Proper alignment of the knee is considered to be one of the most influential factors in determining the long-term outcomes after TKA [2], and is believed to decrease both the mechanical and shear stresses placed on the bearing surfaces, as well as the bone/prosthesis interfaces [3–5]. In addition, proper alignment aids to balance the forces transmitted through the soft-tissue envelope, which is crucial for suitable functioning of the joint [4]. Furthermore, when total knee arthroplasties are poorly aligned this can result in decreased implant survivorship, as well as being implicated as a cause for increased wear, poor functional outcomes, and early failure leading to component loosening with older polyethylene and implant designs [3, 5–10].

There are various different alignment strategies and surgical techniques that have been utilized to attain this goal [11]. Classical alignment has been commonly used for TKA using either the measured resection or gap balancing techniques [11]. In contrast, anatomic alignment sought to try to closely match the true anatomy of the femur and tibia to allow the joint line to be parallel to the ground during the normal stance phase of gait [12••].

In many international joint registries, approximately one-fifth to one-quarter of all patients have been found to be dissatisfied following their total knee arthroplasty [13, 14]. The development of various technologies, including computer navigation and patient-specific instrumentation, has intended to help the surgeon to better replicate the neutral mechanical axis of the knee [15–18]. However, even though these technologies have sometimes led to improved radiographic alignment and fewer axis outliers, these innovations have not necessarily led to improved clinical outcomes [19, 20].

The purpose of this review various alignment schemas used to implant TKA’s specifically mechanical, anatomic, and kinematic axes. This report will specifically review: (1) various definitions of alignment axes, (2) historical concepts of knee alignment, (3) various alignment schemes, and (4) recent evidence on outcomes with the use of mechanical and kinematic alignment.

On normal weight bearing anteroposterior radiographs, a vertical line that extends distally from the center of the pubic symphysis is known as the vertical axis [4]. This axis is used as a reference axis/line from which the other axes are determined.

Mechanical Axis

The mechanical axis of the lower extremity is determined by drawing a line from the center of the femoral head to the center of the ankle joint, which corresponds to an approximately 3° slope compared with that of the vertical axis [21]. This can be subdivided into the femoral mechanical axis, which runs from the head of the femur to the intercondylar notch of the distal femur, and the tibial mechanical axis, which extends from the center of the proximal tibia to the center of the ankle [21]. The medial angle formed between the mechanical axis of the femur and the mechanical axis of the tibia is called the hip–knee–ankle angle, which represented the overall alignment of the lower extremity and is usually slightly less than 180° in normal knees [22–24]. The position of the mechanical axis causes it to usually pass just medial to the tibial spine, but this can vary widely based on the patient height and pelvic width (increased pelvic width as in females and decreased height results in increased axis deviation) [10].

Anatomic Axis

The anatomic axis of the lower extremity is an axis in relation to the intramedullary canals [21]. There are 2 methods that are used to define the anatomic axis of the femur. The first is a line drawn proximal to distal in the intramedullary canal bisecting the femur in one-half, whereas the second method is a point at the femoral shaft center to a point 10 centimeters above the knee joint located at an equal distance between the medial and lateral cortex [21] (Fig. 1). The anatomic axis of the tibia is created by a line drawn proximal to distal in the intramedullary canal bisecting the tibial in half [21] (Fig. 1). On anteroposterior evaluation, the mechanical, and anatomic axes of the tibia commonly correspond exactly with one another. However, the anatomic axis of the femur has an approximate 5°–7° of inclination difference than the mechanical axis. Moreover, the anatomic axis can deviate markedly depending on femoral or tibial deformities, as well as the patient’s hip angle [4]. On a weight-bearing radiograph, the lateral angle between the anatomic axes of the femur and the tibia is called the femorotibial angle (FTA) [21]. The average femorotibial angle is approximately 178° in men, and 176° and 174° in Asian and Caucasian women, respectively [21]. However, some factors such as axial limb rotation and flexion deformity can dramatically affect the femorotibial angle [25]. Swanson et al [26] performed a comparison study of the measurement for femorotibial angle that indicated that there was a statistically significant difference in models with severe valgus or varus when rotated internally or externally. One radiographic study have also found that with increasing flexion deformity the femorotibial angle becomes more valgus [27].

Kinematic Axis

Kinematic alignment in total knee arthroplasty is based on 3 functional kinematic axes about which the knee rotates [28]. Different from the previous axes mentioned, the kinematic axes are intended to mimic the dynamic motions of the knee. They consist of a transverse axis of the femur in which the tibia flexes and extends, which passes through the center of a circle that fits the femoral condyles [28]. Another transverse axis depicts the motion in which the patella flexes and extends in relation to the femur [29••]. This axis is located anterior, proximal, and in parallel to the first transverse axis [30••]. The longitudinal axis is perpendicular to the previous 2 axes and dictates the dynamic movements of internal and external rotation of the tibia in relation to the femur [4].

Historical Concept of Knee Alignment

Normal Knee Alignment

The normal knee joint line alignment is naturally in 2° to 3° of varus compared with the mechanical axis. The primary goal of many of the alignment techniques is to achieve neutral alignment of the knee, however, neutral alignment is not always observed in healthy nonarthritic patients. Hsu et al [31] found that only 2.2 % of patients resided on the 0 degree mechanical axis. While a study by Bellmans et al [32••] of 250 healthy asymptomatic adults noted that 32 % of men and 17 % of women had constitutional varus knees with their natural mechanical alignment being 3 degrees of varus or more. A recent study by Fahlman et al [33•] examined 143 participants, and found based on radiographic evaluation that 81.8 % of the participants had both knees with the same alignment: both straight (11.2 %), both valgus (21.7 %), and both varus (49.0 %). However, they found that the remaining individuals (18.2 %) had knees characterized with different alignments.

Background to TKA Alignment

Historically, there were 2 alignment strategies employed to replicate the mechanical axis of the lower extremity when performing total knee arthroplasty. These were classical and anatomic alignments, which were based on the same limb alignment goal: to obtain a neutral mechanical axis with a line passing through the center of the knee, femoral head, and ankle joint. The classical alignment scheme described where all components are positioned in a neutral mechanical axis, which has been speculated to allow for even distribution of joint stresses. One of the goals of anatomic alignment includes placement of components in order to restore the joint line parallel to the ground.

Mechanical Alignment

John Insall originally described the use of mechanical alignment in total knee arthroplasty [34]. Mechanical alignment is performed by making an initial femoral cut that is perpendicular to the mechanical axis of the femur, which is followed by a tibial resection made perpendicular to the mechanical axis of the tibia (Fig. 2). Insall believed that mechanical alignment was the superior method, because if the joint was anatomically aligned this would lead to medial tibial plateau fixation failure, due to the increased forces across the medial joint component if the knee is anatomically aligned [34]. Insall also noted that despite the even distribution of joint loading forces between compartments found during the stance phase, but during the gait phase there might be uneven loading of the component due to a “laterally” directed ground reaction force [34]. In addition, he argued against the restoration of the anatomic knee back to a predisease state, which he believed would ultimately lead to required adjustments of the soft tissues around the knee. In addition, he placed the femoral component at 3° of external rotation in order to balance the flexion and extension gaps.

Anatomic Alignment

Anatomic alignment for total knee arthroplasties was originally described by Hungerford and Krackow [35]. They purposed that the optimal component position should anatomically recreate the joint line. The anatomic joint line places the overall component alignment at 2°–3° of varus in relation to the mechanical axis of the lower extremity [35]. Tibial resection in anatomic alignment of the knee is made at an angle between that of the true vertical and mechanical axis. This requires that the femoral cut angle be made from the difference between the sum of the vertical inclination of the mechanical axis of the lower extremity and the mechanical axis of the femur [11] (Fig. 2). This angle, which is calculated by knowing the difference between the anatomic axis and the mechanical axis of the femur, is approximately 8°–9°of valgus. When this is combined with the 2°–3° degrees of varus angulation of the tibial cut, it gives a total alignment of approximately 6 degrees of valgus that approaches the normal tibiofemoral angle. Also, this alignment provided for a joint line that is parallel to the ground during normal gait [35].

Kinematic Alignment

The use of kinematic alignment for total knee arthroplasty was developed following the classic research by Hollister et al and others [36, 37] on the kinematics of the knee. This schema of alignment is considered to be a 3-dimensional alignment of components, whereas, the previous 2 techniques of mechanical and anatomic alignment were 2-dimensional [30••]. The goal of this alignment schema is to co-align the 2 transverse axes by providing the most adequate shape fitting of the symmetrical single radius femoral component design in order to achieve a “more natural” knee kinematics [28]. An in vivo study found that the contact mechanics in kinematically aligned total knee arthroplasties had more normal motion and less abnormal reverse axial rotation and adduction [38]. In kinematic alignment the thickness of all femoral bone resections including the bone from the kerf saw and the worn cartilage matches accurately with the thickness of the femoral component. In addition, in a kinematically aligned knee the femoral cut is made 1°–2° more valgus and the tibial cut is made 1°–2° varus compared with the mechanically aligned total knee arthroplasty [28].

Although both kinematic and mechanical aligned knees may have the same hip-knee-and-ankle alignment [30••, 39••], proponents believe that kinematic alignment reestablishes the obliquity and the location of the prearthritic joint line, which may potentially lead to improvements in clinical outcomes, greater ranges-of-motion, and enhanced patient satisfaction [28]. However, further studies are necessary to compare the outcomes of kinematic and mechanical or anatomically aligned total knee arthroplasties.

It is believed that restoration of neutral mechanical axis aids in improved implant durability, and patient function following surgery [40•]. In 2009, Fang et al [41] retrospectively evaluated whether well-aligned total knee arthroplasties resulted in better survivorship compared with that of their outliers (>3° valgus or varus). The authors found that out of 6070 primary total knee arthroplasties there where 51 prosthesis failures; 21 (0.5 % in the neutral cohort), 18 (1.8 %) varus, and 12 (1.5 %) valgus group. Of all 3 alignment groups it was demonstrated that patient who had alignment between 2.4 and 7.2 degrees of valgus had the best overall survivorship. They noted that varus knees resulted in medial tibial collapse, and valgus alignment failed primarily because of ligamentous instability. This is reaffirmation of a previous study by Jeffery et al [8] who published a report examining alignment with total knee arthroplasty and aseptic loosening rates. The authors radiographically assessed the mechanical axis of a consecutive series of 115 total knee arthroplasties. They reported that when the axis passed through the middle one-third of the prosthesis, this resulted in a 3 % rate of loosening (2 out of 78 knees). Moreover, when the axis was shifted either medial or lateral, the loosening rate was noted to be much higher (24 %, 9 out of 37 knees; P = 0.001).

Similarly, a prospective randomized study by Choong et al [42] evaluated whether accurate anatomic alignment resulted in better function and quality of life compared with outliers. The authors evaluated 115 patients (115 total knee arthroplasties) who underwent surgery performed with conventional or computer assisted surgery. They reported that 50 patients (88 %) in the computer assisted group compared with 33 patients (61 %) in the conventional cohort achieved alignment within 3° of neutral axis. In relation to function and quality of life, the authors reported that patients who achieved alignment within 3° of the mechanical axis had a significant increase in International Knee Society Score and Short-Form 12 physical Scores from 6 weeks postoperatively out to 12 months after surgery compared with patients who did not.

Despite the consensus among orthopedic surgeons who believe that well-aligned (within 3° of the mechanical axis) total knee arthroplasty results in improved outcomes, many recent studies have challenged this notion. A study by Khan et al [43•] retrospectively examined the relationship between the mechanical axis of the knee through its functional arc and patient’s functional outcomes. They reported of the 76 patients who underwent computer-assisted total knee arthroplasties, 65 of the individuals achieved a functional arc alignment of 3° or less, whereas 11 were found to be outliers. In addition, the authors found no correlation between the 2 functional arc alignment groups and Western Ontario and McMaster University Scores (WOMAC) or Short-Form 12 surveys outcomes, however, they recognized that in patients who had greater than 3° of alignment that significantly increased difficulty with activities of daily living (P = 0.05). Similarly, a study by Parratte et al [44••] examined the relationship between component alignment and survivorship in 398 total knee arthroplasties. The authors found no difference in Kaplan-Meier 15-year survivorship estimates between the prostheses place within 3° of varus or valgus compared with the prosthesis aligned outside this range. They made note that continuing to report as a dichotomous variable is not appropriate given the results of their study. However, until additional information in available to determine the best total knee arthroplasty alignment, surgeons should aim to achieve neutral mechanical axis.

Kinematic Alignment

Certain studies have questioned the use of classical alignment, and have suggested that a more appropriate method might be to recreate the patient’s normal anatomy through kinematic alignment. In 2012, Dossett and colleagues [30••] published a study of 81 total knee arthroplasties evaluating alignment and clinical outcomes performed using standard mechanical alignment using conventional instruments compared with kinematic alignment with the use of patient specific guides. The authors found that there was no significant difference in relation to the hip-knee-ankle angle and the anatomic angle of the knee between the 2 cohorts in terms of alignment. However, at 6 months postoperatively, patients in the kinematically aligned TKA group had significantly higher Western Ontario and McMaster University Scores (16 points; P < 0.000), Oxford scores (7 points; P = 0.001), combined Knee Society Score (25 points; P = 0.001), and 5° of flexion (P = 0.043). Similarly, a study by Howell et al [29••] evaluated functional outcomes of 214 kinematically aligned total knee arthroplasties for 3 alignment categories. Patients were characterized by alignment as in range (between –2.5° and –7.4° valgus), varus (>– 2.5°), and valgus (<–7.4°). The authors found that the mean Oxford Knee Score of 43 and WOMAC score was 92, were similar in all alignment categories. Another study by Spencer et al [45••] examined the use of custom-fit total knee arthroplasty in relation to long-leg coronal alignment in 21 patients. The authors found that mean deviation from the mechanical axis was 1.2° of varus, which was close to previous reports.

**Conclusions**

The aim of the surgeon during total knee arthroplasty is to achieve good alignment of the femoral, tibial, and patellar components. Inappropriate joint alignment can result in increased implant stress, poor patient outcomes, and decreased survivorship. Historically, the goal of total knee arthroplasty has been to return the patients joint alignment to be within 3 degrees of mechanical axis, however, recent reports have challenged the theory that outliers result in increased revision. Currently, few authors have evaluated the role of kinematic alignment in improving the outcomes following total knee arthroplasty. As these newer alignment systems develop, we believe that larger studies are needed to appropriately define which alignment method will result in the optimal outcomes for patients after total knee arthroplasty.

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1. **DELPORT H, LABEY L, INNOCENTI B, DE CORTE R, VANDER SLOTEN JBELLEMANS J.**

**RESTORATION OF CONSTITUTIONAL ALIGNMENT IN TKA LEADS TO MORE PHYSIOLOGICAL STRAINS IN THE COLLATERAL LIGAMENTS. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2015 AUG;23(8):2159-2169.**

**Abstract**

**PURPOSE:**

Currently, controversy exists whether restoration of neutral mechanical alignment should be attempted in all patients undergoing TKA. Our hypothesis was that restoration of constitutional rather than neutral mechanical alignment may in theory lead to a more physiological strain pattern in the collateral ligaments; therefore, it could potentially be beneficial to patients. Thus, the aim of this study was to measure collateral ligament strains during three motor tasks in the native knee and compare them with the strains noted after TKA in different post-operative alignment conditions.

**METHODS:**

Six cadaver specimens (approval number ML4190 from the Research Ethics Committee of University of Leuven, Belgium) were examined using a validated knee kinematics rig under physiological loading conditions. The effect of coronal malalignment was evaluated by using custom-made tibial implant inserts that induced different alignment conditions. The study of six specimens allows us to show that a difference in the mean strains in MCL and LCL of 3.6 and 5.8 %, respectively, was statistically significant with a probability (power) of 0.8.

**RESULTS:**

The results indicated that after TKA insertion, the strains in the collateral ligaments closely resembled the pre-operative pattern of the native knee specimens when constitutional alignment was restored. Restoration to neutral mechanical alignment was associated with greater collateral strain deviations from the native knee.

**CONCLUSION:**

Based upon this study, it was concluded that restoration of constitutional alignment within a "safe zone" of ±2° during TKA leads to more physiological peri-articular soft tissue strains during loaded as well as unloaded motor tasks.

1. **NEDOPIL AJ, SINGH AK, HOWELL SM, HULL ML.**

**DOES CALIPERED KINEMATICALLY ALIGNED TKA RESTORE NATIVE LEFT TO RIGHT SYMMETRY OF THE LOWER LIMB AND IMPROVE FUNCTION? J ARTHROPLASTY. 2018 FEB;33(2):398-406.**

### Abstract

#### BACKGROUND:

Kinematically aligned total knee arthroplasty (KA TKA) strives to restore the native left to right symmetry of the lowerlimb; however, the reproducibility of achieving this target is unknown. The present study determined the proportion of patients with left to right symmetry and the improvement in patient-reported function after calipered KA TKA.

#### METHODS:

A review of 562 postoperative scanograms identified 102 patients (53 women) with a KA TKA in one limb, no other skeletal abnormalities in either limb, and symmetrical rotation between limbs on the scanogram. All patients were treated with primary TKA that used caliper measurement of the thicknesses of the femoral bone and tibial bone resections to kinematically align the components. The hip-knee-ankle (HKA) angle, distal lateral femoral angle (DLFA), and proximal medial tibial angle (PMTA) were measured. Patient-reported Oxford Knee Score (OKS) measured preoperative and postoperative functions.

#### RESULTS:

The proportion of patients with a difference in the HKA angle, DLFA, and PMTA between limbs within ±3°, >3° varus, and <-3° valgus was 95%, 2%, and 3%, respectively, for the HKA angle; 97%, 1%, and 2%, respectively, for the DLFA; and 97%, 2%, and 1%, respectively, for the PMTA. The mean OKS improved from 20 preoperatively to 44 points (range 18-48 points) at 15 months postoperatively.

#### CONCLUSION:

Calipered KA TKA restored native left to right symmetry of the HKA angle, DLFA, and PMTA in nearly all patients with negligible risk of varus alignment of the tibial component with respect to the native tibial joint line. The mean postoperative OKS indicated clinically important improvement in patient-reported function.

1. **JI HM, HAN J, JIN DS, SEO H, WON YY.**

**KINEMATICALLY ALIGNED TKA CAN ALIGN KNEE JOINT LINE TO HORIZONTAL. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2016 AUG;24(8):2436-41.**

**Abstract**

**PURPOSE:**

The joint line of the native knee is horizontal to the floor and perpendicular to the vertical weight-bearing axis of the patient in a bipedal stance. The purposes of this study were as follows: (1) to find out the distribution of the native joint line in a population of normal patients with normal knees; (2) to compare the native joint line orientation between patients receiving conventional mechanically aligned total knee arthroplasty (TKA), navigated mechanically aligned TKA, and kinematically aligned TKA; and (3) to determine which of the three TKA methods aligns the postoperative knee joint perpendicular to the weight-bearing axis of the limb in bipedal stance.

**METHODS:**

To determine the joint line orientation of a native knee, 50 full-length standing hip-to-ankle digital radiographs were obtained in 50 young, healthy individuals. The angle between knee joint line and the line parallel to the floor was measured and defined as jointline orientation angle (JLOA). JLOA was also measured prior to and after conventional mechanically aligned TKA (65 knees), mechanically aligned TKA using imageless navigation (65 knees), and kinematically aligned TKA (65 knees). The proportion of the knees similar to the native joint line was calculated for each group.

**RESULTS:**

The mean JLOA in healthy individuals was parallel to the floor (0.2° ± 1.1°). The pre-operative JLOA of all treatment groups slanted down to the lateral side. Postoperative JLOA slanted down to the lateral side in conventional mechanically aligned TKA(-3.3° ± 2.2°) and in navigation mechanically aligned TKA (-2.6° ± 1.8°), while it was horizontal to the floor in kinematically aligned TKA(0.6° ± 1.7°). Only 6.9 % of the conventional mechanically aligned TKA and 16.9 % of the navigation mechanically aligned TKA were within one SD of the mean JLOA of the native knee, while the proportion was significantly higher (50.8 %) in kinematically aligned TKA. The portion was statistically greater in mechanically aligned TKA group than the other two.

**CONCLUSION:**

Postoperative joint line orientation after kinematically aligned TKA was more similar to that of native knees than that of mechanically aligned TKA and horizontal to the floor. Kinematically aligned TKA can restore pre-arthritic knee joint line orientation, while mechanically aligned TKA is inefficient in achieving the purpose even if navigation TKA is employed.

**LEVEL OF EVIDENCE:**

III.

1. **SCHIRALDI M, BONZANINI G, CHIRILLO D, DE TULLIO V.**

**MECHANICAL AND KINEMATIC ALIGNMENT IN TOTAL KNEE ARTHROPLASTY. ANN TRANSL MED. 2016 APR;4(7):130.**

### Abstract

In the last 10 years many studies have questioned if the strive to mechanical align any knee may pose some problems related to ligament misbalancing that could explain the high rate of disappointed patients, almost 20% in some reports. Proper indication and difference between patient's and surgeon's expectations are among the most important one's but it must be underlined that, there is indeed a sharp difference between normal knee kinematics, prosthetic knee kinematics and arthritic knee kinematics being the last one extremely variable. A so called kinematic alignment has recently been developed in order to improve patient's knee function and pain control minimizing any surgical gesture focused on ligaments balance. The amount of bone resections may not affect limb alignment but has an important consequence in ligament tension and balance, clinical result and function therefore a measured bone resection technique is essential in order to perform a proper kinematic alignment. Purpose of this paper is to briefly review the different alignmentprocedures used for TKA and to discuss their definitions, concepts and evidence on outcome.

1. **BRAR AS, HOWELL SM, HULL ML, MAHFOUZ MR.**

**DOES KINEMATIC ALIGNMENT AND FLEXION OF A FEMORAL COMPONENT DESIGNED FOR MECHANICAL ALIGNMENT REDUCE THE PROXIMAL AND LATERAL REACH OF THE TROCHLEA? J ARTHROPLASTY. 2016 AUG;31(8):1808-13.**

### Abstract

#### BACKGROUND:

Kinematically aligned total knee arthroplasty uses a femoral component designed for mechanical alignment (MA) and sets the component in more internal, valgus, and flexion rotation than MA. It is unknown how much kinematic alignment (KA) and flexionof the femoral component reduce the proximal and lateral reach of the trochlea; two reductions that could increase the risk of abnormal patella tracking.

#### METHODS:

We simulated MA and KA of the femoral component in 0° of flexion on 20 3-dimensional bone models of normal femurs. The mechanically and kinematically aligned components were then aligned in 5°, 10°, and 15° of flexion and downsized until the flange contacted the anterior femur. The reductions in the proximal and lateral reach from the proximal point of the trochlea of the MA component set in 0° of flexion were computed.

#### RESULTS:

KA at 0° of flexion did not reduce the proximal reach and reduced the lateral reach an average of 3 mm. Flexion of the MA and KA femoral component 5°, 10°, and 15° reduced the proximal reach an average of 4 mm, 8 mm, and 12 mm, respectively (0.8 mm/degree of flexion), and reduced the lateral reach an average of 1 mm and 4 mm regardless of the degree of flexion, respectively.

#### CONCLUSION:

Arthroplasty surgeons and biomechanical engineers striving to optimize patella tracking might consider developing surgical techniques to minimize flexion of the femoral component when performing KA and MA total knee arthroplasty to promote early patella engagement and consider designing a femoral component with a trochlea shaped specifically for KA.

1. **KESHMIRI A, MADERBACHER G, BAIER C, BENDITZ A, GRIFKA J, GREIMEL F.**

**KINEMATIC ALIGNMENT IN TOTAL KNEE ARTHROPLASTY LEADS TO A BETTER RESTORATION OF PATELLAR KINEMATICS COMPARED TO MECHANIC ALIGNMENT. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2019 MAY;27(5):1529-1534.**

**Abstract**

**PURPOSE:**

The influence of different implantation techniques in TKA on tibiofemoral kinematics was analysed in few investigations so far. However, the influence on patellar kinematics remain unclear. The aim of the present investigation was to compare patellarkinematics of the natural knee with those of knees after both kinematically and mechanically aligned TKAs.

**METHODS:**

Patellar kinematics of ten cadaveric knees before and after TKAs implanted using both a kinematic and mechanic alignmenttechnique were investigated and compared using a commercial optical computer navigation system.

**RESULTS:**

There was a statistically significant difference between natural patellar kinematics and both implantation techniques analysing mediolateral shift. Patellar lateral tilt showed significant better results in the kinematically compared to the mechanically aligned TKAs. In terms of patella rotation, the patella of both mechanically and kinematically aligned TKAs showed significant higher values for external rotation compared to the natural knee. Regarding epicondylar distance again a significant better restoration of natural kinematics could be found in the kinematically aligned TKAs.

**CONCLUSION:**

Kinematically aligned TKAs showed a better overall restoration of patellar kinematics compared to a conventional mechanical alignment technique. In terms of clinical usefulness, the present study highlights the potential benefit for clinical outcome using a kinematically aligned implantation technique in TKA to achieve a better restoration of natural patellofemoral kinematics.

1. **KOH IJ, PARK IJ, LIN CC, PATEL NA, CHALMERS CE, MANIGLIO M, MCGARRY MH, LEE TQ.**

**KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY REPRODUCES NATIVE PATELLOFEMORAL BIOMECHANICS DURING DEEP KNEE FLEXION. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2019 MAY;27(5):1520-1528.**

**Abstract**

**PURPOSE:**

The implant positioning for kinematically aligned total knee arthroplasty (TKA) differs fundamentally from conventional mechanically aligned TKA. This difference may affect patellofemoral (PF) biomechanics after TKA. This cadaveric study tested the hypothesis that kinematically aligned TKA would restore PF biomechanics to the native condition better than mechanically aligned TKA.

**METHODS:**

Seven pairs (14 knees) of fresh-frozen cadavers were tested. All specimens were mounted on a customized knee-testing system and digitized using a Microscribe 3DLX instrument (Revware Inc., Raleigh, NC, USA) to measure patellar kinematics in terms of patellar varus/valgus rotation, medial/lateral position, flexion/extension rotation and proximal/distal position at knee flexion angles of 0°, 30°, 60°, 90°, and 120°. The medial and lateral PF joint contact pressure distributions at 120° of knee flexion were measured using a K-scan system (Tekscan Inc., Boston, MA, USA). All patellae remained unresurfaced. For each pair, one knee was randomly assigned to kinematically aligned TKA and the other to mechanically aligned TKA performed using the conventional measured resection technique. During kinematically aligned TKA, the amount of femur and tibia resected was equivalent to implant thickness to maintain the patient-specific joint line. All patellar kinematics were measured and compared between the native condition and after surgery.

**RESULTS:**

The patellae of mechanically aligned TKA rotated more valgus and was positioned more laterally compared with those of kinematically aligned TKA at knee flexion angles ≥ 90°. Neither the patellar flexion/extension rotation nor the proximal/distal position differed between either prosthetic knee design and the native knee at all flexion angles. The contact pressure distribution between the medial and lateral PF joint after kinematically aligned TKA were similar to those of the native knee, while the lateral PF joint contact pressure after mechanically aligned TKA was higher than that of the native knee (p = 0.038).

**CONCLUSIONS:**

Kinematically aligned TKA better restores patellar kinematics and PF contact pressure distribution to the nativecondition than mechanically aligned TKA during deep knee flexion. These findings provide clues to understand why kinematically alignedTKA is associated with less anterior knee pain and better PF functional performance compared to mechanically aligned TKA. Patients undergoing kinematically aligned TKA may experience a more normal feeling during deep knee flexion activities.

1. **LOZANO R, CAMPANELLI V, HOWELL S, HULL M.**

**KINEMATIC ALIGNMENT MORE CLOSELY**

**RESTORES THE GROOVE LOCATION AND THE SULCUS ANGLE OF THE NATIVE TROCHLEA THAN MECHANICAL ALIGNMENT: IMPLICATIONS FOR PROSTHETIC DESIGN. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2019 MAY;27(5):1504-1513.**

### Abstract

#### PURPOSE:

Kinematic alignment (KA) and mechanical alignment (MA) position the prosthetic trochlea that guides patellar tracking differently. The present study determined whether KA or MA more closely restores the groove location and sulcus angle of the prosthetictrochlea to the native trochlea for three femoral component designs.

#### METHODS:

Ten 3D femur-cartilage models were created by combining computer tomographic (CT) and laser scans of native human cadaveric femurs. Three femoral component designs were positioned using KA and MA. Measurements of the prosthetic and nativetrochlea were made along the arc length of the native trochlear groove. The alignment technique with the smaller absolute difference between prosthetic and native for the medial-lateral and radial locations of the groove and sulcus angle of the trochlea more closelyrestored the native trochlea.

#### RESULTS:

For three femoral component designs, KA more closely restored to native the mean medial-lateral location (p = 0.0033 to < 0.0001) and mean radial location (p = 0.0150 to < 0.0001) than MA. For two femoral component designs, KA more closely restored to native the mean sulcus angle (p = 0.0326 to 0.0006) than MA. However, the differences in the mean sulcus angles between KA and MA were less than 2° for all three designs.

#### CONCLUSION:

KA more closely restored the native trochlea, which explains why the reported risk of patellofemoral complications for KA is not higher than MA according to five randomized clinical trials. Small design modifications of the medial-lateral and radial locations and sulcus angle are strategies for restoring the native trochlea. Such modifications might further reduce the risk of patellofemoral complications.

#### LEVEL OF EVIDENCE:

II.

1. **RIVIÈRE C, IRANPOUR F, HARRIS S, AUVINET E, AFRAMIAN A, PARRATTE S, COBB J.**

**DIFFERENCES IN TROCHLEAR PARAMETERS BETWEEN NATIVE AND PROSTHETIC KINEMATICALLY OR MECHANICALLY ALIGNED KNEES. ORTHOP TRAUMATOL SURG RES. 2018 APR;104(2):165-170.**

### Abstract

#### INTRODUCTION:

Kinematic (KA) and mechanical (MA) alignment techniques are two different philosophies of implant positioning that use the same TKA implants. This might generate differences in the resulting prosthetic trochleae parameters between the two techniques of alignment. Our study aim was to test the following hypotheses : (1) mechanically or kinematically aligned femoral implant understuffs the native trochlear articular surface and poorly restores the native groove orientation, and (2) the orientation of the prosthetic trochlear groove and trochlear fill are different between MA and KA.

#### METHODS:

Three-dimensional models of the femur were made from segmentation of preoperative Magnetic Resonance Imaging scans (MRIs) of ten subjects with isolated medial tibiofemoral osteoarthritis. In-house planning and analysis software kinematically and mechanically aligned a modern cruciate retaining femoral component and determined differences in parameters of the trochlear fit between native and prosthetic trochleae, and between KA and MA prosthetic trochleae.

#### RESULTS:

The MA prosthetic trochleae did not fill (understuffed) the entire length of the native medial facet and the proximal 70% of the native groove and lateral facet, and oriented the trochleae groove 8° more valgus than native. The KA prosthetic trochleae understuffed the proximal 70% of the native trochleae, and had a groove 6° more valgus than native. The KA trochleae understuffed the medial facet distally and oriented the groove 2° less valgus and 3° more internally rotated than the MA trochleae.

#### CONCLUSION:

MA and KA prosthetic trochleae substantially understuff and create a prosthetic groove more valgus compared to nativetrochlear anatomy, and they also differed between each other regarding trochleae stuffing and groove alignment. Although randomized trials have not shown differences in patellofemoral complications between KA and MA, a femoral component designed specifically for KA that more closely restores the native trochlear anatomy might improve patient reported satisfaction and function.

#### LEVEL OF EVIDENCE:

Level 2 controlled laboratory study.

1. **RIVIÈRE C, DHAIF F, SHAH H, ALI A, AUVINET E, AFRAMIAN A, COBB J, HOWELL S, HARRIS S.**

**KINEMATIC ALIGNMENT OF CURRENT TKA IMPLANTS DOES NOT RESTORE THE NATIVE TROCHLEAR ANATOMY. ORTHOP TRAUMATOL SURG RES. 2018 NOV;104(7):983-995.**

### Abstract

#### INTRODUCTION:

Preserving constitutional patellofemoral anatomy, and thus producing physiological patellofemoral kinematics, could prevent patellofemoral complications and improve clinical outcomes after kinematically aligned TKA (KA TKA). Our study aims 1) to compare the native and prosthetic trochleae (planned or implanted), and 2) to estimate the safety of implanting a larger Persona®femoral component size matching the proximal lateral trochlea facet height (flange area) in order to reduce the native articular surfaces understuffing generated by the prosthetic KA trochlea.

#### METHODS:

Persona® femoral component 3D model was virtually kinematically aligned on 3D bone-cartilage models of healthy knees by using a conventional KA technique (group 1, 36models, planned KA TKA) or an alternative KA technique (AT KA TKA) aiming to match the proximal (flange area) lateral facet height (10 models, planned AT KA TKA). Also, 13postoperative bone-implant (KA Persona®) models were co-registered to the same coordinate geometry as their preoperative bone-cartilage models (group 2implanted KA TKA). In-house analysis software was used to compare native and prosthetic trochlea articular surfaces and medio-lateral implant overhangs for every group.

#### RESULTS:

The planned and performed prosthetic trochleae were similar and valgus oriented (6.1 and 8.5, respectively), substantially proximally understuffed compared to the native trochlea. The AT KA TKAs shows a high rate of native trochlea surface overstuffing (70%, 90%, and 100% for lateral facet, groove, medial facet) and mediolateral implant overhang (60%). There was no overstuffing with conventional KA TKAs having their anterior femoral cut flush.

#### CONCLUSION:

We found that with both the planned and implanted femoral components, the KA Persona® trochlea was more valgus oriented and understuffed compared to the native trochlear anatomy. In addition, restoring the lateral trochlea facet height by increasing the femoral component size generated a high rate of trochlea overstuffing and mediolateral implant overhang. While restoring a native trochlea with KA TKA is not possible, the clinical impact of this is low, especially on PF complications. In current practice it is better to undersize the implants even if it does not restore the native anatomy. Longer follow-up is needed for KA TKAs performed with currentimplant, and the debate of developing new, more anatomic, implants specifically designed for KA technique is now opened.

#### LEVEL OF EVIDENCE:

II, Laboratory controlled study.

1. **BLAKENEY W, CLÉMENT J, DESMEULES F, HAGEMEISTER N, RIVIÈRE C, VENDITTOLI PA.**

**KINEMATIC ALIGNMENT IN TOTAL KNEE ARTHROPLASTY BETTER REPRODUCES NORMAL GAIT THAN MECHANICAL ALIGNMENT. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2019 MAY;27(5):1410-1417.**

### Abstract

#### PURPOSE:

Kinematic alignment technique for TKA aims to restore the individual knee anatomy and ligament tension, to restore native knee kinematics. The aim of this study was to compare parameters of kinematics during gait (knee flexion-extension, adduction-abduction, internal-external tibial rotation and walking speed) of TKA patients operated by either kinematic alignment or mechanicalalignment technique with a group of healthy controls. The hypothesis was that the kinematic parameters of kinematically aligned TKAs would more closely resemble that of healthy controls than mechanically aligned TKAs.

#### METHODS:

This was a retrospective case-control study. Eighteen kinematically aligned TKAs were matched by gender, age, operating surgeon and prosthesis to 18 mechanically aligned TKAs. Post-operative 3D knee kinematics analysis, performed with an optoelectronic knee assessment device (KneeKG®), was compared between mechanical alignment TKA patients, kinematic alignment TKA patients and healthy controls. Radiographic measures and clinical scores were also compared between the two TKA groups.

#### RESULTS:

The kinematic alignment group showed no significant knee kinematic differences compared to healthy knees in sagittal plane range of motion, maximum flexion, abduction-adduction curves or knee external tibial rotation. Conversely, the mechanical alignmentgroup displayed several significant knee kinematic differences to the healthy group: less sagittal plane range of motion (49.1° vs. 54.0°, p = 0.020), decreased maximum flexion (52.3° vs. 57.5°, p = 0.002), increased adduction angle (2.0-7.5° vs. - 2.8-3.0°, p < 0.05), and increased external tibial rotation (by a mean of 2.3 ± 0.7°, p < 0.001). The post-operative KOOS score was significantly higher in the kinematic alignment group compared to the mechanical alignment group (74.2 vs. 60.7, p = 0.034).

#### CONCLUSIONS:

The knee kinematics of patients with kinematically aligned TKAs more closely resembled that of normal healthy controls than that of patients with mechanically aligned TKAs. This may be the result of a better restoration of the individual's knee anatomy and ligament tension. A return to normal gait parameters post-TKA will lead to improved clinical outcomes and greater patient satisfaction.

#### LEVEL OF EVIDENCE:

III.

1. **MCNAIR PJ, BOOCOCK MG, DOMINICK ND, KELLY RJ, FARRINGTON BJ, YOUNG SW.**

**A COMPARISON OF WALKING GAIT FOLLOWING MECHANICAL AND KINEMATIC ALIGNMENT IN TOTAL KNEE JOINT REPLACEMENT. J ARTHROPLASTY. 2018 FEB;33(2):560-564.**

### Abstract

#### BACKGROUND:

Although previous studies have compared radiological, pain, and function scores in kinematically aligned (KA) and mechanically aligned (MA) total knee arthroplasty (TKA), no previous studies have undertaken a three-dimensional (3D) gait analysis in these groups. This study compared kinematic and kinetic variables recorded during level walking in patients at least 2 years post-surgery who underwent an MA or KA procedure.

#### METHODS:

Utilizing a 9-camera motion analysis system, gait analysis was undertaken on 29 patients (MA = 15, KA = 14). A 9-camera motion analysis system was used to collect 3D kinematic data of the involved and uninvolved limbs during walking at a self-selected speed. Additionally, 3D ground reaction forces and moments during the stance phase were recorded, and an inverse dynamics approach was utilized to analyze these data.

#### RESULTS:

There were no significant differences in spatial-temporal variables between MA and KA groups (P > .05). Local minima and maxima for knee joint angles were not significantly different (P > .05) across involved and uninvolved legs and MA/KA groups in any of the 3 planes of motion. Principal component analysis revealed a significant difference (P < .05) in the transverse plane moment in late stance. No other significant differences were observed for knee, hip, or ankle joint moments.

#### CONCLUSION:

Differences in gait parameters across the KA and MA groups at 2 years post-surgery were insufficient to support either one of the operative procedures over the other.

1. **YEO JH, SEON JK, LEE DH, SONG EK.**

**NO DIFFERENCE IN OUTCOMES AND GAIT ANALYSIS BETWEEN MECHANICAL AND KINEMATIC KNEE ALIGNMENT METHODS USING ROBOTIC TOTAL KNEE ARTHROPLASTY. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2019 APR;27(4):1142-1147.**

### Abstract

#### PURPOSE:

The purpose of this study was to compare clinical outcomes and perform gait analysis during walking to identify differences in kinematic and kinetic parameters between two alignment methods in robotic-assisted total knee arthroplasty (TKA).

#### METHODS:

Sixty patients were randomly assigned to undergo robotic-assisted TKA using either mechanical (30 patients) or kinematic(30 patients) alignment method. Clinical outcomes including varus and valgus laxities, range of motion (ROM), Hospital for Specific Surgery (HSS), Knee Society Score (KSS), and Western Ontario and McMaster Universities (WOMAC) scores and radiological outcomes were evaluated. Gait analysis of 3D spatiotemporal, kinetic, and kinematic parameters during walking was then performed for 10 age and gender matched patients of each group to determine differences between the two alignment methods.

#### RESULTS:

The median follow-up duration of the mechanical method group was 8.7 (range 8.1-9.4) years and that of the kinematicmethod group was 8.4 (range 8.0-9.1) years. Clinical outcomes between the two groups showed no significant difference in HSS, WOMAC, ROM, KS pain, or function score at the last follow-up. No significant difference in varus and valgus laxity assessment, mechanical alignment of the lower limb, or perioperative complications was shown between the two groups. In gait analysis, no significant difference in kinematic or kinetic parameters was found except for varus angle (p < 0.05) and mediolateral ground reaction force (p < 0.05).

#### CONCLUSIONS:

Results of this study show that mechanical and kinematic knee alignment methods provide comparable clinical and radiological outcomes after robotic total knee arthroplasty with an average follow-up of 8 years. There were no functional differenceduring walking between the two alignment methods either.

#### LEVEL OF EVIDENCE:

II.

1. **SHELTON TJ, NEDOPIL AJ, HOWELL SM, HULL ML.**

**DO VARUS OR VALGUS OUTLIERS HAVE HIGHER FORCES IN THE MEDIAL OR LATERAL COMPARTMENTS THAN THOSE WHICH ARE IN-RANGE AFTER A KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY? LIMB AND JOINT LINE ALIGNMENT AFTER KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY. BONE JOINT J. 2017 OCT;99-B(10):1319-1328.**

### Abstract

#### AIMS:

The aims of this study were to determine the proportion of patients with outlier varus or valgus alignment in kinematically alignedtotal knee arthroplasty (TKA), whether those with outlier varus or valgus alignment have higher forces in the medial or lateralcompartments of the knee than those with in-range alignment and whether measurements of the alignment of the limb, knee and components predict compartment forces.

#### PATIENTS AND METHODS:

The intra-operative forces in the medial and lateral compartments were measured with an instrumented tibial insert in 67 patients who underwent a kinematically aligned TKA during passive movement. The mean of the forces at full extension, 45° and 90° of flexion determined the force in the medial and lateral compartments. Measurements of the alignment of the limb and the components included the hip-knee-ankle (HKA) angle, proximal medial tibial angle (PMTA), and distal lateral femoral angle (DLFA). Measurements of the alignment of the knee and the components included the tibiofemoral angle (TFA), tibial component angle (TCA) and femoral component angle (FCA). Alignment was measured on post-operative, non-weight-bearing anteroposterior (AP) scanograms and categorised as varus or valgus outlier or in-range in relation to mechanically aligned criteria.

#### RESULTS:

The proportion of patients with outlier varus or valgus alignment was 16%/24% for the HKA angle, 55%/0% for the PMTA, 0%/57% for the DLFA, 25%/12% for the TFA, 100%/0% for the TCA, and 0%/64% for the FCA. In general, the forces in the medial and lateral compartments of those with outlier alignment were not different from those with in-range alignment except for the TFA, in which patients with outlier varus alignment had a mean paradoxical force which was 6 lb higher in the lateral compartment than those with in-range alignment. None of the measurements of alignment of the limb, knee and components predicted the force in the medial or lateralcompartment.

#### CONCLUSION:

Although kinematically aligned TKA has a high proportion of varus or valgus outliers using mechanically aligned criteria, the intra-operative forces in the medial and lateral compartments of patients with outlier alignment were comparable with those with in-range alignment, with no evidence of overload of the medial or lateral compartment of the knee. Cite this article: *Bone Joint J* 2017;99-B:1319-28.

1. **NG CK, CHEN JY, YEH JZY, HO JPY, MERICAN AM, YEO SJ.**

**DISTAL FEMORAL ROTATION CORRELATES WITH PROXIMAL TIBIAL JOINT LINE OBLIQUITY: A CONSIDERATION FOR KINEMATIC TOTAL KNEE ARTHROPLASTY. J ARTHROPLASTY. 2018 JUN;33(6):1936-1944.**

### Abstract

#### BACKGROUND:

We hypothesized that there is a correlation between the distal femoral rotation and proximal tibial joint line obliquity in nonarthritic knees. This has significance for kinematic knee arthroplasty, in which the target knee alignment desired approximates the knee before disease.

#### METHODS:

Fifty computed tomography scans of nonarthritic knees were evaluated using three-dimensional image processing software. Four distal femoral rotational axes were determined in the axial plane: the transepicondylar axis (TEA), transcondylar axis (TCA), posterior condylar axis (PCA), and a line perpendicular to Whiteside's anterior-posterior axis. Then, angles were measured relative to the TEA. Tibial joint line obliquity was measured as the angle between the proximal tibial plane and a line perpendicular to the axis of the tibia.

#### RESULTS:

There was a strong positive correlation between PCA-TEA and tibial joint line obliquity (r = 0.68, P < .001) as well as TCA-TEA and tibial joint line obliquity (r = 0.69, P < .001). In addition, the tibial joint line obliquity and TCA-TEA angles were similar, 3.7° ± 2.2° (mean ± standard deviation) and 3.5° ± 1.7°, respectively (mean difference, 0.2° ± 0.2°; P = .369).

#### CONCLUSION:

Both PCA-TEA and TCA-TEA strongly correlated with proximal tibial joint line obliquity indicating a relationship between distal femoral rotational geometry and proximal tibial inclination. These findings could imply that the native knee in flexion attempts to balance the collateral ligaments toward a rectangular flexion space. A higher tibial varus inclination is matched with a more internally rotated distal femur relative to the TEA.

1. **SHELTON TJ, HOWELL SM, HULL ML.**

**IS THERE A FORCE TARGET THAT PREDICTS EARLY PATIENT-REPORTED OUTCOMES AFTER KINEMATICALLY ALIGNED TKA? CLIN ORTHOP RELAT RES. 2019 MAY;477(5):1200-1207.**

### Abstract

#### BACKGROUND:

Four mechanical alignment force targets are used to predict early patient-reported outcomes and/or to indicate a balanced TKA. For surgeons who use kinematic alignment, there are no reported force targets. To date the usefulness of these mechanical alignment force targets with kinematic alignment has not been reported nor has a specific force target for kinematic alignment been identified.

#### QUESTIONS/PURPOSES:

(1) Does hitting one of four mechanical alignment force targets proposed by Gustke, Jacobs, Meere, and Menghini determine whether a patient with a kinematically aligned TKA had better patient-reported Oxford Knee and WOMAC scores at 6 months? (2) Can a new force target be identified for kinematic alignment that determines whether the patient had a good/excellent Oxford Knee Score of ≥ 34 points (48 best, 0 worst)?

#### METHODS:

Between July 2017 and November 2017, we performed 148 consecutive primary TKAs of which all were treated with kinematic alignment using 10 caliper measurements and verification checks. A total of 68 of the 148 (46%) TKAs performed during the study period had intraoperative measurements of medial and lateral tibial compartment forces during passive motion with an instrumented tibial insert and were evaluated in this retrospective study. Because the surgeon and surgical team were blinded from the display showing the compartment forces, there was no attempt to hit a mechanical alignment force target when balancing the knee. The Oxford Knee Score and WOMAC score measured patient-reported outcomes at 6 months postoperatively. For each mechanical alignment force target, a Wilcoxon rank-sum test determined whether patients who hit the target had better outcome scores than those who missed. An area under the curve (AUC) analysis tried to identify a new force target for kinematic alignment at full extension and 10°, 30°, 45°, 60°, 75°, and 90° of flexion that predicted whether patients had a good/excellent Oxford Knee Score, defined as a score of ≥ 34 points.

#### RESULTS:

Patients who hit or missed each of the four mechanical alignment force targets did not have higher or lower Oxford Knee Scores and WOMAC scores at 6 months. Using the Gustke force target as a representative example, the Oxford Knee Score of 41 ± 6 and WOMAC score of 13 ± 11 for the 31 patients who hit the target were not different from the Oxford Knee Score of 39 ± 8 (p = 0.436) and WOMAC score of 17 ± 17 (p = 0.463) for the 37 patients who missed the target. The low observed AUCs (from 0.56 to 0.58) at each of these flexion angles failed to identify a new kinematic alignment force target associated with a good/excellent (≥ 34) Oxford Knee Score.

#### CONCLUSIONS:

Tibial compartment forces comparable to those reported for the native knee and insufficient sensitivity of the Oxford Knee and WOMAC scores might explain why mechanical alignment force targets were not useful and a force target was not identified for kinematic alignment. Intraoperative sensors may allow surgeons to measure forces very precisely in the operating room, but that level of precision is not called for to achieve a good/excellent result after calipered kinematically aligned TKA, and so its use may simply add expense and time but does not improve the results from the patient's viewpoint.

#### LEVEL OF EVIDENCE:

Level III, therapeutic study.

1. **KOH IJ, LIN CC, PATEL NA, CHALMERS CE, MANIGLIO M, HAN SB, MCGARRY MH, LEE TQ.**

**KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY REPRODUCES MORE NATIVE ROLLBACK AND LAXITY THAN MECHANICALLY ALIGNED TOTAL KNEE ARTHROPLASTY: A MATCHED PAIR CADAVERIC STUDY. ORTHOP TRAUMATOL SURG RES. 2019 JUN;105(4):605-611.**

### Abstract

#### BACKGROUND:

A growing body of evidence supports that kinematically aligned (KA) total knee arthroplasty (TKA) provides superior clinical outcomes and satisfaction than mechanically aligned (MA) TKA. In theory, KA TKA would restore knee kinematics closer to the native condition than MA TKA, but the current biomechanical evidence is lacking.

#### HYPOTHESIS:

KA TKA would restore knee biomechanics to the native condition better than MA TKA.

#### METHODS:

Seven pairs of cadavers were tested. For each pair, one knee was randomly assigned to KA TKA and the other to MA TKA. During KA TKA, the sizes of femur and tibia resections were equivalent to implant thickness to align with the patient-specific joint line. MA TKA was performed using conventional measured resection techniques. All specimens were mounted on a customized knee-testing system and digitized. Knee motions measured during flexion included rollback, axial tibiofemoral rotation, and laxities, specifically varus-valgus laxity, anterior-posterior translation, and internal-external rotation.

#### RESULTS:

The pattern of knee motion following KA TKA was similar to the native knee. However, following MA TKA, both medial and lateral rollback and tibiofemoral axial rotation were decreased relative to those of the native knee. Valgus laxity was restored only after KA TKA, whereas varus laxity was restored only after MA TKA. Anterior translation was increased regardless of the alignment strategy. In addition, rotational laxities were restored after KA TKA, but external rotation laxity increased after MA TKA.

#### CONCLUSION:

KA TKA restores femoral rollback and laxity to the native condition better than MA TKA. KA TKA may enhance functional performance and provide a more normal knee sensation.

#### LEVEL OF EVIDENCE:

II, Controlled laboratory study.

1. **NIKI Y, NAGURA T, NAGAI K, KOBAYASHI S, HARATO K.**

**KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY REDUCES KNEE ADDUCTION MOMENT MORE THAN MECHANICALLY ALIGNED TOTAL KNEE ARTHROPLASTY. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2018 JUN;26(6):1629-1635.**

### Abstract

#### PURPOSE:

Knee adduction moment (KAM) has been recognized as a good clinical surrogate for medial tibiofemoral joint loading and is associated with implant durability after total knee arthroplasty (TKA). This study aimed to examine the effects of joint line obliquity in kinematically aligned TKA (KA-TKA) on KAM during gait.

#### METHODS:

The study enrolled 21 knees from 18 patients who underwent cylindrical axis reference KA-TKA and a matched group of 21 knees from 18 patients who underwent mechanically aligned (MA)-TKA as controls. Gait analyses were performed the day before TKA and at an overall mean of 2.6 years postoperatively. First peak KAM and variables associated with frontal knee kinetics were determined and compared between groups.

#### RESULTS:

In KA-TKA, the proximal tibia was resected with 3.4° ± 1.5° of varus in relation to the mechanical axis, and the final femorotibial shaft axis was 176.7° ± 3.8° with KA-TKA and 174.4° ± 3.0° with MA-TKA. KAM was significantly smaller with KA-TKA than with MA-TKA (p < 0.032). Regarding variables affecting KAM, significant differences were evident between the two TKAs for kneeadduction angle (p = 0.0021), lever arm (p = 0.028), and Δlever arm (p = 0.0001).

#### CONCLUSIONS:

In KA-TKA, joint line obliquity reduced peak KAM during gait, despite slight varus limb alignment, and this reduced KAM in KA-TKA can tolerate constitutional varus alignment. In clinical settings, KA-TKA thus represents a promising technical option for patients with large coronal bowing of the shaft carrying a risk of increased KAM after TKA.

#### LEVEL OF EVIDENCE:

III.

1. **RILEY J, ROTH JD, HOWELL SM, HULL ML.**

**INCREASES IN TIBIAL FORCE IMBALANCE BUT NOT CHANGES IN TIBIOFEMORAL LAXITIES ARE CAUSED BY VARUS-VALGUS MALALIGNMENT OF THE FEMORAL COMPONENT IN KINEMATICALLY ALIGNED TKA. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2018 NOV;26(11):3238-3248.**

### Abstract

#### PURPOSE:

The purposes of this study were to quantify the increase in tibial force imbalance (i.e. magnitude of difference between medial and lateral tibial forces) and changes in laxities caused by 2° and 4° of varus-valgus (V-V) malalignment of the femoral component in kinematically aligned total knee arthroplasty (TKA) and use the results to detemine sensitivities to errors in making the distal femoral resections. Because V-V malalignment would introduce the greatest changes in the alignment of the articular surfaces at 0° flexion, the hypotheses were that the greatest increases in tibial force imbalance would occur at 0° flexion, that primarily V-V laxity would significantly change at this flexion angle, and that the tibial force imbalance would increase and laxities would change in proportion to the degree of V-V malalignment.

#### METHODS:

Kinematically aligned TKA was performed on ten human cadaveric knee specimens using disposable manual instruments without soft tissue release. One 3D-printed reference femoral component, with unmodified geometry, was aligned to restore the native distal and posterior femoral joint lines. Four 3D-printed femoral components, with modified geometry, introduced V-V malalignments of 2° and 4° from the reference component. Medial and lateral tibial forces were measured during passive knee flexion-extension between 0° to 120° using a custom tibial force sensor. Eight laxities were measured from 0° to 120° flexion using a six degree-of-freedom load application system.

#### RESULTS:

With the tibial component kinematically aligned, the increase in the tibial force imbalance from that of the reference component at 0° of flexion was sensitive to the degree of V-V malalignment of the femoral component. Sensitivities were 54 N/deg (medial tibial force increasing > lateral tibial force) (p < 0.0024) and 44 N/deg (lateral tibial force increasing > medial tibial force) (p < 0.0077) for varus and valgus malalignments, respectively. Varus-valgus malalignment did not significantly change varus, internal-external rotation, anterior-posterior, and compression-distraction laxities from 0° to 120° flexion. At only 30° of flexion, 4° of varus malalignment increased valgus laxity 1° (p = 0.0014).

#### CONCLUSION:

At 0° flexion, V-V malalignment of the femoral component caused the tibial force imbalance to increase significantly, whereas the laxities were relatively unaffected. Because tibial force imbalance has the potential to adversely affect patient-reported outcomes and satisfaction, surgeons should strive to limit errors in resecting the distal femoral condyles to within ± 0.5 mm which in turn limits the average increase in tibial force imbalance to 68 N. Because laxities were generally unaffected, instability resulting from large increases in laxity is not a clinical concern within the ± 4° range tested.

#### LEVEL OF EVIDENCE:

Therapeutic, Level II.

1. **RILEY J, ROTH JD, HOWELL SM, HULL ML.**

**INTERNAL-EXTERNAL MALALIGNMENT OF THE FEMORAL COMPONENT IN KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY INCREASES TIBIAL FORCE IMBALANCE BUT DOES NOT CHANGE LAXITIES OF THE TIBIOFEMORAL JOINT. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2018 JUN;26(6):1618-1628.**

### Abstract

#### PURPOSE:

The purposes of this study were to quantify the increase in tibial force imbalance (i.e. magnitude of difference between medial and lateral tibial forces) and changes in laxities caused by  2° and 4° of internal-external (I-E) malalignment of the femoralcomponent in kinematically aligned total knee arthroplasty. Because I-E malalignment would introduce the greatest changes to the articular surfaces near 90° of flexion, the hypotheses were that the tibial force imbalance would be significantly increased near 90° flexion and that primarily varus-valgus laxity would be affected near 90° flexion.

#### METHODS:

Kinematically aligned TKA was performed on ten human cadaveric knee specimens using disposable manual instruments without soft tissue release. One 3D-printed reference femoral component, with unmodified geometry, was aligned to restore the native distal and posterior femoral joint lines. Four 3D-printed femoral components, with modified geometry, introduced I-E malalignments of 2° and 4° from the reference component. Medial and lateral tibial forces were measured from 0° to 120° flexion using a custom tibial forcesensor. Bidirectional laxities in four degrees of freedom were measured from 0° to 120° flexion using a custom load application system.

#### RESULTS:

Tibial force imbalance increased the greatest at 60° flexion where a regression analysis against the degree of I-E malalignment yielded sensitivities (i.e. slopes) of 30 N/° (medial tibial force > lateral tibial force) and 10 N/° (lateral tibial force > medial tibial force) for internal and external malalignments, respectively. Valgus laxity increased significantly with the 4° external component with the greatest increase of 1.5° occurring at 90° flexion (p < 0.0001).

#### CONCLUSION:

With the tibial component correctly aligned, I-E malalignment of the femoral component caused significant increases in tibial force imbalance. Minimizing I-E malalignment lowers the increase in the tibial force imbalance. By keeping the resection thickness of each posterior femoral condyle to within ± 0.5 mm of the thickness of the respective posterior region of the femoral component, the increase in imbalance can be effectively limited to 38 N. Generally laxities were unaffected within the ± 4º range tested indicating that instability is not a clinical concern and that manual testing of laxities is not useful to detect I-E malalignment.

1. **RIVIÈRE C, IRANPOUR F, HARRIS S, AUVINET E, AFRAMIAN A, CHABRAND P, COBB J.**

**THE KINEMATIC ALIGNMENT TECHNIQUE FOR TKA RELIABLY ALIGNS THE FEMORAL COMPONENT WITH THE CYLINDRICAL AXIS. ORTHOP TRAUMATOL SURG RES. 2017 NOV;103(7):1069-1073.**

### Abstract

#### INTRODUCTION:

Kinematic alignment (KA) technique is an alternative technique for positioning a TKA, which aims a patient-specific implant positioning in order to reproduce the pre-arthritic knee anatomy. Because reliability in implant positioning is of interest to obtain reproducible good functional results, our study tests the hypothesis that the medial and lateral distal and posterior positions of the planned and surgically implanted kinematically aligned femoral component are similar.

#### METHODS:

Preoperative knee magnetic resonance imaging (MRI) and postoperative knee computed tomography (CT) of 13 patients implanted with a KA Persona® TKA (Zimmer, Warsaw, USA) using manual instrumentation (kinematically-aligned TKA procedure pack®, Zimmer Biomet, Warsaw, USA) were segmented to create 3D femoral models. The kinematic alignment position of the femoralcomponent was planned on the 3D model created from the preoperative MRI. Differences in the positions of the planned and surgically implanted kinematically-aligned femoral component were determined with in-house analysis software.

#### RESULTS:

The average differences between the medial and lateral distal and posterior positions of the planned and surgically implanted kinematically-aligned femoral component were inferior to 1mm and no statistically significant. In terms of variability, 62% (8/13) of performed implants matched all four positions within 1.5mm, and the maximum difference was 3mm.

#### CONCLUSION:

In this small series, intraoperative kinematic positioning of the femoral component with the specific manual instrumentation closely matched the planned position, which suggests that this technique reliably aligned the flexion-extension axis of the femoral component to the cylindrical axis.

#### LEVEL OF EVIDENCE:

Level 3.

1. **ROTH JD, HOWELL SM, HULL ML.**

**NATIVE KNEE LAXITIES AT 0°, 45°, AND 90° OF FLEXION AND THEIR RELATIONSHIP TO THE GOAL OF THE GAP-BALANCING ALIGNMENT METHOD OF TOTAL KNEE ARTHROPLASTY. J BONE JOINT SURG AM. 2015 OCT 21;97(20):1678-84.**

### Abstract

#### BACKGROUND:

Gap-balancing is an alignment method for total knee arthroplasty with the goal of creating uniform tension in the periarticular soft-tissue restraints and equal laxities throughout the arc of flexion. However, there is little evidence that achieving equal laxities prevents either overly tight or overly loose soft-tissue restraints after total knee arthroplasty. Accordingly, the purpose of the present study was to determine whether the laxities at 0°, 45°, and 90° of flexion are equal in the native knee.

#### METHODS:

Seven different laxities were measured at 0°, 45°, and 90° of flexion in ten fresh-frozen native cadaveric knees (with intact menisci, cartilage, and ligaments) by applying loads of ±5 Nm in varus-valgus rotation, ±3 Nm in internal-external rotation, 100 N in distraction, and ±45 N in anterior-posterior translation with use of a six-degrees-of-freedom load application system.

#### RESULTS:

The mean laxities (and standard deviations) at 45° of flexion were 1.7° ± 0.6° greater in varus, 0.9° ± 0.4° greater in valgus, 10.2° ± 2.7° greater in internal rotation, 10.1° ± 2.0° greater in external rotation, 1.7 ± 1.0 mm greater in distraction translation, and 3.3 ± 1.5 mm greater in anterior translation than those at 0° of flexion. The mean laxities at 90° of flexion were 2.5° ± 0.8° greater in varus, 1.0° ± 0.5° greater in valgus, 10.0° ± 4.6° greater in internal rotation, 10.1° ± 4.5° greater in external rotation, 1.8 ± 0.7 mm greater in distraction, and 1.6 ± 1.2 mm greater in anterior translation than those at 0° of flexion. The mean anterior translation at 90° of flexion was 1.7 ± 0.9 mm less than that at 45° of flexion.

#### CONCLUSIONS:

Because five of the seven laxities were at least 1.7° or 1.6 mm greater at both 45° and 90° of flexion than those at 0° of flexion, the laxities of the native knee measured in this study are unequal at these flexion angles and therefore do not support the goal of gap-balancing in total knee arthroplasty.

#### CLINICAL RELEVANCE:

One possible disadvantage of changing the native laxities at 45° and 90° of flexion to match those at 0° of flexion in a total knee arthroplasty is the overly tight soft-tissue restraints relative to those of the native knee, which patients may perceive as pain, stiffness, and/or limited flexion.

1. **ROTH JD, HOWELL SM, HULL ML.**

**KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY LIMITS HIGH TIBIAL FORCES, DIFFERENCES IN TIBIAL FORCES BETWEEN COMPARTMENTS, AND ABNORMAL TIBIAL CONTACT KINEMATICS DURING PASSIVE FLEXION. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2018 JUN;26(6):1589-1601.**

### Abstract

#### PURPOSE:

Following total knee arthroplasty (TKA), high tibial forces, large differences in tibial forces between the medial and lateral compartments, and anterior translation of the contact locations of the femoral component on the tibial component during passive flexionindicate abnormal knee function. Because the goal of kinematically aligned TKA is to restore native knee function without soft tissue release, the objectives were to determine how well kinematically aligned TKA limits high tibial forces, differences in tibial forces between compartments, and anterior translation of the contact locations of the femoral component on the tibial component during passive flexion.

#### METHODS:

Using cruciate retaining components, kinematically aligned TKA was performed on thirteen human cadaveric kneespecimens with use of manual instruments without soft tissue release. The tibial forces and tibial contact locations were measured in both the medial and lateral compartments from 0° to 120° of passive flexion using a custom tibial force sensor.

#### RESULTS:

The average total tibial force (i.e. sum of medial + lateral) ranged from 5 to 116 N. The only significant average differences in tibial force between compartments occurred at 0° of flexion (29 N, p = 0.0008). The contact locations in both compartments translated posteriorly in all thirteen kinematically aligned TKAs by an average of 14 mm (p < 0.0001) and 18 mm (p < 0.0001) in the medial and lateral compartments, respectively, from 0° to 120° of flexion.

#### CONCLUSIONS:

After kinematically aligned TKA, average total tibial forces due to the soft tissue restraints were limited to 116 N, average differences in tibial forces between compartments were limited to 29 N, and a net posterior translation of the tibial contactlocations was observed in all kinematically aligned TKAs during passive flexion from 0° to 120°, which are similar to what has been measured previously in native knees. While confirmation in vivo is warranted, these findings give surgeons who perform kinematicallyaligned TKA confidence that the alignment method and surgical technique limit high tibial forces, differences in tibial forces between compartments, and anterior translation of the tibial contact locations during passive flexion.

1. **HOWELL SM, HOWELL SJ, HULL ML.**

**ASSESSMENT OF THE RADII OF THE MEDIAL AND LATERAL FEMORAL CONDYLES IN VARUS AND VALGUS KNEES WITH OSTEOARTHRITIS. J BONE JOINT SURG AM. 2010 JAN;92(1):98-104.**

### Abstract

#### BACKGROUND:

Understanding the relationship between the radii of the medial and lateral femoral condyles in varus and valgus kneesis important for aligning the femoral component and for restoring kinematics in total knee arthroplasty. The purpose of this study was to test the hypothesis that the asymmetry between the radii of the medial and lateral femoral condyles in varus and valgus knees with osteoarthritis is small enough to be clinically unimportant.

#### METHODS:

A magnetic resonance imaging scan was obtained with use of a biplanar, rotational alignment protocol in a consecutive series of subjects with end-stage osteoarthritis prior to total knee arthroplasty. The alignment protocol oriented the scanning plane so that both condyles were imaged in a plane perpendicular to the primary femoral axis of the knee about which the tibia flexes and extends. The study included 155 varus knees and forty-four valgus knees. Radii were calculated from the area of the best-fit circle overlaid from 10 degrees to 160 degrees on the subchondral corticocancellous bone interface of the medial and lateral femoralcondyles. The radius of a condyle was the average of the radii on four adjacent images that showed the femoral condyle with the largest curvature.

#### RESULTS:

In the 155 varus knees, the radius of the lateral condyle was an average of 0.1 mm larger than that of the medial condyle (p = 0.003). In the forty-four valgus knees, the radius of the lateral condyle was an average of 0.2 mm larger than that of the medial condyle (p < 0.006). There was a strong association between the radii of the medial and lateral femoral condyles in both the varus (r(2) = 0.9210) and the valgus (r(2) = 0.9129) knees.

#### CONCLUSIONS:

As determined by imaging of the femoral condyles perpendicular to the primary femoral axis of the knee, the asymmetry between the radii of the medial and lateral femoral condyles in varus and valgus knees with end-stage osteoarthritis was < or =0.2 mm, which is small enough to be considered clinically unimportant when aligning a total knee prosthesis.

1. **NEDOPIL AJ, HOWELL SM, HULL ML.**

**DOES MALROTATION OF THE TIBIAL AND FEMORAL COMPONENTS COMPROMISE FUNCTION IN KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY? ORTHOP CLIN NORTH AM. 2016 JAN;47(1):41-50.**

### Abstract

Internal and external malrotation of the femoral and tibial components is associated with poor function after total knee arthroplasty(TKA). We determined the degree of malrotation for both components in kinematically aligned TKA and whether this malrotationcompromised function. Seventy-one patients (mean age 68 years) were followed after TKA. Malrotation was measured. Simple regression determined the association between malrotation and function. Even though the range of malrotation of the tibial component can be greater than that of the femoral component, the malrotation of the femoral and tibial components bounded by the ranges reported in this study is compatible with a well-functioning TKA.

1. **NEDOPIL AJ, HOWELL SM, HULL ML.**

**WHAT MECHANISMS ARE ASSOCIATED WITH TIBIAL COMPONENT FAILURE AFTER KINEMATICALLY-ALIGNED TOTAL KNEE ARTHROPLASTY? INT ORTHOP. 2017 AUG;41(8):1561-1569.**

### Abstract

#### PURPOSE:

Eight patients treated with kinematically-aligned (KA) total knee arthroplasty (TKA) presented with tibial component failure. We determined whether radiographic measurements and clinical characteristics are different between patients with and without tibialcomponent failure to identify mechanisms of failure and strategies to reduce the risk.

#### METHODS:

Out of 3,212 primary TKAs (2,725 TKAs with a two-year minimum follow up), of which all were performed with KA, eight patients presented with tibial component failure. Radiographic measurements, clinical characteristics (e.g. age, gender, BMI, etc.), revision surgical records, and Oxford knee scores were compared to control cohort patients matched 1:3.

#### RESULTS:

Tibial component failure presented at an average of 28 ± 15 months after primary TKA. Patients with tibial component failurehad a 6 kg/m2 greater body mass index (p = 0.034) and 5° greater posterior slope of the tibia component (p = 0.002) than controls. Final follow-up averaged 56 ± 19 months after the primary TKA and 28 ± 24 months after the revision TKA. The final Oxford knee score was 39 ± 4.6 for patients with tibial component failure and 44 ± 6.5 for the controls (p = 0.005).

#### CONCLUSIONS:

The incidence of tibial component failure after KA TKA was 0.3% and was caused by posterior subsidence or posterior edge wear and not varus subsidence. The strategy for lowering the risk of tibial component failure when performing KA is to set the tibialcomponent parallel to the flexion-extension plane (slope) and varus-valgus plane of the native joint line.

1. **THEODORE W, TWIGGS J, KOLOS E, ROE J, FRITSCH B, DICKISON D, LIU D, SALMON L, MILES B**

**HOWELL S. VARIABILITY IN STATIC ALIGNMENT AND KINEMATICS FOR KINEMATICALLY ALIGNED TKA. KNEE. 2017 AUG;24(4):733-744.**

### Abstract

#### BACKGROUND:

Total knee arthroplasty (TKA) significantly improves pain and restores a considerable degree of function. However, improvements are needed to increase patient satisfaction and restore kinematics to allow more physically demanding activities that active patients consider important. The aim of our study was to compare the alignment and motion of kinematically and mechanically aligned TKAs.

#### METHODS:

A patient specific musculoskeletal computer simulation was used to compare the tibio-femoral and patello-femoral kinematicsbetween mechanically aligned and kinematically aligned TKA in 20 patients.

#### RESULTS:

When kinematically aligned, femoral components on average resulted in more valgus alignment to the mechanical axis and internally rotated to surgical transepicondylar axis whereas tibia component on average resulted in more varus alignment to the mechanical axis and internally rotated to tibial AP rotational axis. With kinematic alignment, tibio-femoral motion displayed greater tibial external rotation and lateral femoral flexion facet centre (FFC) translation with knee flexion than mechanical aligned TKA. At the patellofemoral joint, patella lateral shift of kinematically aligned TKA plateaued after 20 to 30° flexion while in mechanically aligned TKAit decreased continuously through the whole range of motion.

#### CONCLUSIONS:

Kinematic alignment resulted in greater variation than mechanical alignment for all tibio-femoral and patello-femoral motion. Kinematic alignment places TKA components patient specific alignment which depends on the preoperative state of the knee resulting in greater variation in kinematics. The use of computational models has the potential to predict which alignment based on native alignment, kinematic or mechanical, could improve knee function for patient's undergoing TKA.

1. **ETTINGER M, CALLIESS T, HOWELL SM.**

**DOES A POSITIONING ROD OR A PATIENT-SPECIFIC GUIDE RESULT IN MORE NATURAL FEMORAL FLEXION IN THE CONCEPT OF KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY? ARCH ORTHOP TRAUMA SURG. 2017 JAN;137(1):105-110.**

### Abstract

#### PURPOSE:

Flexion of the femoral component in 5° increments downsizes the femoral component, decreases the proximal reach and surface area of the trochlea, delays the engagement of the patella during flexion, and is associated with a higher risk of patellar-femoralinstability after kinematically aligned TKA. The present study evaluated flexion of the femoral component after use of two kinematic alignment instrumentation systems. We determined whether a distal cutting block attached to a positioning rod inserted perpendicular to the distal femoral joint line in the axial plane and 8-10 cm into the distal femur anterior and posterior to the distal cortex of the femur in the sagittal plane or a femoral patient-specific cutting guide sets the femoral component in more natural flexion.

#### METHODS:

Flexion of the femoral component was measured with respect to the sagittal femoral anatomic axis of the distal diaphysis and the sagittal femoral axis on rotationally controlled long-leg lateral computer scanograms. Measurements were performed on 53 consecutive patients treated with a kinematically aligned TKA performed with a distal cutting block attached to a positioning rod, and 53 consecutive patients treated with a kinematically aligned TKA performed with a femoral patient-specific cutting guide.

#### RESULTS:

The average flexion and variability (±standard deviation) of the femoral component of patients treated with a positioning rodwas 1° ± 2° and 7° ± 4° with respect to the anatomic and mechanical axes, respectively, which was 5° less than the average flexion of the femoral component of patients treated with a femoral patient-specific cutting guide of 6° ± 4° and 12° ± 5° (p = 0.0001, p = 0.0001, respectively).

#### CONCLUSIONS:

Because a distal cutting block attached to a positioning rod sets the femoral component in 5° less flexion and with less variability than a femoral patient-specific cutting guide, we prefer this instrumentation system when performing kinematically aligned TKA to reduce the risk of patellar-femoral instability. Each surgeon should determine the repeatability of setting the flexion of the femoralcomponent with this instrumentation system.

1. **HOWELL SM. CALIPERED KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY: AN ACCURATE TECHNIQUE THAT IMPROVES PATIENT OUTCOMES AND IMPLANT SURVIVAL. ORTHOPEDICS. 2019 MAY 1;42(3):126-135.**

### Abstract

Kinematic alignment performed with caliper measurements and verification checks accurately co-align the femoral and tibial components with the 3 axes and joint lines of the native knee without ligament release and without restrictions on the degree of preoperative varus, valgus, flexion, and extension deformities and the degree of postoperative correction. [Orthopedics. 2019; 42(3):126-135.].

1. **AN VVG, TWIGGS J, LEIE M, FRITSCH BA.**

**KINEMATIC ALIGNMENT IS BONE AND SOFT TISSUE PRESERVING COMPARED TO MECHANICAL ALIGNMENT IN TOTAL KNEE ARTHROPLASTY. KNEE. 2019 MAR;26(2):466-476.**

### 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.

1. **CINOTTI G, RIPANI FR, CIOLLI G, LA TORRE G, GIANNICOLA G.**

**THE NATIVE CORONAL ORIENTATION OF TIBIAL PLATEAUS MAY LIMIT THE INDICATIONS TO PERFORM A KINEMATIC ALIGNED TOTAL KNEE ARTHROPLASTY. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2019 MAY;27(5):1442-1449.**

### Abstract

#### PURPOSE:

To investigate the coronal alignment of tibial plateaus in normal and osteoarthritic knees and to simulate the effects of a tibialcut performed in total knee arthroplasty (TKA) using a kinematic alignment technique with standard instrumentation.

#### METHODS:

The coronal alignment of tibial plateaus was measured in three groups including group 1 (reference group), 50 cadaveric tibiae showing no evidence of degenerative changes of tibial plateaus; group 2, 49 patients who underwent MR of the knee, showing no or mild degenerative changes of the knee joint and, group 3, 54 patients with knee osteoarthritis who underwent computer-assisted totalknee arthroplasty.

#### RESULTS:

The coronal alignment of tibial plateaus averaged 2.4° with no significant differences between groups. The mean coronalorientation of tibial plateaus was 3° ± 2° in men and 1.6° ± 2° in women (p = 0.03). A coronal alignment of tibial plateaus of 3° or more was found in 69 cases (45%) and 5° or more in 23 (14.7%). The simulation of a tibial cut performed with an error of 3° in varus in 15% of the subjects showing a native coronal orientation of tibial plateaus of 3° or more, led to a final tibial cut greater 6° in 13.7% of cases.

#### CONCLUSIONS:

A coronal alignment of tibial plateaus of 3° or more in varus was found in near half of normal subjects and osteoarthritic patients. A preoperative measurement of the coronal alignment of tibial plateaus is advisable in any patients scheduled for kinematicaligned TKA. As errors in the alignment of the tibial component of 3° or more may occur using standard instrumentations, the results of this study raise questions on performing a kinematic aligned TKA with standard instrumentations.

#### LEVEL OF EVIDENCE:

IV.

1. **HOWELL SM, HODAPP EE, VERNACE JV, HULL ML, MEADE TD.**

**ARE UNDESIRABLE CONTACT KINEMATICS MINIMIZED AFTER KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY? AN INTERSURGEON ANALYSIS OF CONSECUTIVE PATIENTS. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2013 OCT;21(10):2281-7.**

### Abstract

#### PURPOSE:

Tibiofemoral contact kinematics or knee implant motions have a direct influence on patient function and implant longevity and should be evaluated for any new alignment technique such as kinematically aligned total knee arthroplasty (TKA). Edge loading of the tibial liner and external rotation (reverse of normal) and adduction of the tibial component on the femoral component are undesirablecontact kinematics that should be minimized. Accordingly, this study determined whether the overall prevalence of undesirable contactkinematics during standing, mid kneeling near 90 degrees and full kneeling with kinematically aligned TKA are minimal and not different between groups of consecutive patients treated by different surgeons.

#### METHODS:

Three surgeons were asked to perform cemented, kinematically aligned TKA with patient-specific guides in a consecutiveseries of patients with their preferred cruciate-retaining (CR) implant. In vivo tibiofemoral contact positions were obtained using a 3- to 2-dimensional image registration technique in 69 subjects (Vanguard CR-TKA N = 22, and Triathlon CR-TKA N = 47).

#### RESULTS:

Anterior or posterior edge loading of the tibial liner was not observed. The overall prevalence of external rotation of the tibial component on the femoral component of 6 % was low and not different between surgeons (n.s.). The overall prevalence of adduction of the tibial component on the femoral component of 4 % was low and not different between surgeons (n.s.).

#### CONCLUSIONS:

Kinematically aligned TKA minimized the undesirable contact kinematics of edge loading of the tibial liner, and external rotation and adduction of the tibial component on the femoral component during standing and kneeling, which suggests an optimistic prognosis for durable long-term function.

#### LEVEL OF EVIDENCE:

III.

1. **HUTT J, MASSÉ V, LAVIGNE M, VENDITTOLI PA.**

**FUNCTIONAL JOINT LINE OBLIQUITY AFTER KINEMATIC TOTAL KNEE ARTHROPLASTY. INT ORTHOP. 2016 JAN;40(1):29-34.**

### Abstract

#### PURPOSE:

Kinematic total knee arthroplasty (TKA) is an emerging technique, but concerns remain around the effect of implanting the prosthesis in more anatomic orientations. Native knees show variation in joint line orientation relative to the tibial mechanical axis but the joint line remains parallel to the floor when standing. This study was undertaken to evaluate joint line obliquity relative to the floor when weight-bearing after kinematic TKA to see if a similar effect occurs.

#### METHODS:

Preoperative and postoperative measurements were taken for 55 consecutive kinematically aligned TKAs, including the jointline orientation angle (JLOA), formed between the joint line and a line parallel to the floor.

#### RESULTS:

The mean medial proximal tibial angle (MPTA) was 3.4° varus pre-operatively (1.7° valgus to 7.9° varus, SD 2.0), and 3.0° varus postoperatively (5.5° valgus to 6.5° varus, SD 2.1). The mean postoperative JLOA was 1.0° varus with a smaller range than the MPTA (2.6° valgus to 6° varus, SD 1.9). The difference between these two measurements was significant (mean 2°, SD 2.5, p < 0.001).

#### CONCLUSIONS:

Relative to the mechanical axis, 33 tibial components would be considered at risk outliers, being orientated at more than 3° in varus or valgus. However, only six components were outside this range relative to the vertical, all in varus (mean 4.2°). This latter measurement may better represent how the prosthesis is functionally loaded and is similar to mechanically aligned TKAs with good survivorship. This may help explain why kinematic alignment does not lead to higher earlier failure rates that may result if similar orientations were seen with mechanically aligned TKA.

1. **ISHIKAWA M, KURIYAMA S, ITO H, FURU M, NAKAMURA S, MATSUDA S.**

**KINEMATIC ALIGNMENT PRODUCES NEAR-NORMAL KNEE MOTION BUT INCREASES CONTACT STRESS AFTER TOTAL KNEE ARTHROPLASTY: A CASE STUDY ON A SINGLE IMPLANT DESIGN. KNEE. 2015 JUN;22(3):206-12.**

### Abstract

#### BACKGROUND:

Kinematically aligned total knee arthroplasty (TKA) is of increasing interest because this method might improve postoperative patient satisfaction. In kinematic alignment the femoral component is implanted in a slightly more valgus and internally rotated position, and the tibial component is implanted in a slightly more varus and internally rotated position, than in mechanical alignment. However, the biomechanics of kinematically aligned TKA remain largely unknown. The aim of this study was to compare the kinematics and contact stresses of mechanically and kinematically aligned TKAs.

#### METHODS:

A musculoskeletal computer simulation was used to determine the effects of mechanically or kinematically aligned TKA. Knee kinematics were examined for mechanically aligned, kinematically aligned, and kinematically aligned outlier models. Patellofemoral and tibiofemoral contact forces were measured using finite element analysis.

#### RESULTS:

Greater femoral rollback and more external rotation of the femoral component were observed with kinematically aligned TKA than mechanically aligned TKA. However, patellofemoral and tibiofemoral contact stresses were increased in kinematically aligned TKA.

#### CONCLUSIONS:

These findings suggest that kinematically aligned TKA produces near-normal knee kinematics, but that concerns for long-term outcome might arise because of high contact stresses.

1. **KIM JT, HAN J, SHEN QH, MOON SW, WON YY.**

**MORPHOLOGICAL PATTERNS OF ANTERIOR FEMORAL CONDYLAR RESECTION IN KINEMATICALLY AND MECHANICALLY ALIGNED TOTAL KNEE ARTHROPLASTY. J ARTHROPLASTY. 2018 AUG;33(8):2506-2511.**

### Abstract

#### BACKGROUND:

"Grand-piano sign" has been used as a popular benchmark to facilitate correct rotational alignment during total kneearthroplasty (TKA). The purpose was to quantitatively determine morphological patterns on anterior femoral resection in mechanicallyaligned (MA) and kinematically aligned (KA) TKA.

#### METHODS:

Computed tomography scans of 60 TKA candidates were reconstructed into 3D models. Femurs were virtually cut with a 3D imaging program using various anterior flange flexion angles (AFFAs) of 3°, 5°, and 7°. The anterior femoral resection was performed parallel to the surgical epicondylar axis, at an external rotation and internal rotation of 3° relative to surgical epicondylar axis for MA-TKA, and parallel to the cylindrical axis, at an external rotation and internal rotation of 3° to cylindrical axis for KA-TKA. The ratio of vertical distance from the anterior margin of distal femoral resection to the most proximal peak of each medial and lateral condyle of anterior femoral resection was defined as AC/BC ratio.

#### RESULTS:

The mean ratios of AC/BC were 0.57, 0.60, and 0.63 respectively, according to 3°, 5°, and 7° of AFFA with standard MA-TKA method and were 0.73, 0.74, and 0.76, respectively, according to 3°, 5°, and 7° of AFFA with standard KA-TKA method. The AC/BC ratios of malrotated planes were significantly different from those of both standard MA- and KA-TKAs (P-values < .01).

#### CONCLUSION:

Surgeons can accessorily use the quantifying method for anterior femoral resection intraoperatively to ensure correct rotational alignment of femoral resection in both mechanically and kinematically aligned TKA.

1. **MADERBACHER G, KESHMIRI A, KRIEG B, GREIMEL F, GRIFKA J, BAIER C.**

**KINEMATIC COMPONENT ALIGNMENT IN TOTAL KNEE ARTHROPLASTY LEADS TO BETTER RESTORATION OF NATURAL TIBIOFEMORAL KINEMATICS COMPARED TO MECHANIC ALIGNMENT. KNEE SURG SPORTS TRAUMATOL ARTHROSC. 2019 MAY;27(5):1427-1433.**

### Abstract

#### PURPOSE:

Kinematically aligned total knee arthroplasty is associated with superior pain relief, increased flexion and a more normal feeling knee. It was hypothesized that due to restoring the knee's natural anatomy, kinematically aligned knees show more physiological tibiofemoral kinematics than mechanically aligned knees.

#### METHODS:

Investigations were performed in nine healthy cadaveric knees of whole bodies fixed by the Thiel method. Tibiofemoralkinematics of healthy knees and after kinematically and mechanically aligned total knee arthroplasty were assessed between 0° and 90° of flexion by a navigational device.

#### RESULTS:

Regarding tibial internal rotation or femoral roll back, respectively, kinematically aligned total knee arthroplasties showed no significant differences between 0° and 70° of flexion in comparison to knees before total knee arthroplasty. In contrast, mechanically aligned total knee arthroplasties showed significant changes between 10° and 90° of flexion. Kinematically aligned knees showed a significant changed abduction/adduction between 20° and 70° of flexion, mechanically aligned knees within 20° and 90° of flexion.

#### CONCLUSION:

In the present study setting kinematically aligned total knee arthroplasties showed more natural and physiological tibiofemoral kinematic pattern with regard to tibial internal rotation or femoral rollback, respectively, and tibial adduction than mechanically aligned total knee arthroplasties. While these results may support promising early clinical results of kinematical alignmentproposing a better function, long-term results especially implant survival need to be awaited.

1. **MAILLOT C, LEONG A, HARMAN C, MORELLI A, MOSPAN R, COBB J, RIVIÈRE C.**

**POOR RELATIONSHIP BETWEEN FRONTAL TIBIOFEMORAL AND TROCHLEAR ANATOMIC PARAMETERS: IMPLICATIONS FOR DESIGNING A TROCHLEA FOR KINEMATIC ALIGNMENT. KNEE. 2019 JAN;26(1):106-114.**

### Abstract

#### BACKGROUND:

The kinematic alignment (KA) technique for total knee arthroplasty (TKA) is an emerging implant positioning philosophy that aims to restore constitutional knee anatomy to improve knee kinematics. At present, the KA technique aims to reconstruct native femorotibial (FT) joint alignment, however there is still insufficient consideration towards the inter-individual trochlear anatomy variability. Poor trochlear restoration may compromise clinical outcomes. Our study aimed at assessing the anatomical relationship between the native trochlea and other FT anatomical parameters.

#### METHODS:

Fifty-eight preoperative CT scans of low-grade knee arthritic patients were segmented to create 3D bone models. The FT and the PF anatomical parameters were measured using in-house software. Values were compared between different groups of lower limb and FT joint line (JL) orientation, and correlations between FT and PF anatomical parameters were assessed.

#### RESULTS:

We were unable to detect any significant correlation between groove orientation (frontal and axial) or groove radius and either the hip-knee-ankle (HKA), or the lateral distal femoral (LDFA), or the medial proximal tibial (MPTA), or the FTJL-mechanical axis (FTJLMAA) Angles. When considering the correlation within sub-groups of limb or JL orientation, we only found a positive correlation (r = 0.464, p = 0.022) in the varus lower limb (HKA ≤ 180°) sub-group between groove frontal orientation and LDFA.

#### CONCLUSION:

Our study shows that the determination of several limb, knee, and JL parameters is of poor value to predict individual trochlea anatomy. This raises the issue of how to improve femoral component design to achieve individualised FT and PF anatomical restoration with KATKA.

#### LEVEL OF EVIDENCE:

Level 1 - computational study.

1. **NAKAJIMA A, SONOBE M, AKATSU Y, AOKI Y, TAKAHASHI H, SUGURO T, NAKAGAWA K.**

**ASSOCIATION BETWEEN LIMB ALIGNMENT AND PATIENT-REPORTED OUTCOMES AFTER TOTAL KNEE ARTHROPLASTY USING AN IMPLANT THAT REPRODUCES ANATOMICAL GEOMETRY. J ORTHOP SURG RES. 2018 DEC 17;13(1):320.**

### Abstract

#### BACKGROUND:

A kinematically aligned (KA) total knee arthroplasty (TKA) is expected to improve patient satisfaction, but its effect remains controversial. We investigated differences in patient-reported outcomes (PROs) between KA and non-KA TKAs using an implantthat reproduces anatomical geometry.

#### METHODS:

TKAs for varus deformity were performed in consecutive 129 patients (149 knees) via a measured resection technique with conventional instruments. The femorotibial angle (FTA), hip-knee-ankle angle (HKAA), and the angle between the joint line and the line perpendicular to the mechanical axis (AJLMA) were measured postoperatively (mean 13.6 months), and an AJLMA of ≥ 2° was defined as kinematic alignment. Patients were assigned to two or three alignment categories in each measurement method, and the KneeSociety Scores (KSS) and Japanese Knee Injury and Osteoarthritis Outcome Scores (J-KOOS) was compared among the groups.

#### RESULTS:

For patients assessed by FTA, an ADL-related J-KOOS subscale (J-KOOS-A) showed a significant difference between valgus and varus outliers (p < 0.05). When assessed by HKAA, neither the KSS nor J-KOOS subscales were significantly different among groups. When assessed by AJLMA, J-KOOS-A was significantly different between groups, and a group for AJLMA of ≥ 2° had higher scores than a group for AJLMA of < 2° (95% CI 0.323-7.763; p < 0.05).

#### CONCLUSIONS:

Patients with an AJLMA of ≥ 2° reported significantly higher patient's satisfaction regarding ADL. This suggests the importance of restoration of the physiological joint line which can be achieved via KA TKAs.

1. **NOGLER M, HOZACK W, COLLOPY D, MAYR E, DEIRMENGIAN G, SEKYRA K.**

**ALIGNMENT FOR TOTAL KNEE REPLACEMENT: A COMPARISON OF KINEMATIC AXIS VERSUS MECHANICAL AXIS TECHNIQUES. A CADAVER STUDY. INT ORTHOP. 2012 NOV;36(11):2249-53**

### Abstract

#### PURPOSE:

Standard instrumentation tries to reproduce mechanical axes based on mechanical alignment (MA) guides. A kinematicalignment (KA) technique derives its plan from pre-operative MRI-measurements. This matched-pair cadaveric study compared the resulting postoperative alignments.

#### METHODS:

A prospective series of 12 torsos were acquired for a total of 24 limb specimens including intact pelvises, femoral heads, knees, and ankles.The cadavers received MRI scans to manufacture the kinematic alignment cutting guides. Two investigating surgeons performed total knee arthroplasties on randomly chosen sides using MA instruments. On the contralateral sides, KA cutting guides were used. A navigation system was used to measure final alignment.

#### RESULTS:

The overall alignment showed no significant differences between the systems. In the MA group the differences between the planned and the final implantation regarding overall limb alignment ranged between 0.2° and 6.2°. In the KA group the differences between the planned and final implantation regarding overall limb alignment ranged between 0.3° and 9.1°. The differences of the deviation from plan for overall limb alignment showed no significant differences between the methods.

#### CONCLUSIONS:

The different alignment strategies resulted in variations of the combinations of the three-dimensional component position on the femur and the tibia. However, the legs were aligned within comparable range for both chosen techniques.

1. **PARK A, DUNCAN ST, NUNLEY RM, KEENEY JA, BARRACK RL, NAM D.**

**RELATIONSHIP OF THE POSTERIOR FEMORAL AXIS OF THE "KINEMATICALLY ALIGNED" TOTAL KNEE ARTHROPLASTY TO THE POSTERIOR CONDYLAR, TRANSEPICONDYLAR, AND ANTEROPOSTERIOR FEMORAL AXES. KNEE. 2014 DEC;21(6):1120-3.**

### Abstract

#### BACKGROUND:

A recent proposed modification in surgical technique in total knee arthroplasty (TKA) has been the introduction of the "kinematically aligned" TKA, in which the angle and level of the posterior joint line of the femoral component and joint line of the tibial component are aligned to those of the "normal," pre-arthritic knee. The purpose of this study was to establish the relationship of the posterior femoral axis of the "kinematically aligned" total knee arthroplasty (TKA) to the traditional axes used to set femoral component rotation.

#### METHODS:

One hundred and fourteen consecutive, unselected patients with preoperative MRI images undergoing TKA were retrospectively reviewed. The transepicondylar axis (TEA), posterior condylar axis (PCA), antero-posterior axis (APA) of the trochlear groove, and posterior femoral axis of the kinematically aligned TKA (KAA) were templated on axial MRI images by two independent observers. The relationships between the KAA, TEA, APA, and PCA were determined, with a negative value indicating relative internal rotation of the axis.

#### RESULTS:

On average, the KAA was 0.5° externally rotated relative to the PCA (minimum of -3.6°, maximum of 5.8°), -4.0° internally rotated relative to the TEA (minimum of -10.5°, maximum of 2.3°), and -96.4° internally rotated relative to the APA (minimum of -104.5°, maximum of -88.5°). Each of these relationships exhibited a wide range of potential values.

#### CONCLUSIONS:

Using a kinematically aligned surgical technique internally rotates the posterior femoral axis relative to the transepicondylar axis, which significantly differs from current alignment instrument targets.

1. **ALMAAWI AM, HUTT JRB, MASSE V, LAVIGNE M, VENDITTOLI PA.**

**THE IMPACT OF MECHANICAL AND RESTRICTED KINEMATIC ALIGNMENT ON KNEE ANATOMY IN TOTAL KNEE ARTHROPLASTY. J ARTHROPLASTY. 2017 JUL;32(7):2133-2140.**

### Abstract

#### BACKGROUND:

Total knee arthroplasty (TKA), aiming at neutral mechanical alignment (MA), inevitably modifies the patient's native kneeanatomy. Another option is kinematic alignment (KA), which aims to restore the original anatomy of the knee. The aim of this study was to evaluate the variations in lower limb anatomy of a patient population scheduled for TKA, and to assess the use of a restricted KA TKA protocol and compare the resulting anatomic modifications with the standard MA technique.

#### METHODS:

A total of 4884 knee computed tomography scans were analyzed from a database of patients undergoing TKA with patient-specific instrumentation. The lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA), and hip-knee-ankle angle (HKA) were measured. Bone resections were compared using a standard MA and a restricted KA aiming for independent tibial and femoral cuts of maximum ±5° deviation from the coronal mechanical axis and a resulting overall coronal HKA within ±3° of neutral.

#### RESULTS:

The mean preoperative MPTA was 2.9° varus, LDFA was 2.7° valgus, and overall HKA was 0.1° varus. Using our protocol, 2475 knees (51%) could have undergone KA without adjustment. To include 4062 cases (83%), mean corrections of 0.5° for MPTA and 0.3° for LDFA were needed, significantly less than with MA (3.3° for MPTA and 3.2° for LDFA; P < .001).

#### CONCLUSION:

The range of knee anatomy in patients scheduled for TKA is wide. MA leads to greater modifications of knee joint anatomy. To avoid reproducing extreme anatomy, the proposed restricted KA protocol provides an interesting hybrid option between MA and true KA.

1. **NAKAMURA S, TIAN Y, TANAKA Y, KURIYAMA S, ITO H, FURU M, MATSUDA S.**

**THE EFFECTS OF KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY ON STRESS AT THE MEDIAL TIBIA: A CASE STUDY FOR VARUS KNEE. BONE JOINT RES. 2017 JAN;6(1):43-51.**

### Abstract

#### OBJECTIVES:

Little biomechanical information is available about kinematically aligned (KA) total knee arthroplasty (TKA). The purpose of this study was to simulate the kinematics and kinetics after KA TKA and mechanically aligned (MA) TKA with four different limb alignments.

#### MATERIALS AND METHODS:

Bone models were constructed from one volunteer (normal) and three patients with three different kneedeformities (slight, moderate and severe varus). A dynamic musculoskeletal modelling system was used to analyse the kinematics and the tibiofemoral contact force. The contact stress on the tibial insert, and the stress to the resection surface and medial tibial cortex were examined by using finite element analysis.

#### RESULTS:

In all bone models, posterior translation on the lateral side and external rotation in the KA TKA models were greater than in the MA TKA models. The tibiofemoral force at the medial side was increased in the moderate and severe varus models with KA TKA. In the severe varus model with KA TKA, the contact stress on the tibial insert and the stress to the resection surface and to the medial tibial cortex were increased by 41.5%, 32.2% and 53.7%, respectively, compared with MA TKA, and the bone strain at the medial side was highest among all models.

#### CONCLUSION:

Near normal kinematics was observed in KA TKA. However, KA TKA increased the contact force, stress and bone strain at the medial side for moderate and severe varus knee models. The application of KA TKA for severe varus knees may be inadequate.Cite this article: S. Nakamura, Y. Tian, Y. Tanaka, S. Kuriyama, H. Ito, M. Furu, S. Matsuda. The effects of kinematicallyaligned total knee arthroplasty on stress at the medial tibia: A case study for varus knee

1. **KARUPPAL R.**

**KINEMATIC ALIGNMENT IN TOTAL KNEE ARTHROPLASTY: DOES IT REALLY MATTER? J ORTHOP. 2016 NOV 1;13(4):A1-A3.**

**1. Introduction**

The perfect placement of the femoral and tibial components is the most important predictor of the best clinical outcome in total knee arthroplasty (TKA). Clinical studies prove substantial variation in kinematic and functional performance within the TKA patient population. The variations in some situations are due to differences in implant design or surgical technique, the component alignment being considered as another important factor. These alignment errors in TKA have lead to the continuous evaluation of surgical alignment techniques. Many studies have shown that knee kinematics after TKA are still altered compared to the normal knee joint. But very little is evident to the patients regarding impairments and functional limitations. There are three alignment options in TKA, which includes anatomical alignment, mechanical alignment and the kinematical alignment. Mechanical and anatomical alignment assumes to keep the implants in an ‘average’ position in view that it changes the natural alignment of the limb and knee and causes uncorrectable knee instabilities.1 Evidences have shown that a significant number of patients with mechanically aligned TKA continue to complain of pain, stiffness, instability and failure. Even though the primary aim of kinematic alignment is to recreate the normal knee joint kinematics and not to restore a neutral or 0° hip–knee–ankle axis. However, the kinematic alignment does not mal-align the hip–knee–ankle axis.

2. Alignment options in TKA

The normal knee joint line alignment is in 2°–3° of varus compared with the mechanical axis of lower limb. The main aim of all the alignment techniques is to achieve neutral alignment of the knee. This neutral alignment is rarely seen in healthy non-arthritic patients. A successful TKA is often based on reproducing the neutral knee alignment postoperatively. The normal movement of the knee joint is determined by the biomechanical interaction between the menisci, ligaments and the articulating surfaces of the femur, tibia and patella. There are three alignment philosophies of mechanical, anatomic, and kinematic alignment methods used in TKA. These alignment options are based on the distal femoral and proximal cuts taken according to the reference axis opted by the surgeon. Changes in the natural angle or joint level definitely cause alteration of the normal knee joint kinematics and ultimately results poor function.

3. Anatomical alignment

The anatomic axis of the lower limb is an axis in relation to the intramedullary canals of femur and tibia.2 On antero-posterior evaluation the anatomical and mechanical axis of tibia coincides exactly but in the femur it makes an angle of 5°–7°. The most important fact is the anatomic axis can deviate significantly depending on femoral or tibial angular deformities, and patient's hip angle.3 Femoro-tibial angle (FTA) is the angle subtended between the anatomic axes of the femur and the tibia on a weight-bearing X-ray.2 The average value of the FTA is approximately 178° in men, and 176°–174° in women.2 The FTA can be affected by various factors like axial limb rotation and flexion deformity.4 The FTA becomes more valgus with increasing valgus deformity.5

Hungerford and Krackow were described the anatomical alignment of TKA.6 They believed that the optimal TKA component position should anatomically recreate the joint line. Here the component alignment is 2°–3° of varus in relation to the mechanical axis of the lower extremity.6 The cuts are taken to mimic the natural knee by cutting the tibia at 3° varus to the anatomical (or mechanical) axis of the tibia and a distal femoral cut angle be made from the difference between the anatomic axis and the mechanical axis of the femur, is approximately 8°–9° of valgus.7 When this is combined, it gives a total alignment of approximately 6° of valgus that approaches the normal tibiofemoral angle. Also, this alignment provided for a joint line that is parallel to the ground during normal gait.6

4. Mechanical alignment

The mechanical axis of the lower extremity pass from the center of the femoral head to the center of the ankle joint.2 In normal individuals the position of the mechanical axis usually passes just medial to the tibial spine. This can vary widely based on the patient height (decreased height results in increased axis deviation) and pelvic width (increased pelvic width in increased axis deviation).

The use of mechanical alignment in TKA was originally described by John Insall.8 Mechanical alignment is achieved by making an initial femoral cut perpendicular to the mechanical axis of the femur, which is followed by a tibial cut made perpendicular to the mechanical axis of the tibia. Insall believed that mechanical alignment was the superior method. His philosophy was in anatomically aligned knee, because of the increased forces across the medial joint component, lead to medial tibial plateau fixation failure.1 Insall pointed out that even though the joint loading forces between compartments are even during the stance phase, it will be uneven during the gait phase due to a “laterally” directed ground reaction force.1 He also argued for the 3° of external rotation of femoral component to balance the flexion and extension gaps.

5. Kinematic alignment

In kinematically aligned TKA, three axes govern the movement of the patella and tibia with respect to the femur. The better understanding of these axes is the key to kinematically aligning a TKA. The primary axis is a transverse axis which passes through the center of a circle fit to the articular surface of the femoral condyles from 10° to 160° of flexion. The tibia flexes and extends around this axis.8 Through the second transverse axis in the femur about which the patella flexes and extends. Second axis is parallel, proximal, and anterior to the first axis. The third axis is a longitudinal axis in the tibia about which the tibia internally and externally rotates on the femur. The third axis is perpendicular to the first and second transverse axes.8 Although each of the three axes is aligned parallel or perpendicular to one another, none are aligned orthogonally to the three anatomic planes, which mean that the axis cannot be found with imaging studies performed in the sagittal, coronal, and axial planes.9 So it is to co-align the transverse axis of the femoral component with the primary transverse axis in the femur about which the tibia flexes and extends is the main goal of kinematic alignment of the femoral component.8

This is done by shape-matching the femoral component to the articular surface of the femur. The femoral component should co-align with the primary transverse axis, which is important for the restoration of the normal interrelationships among the three axes.10 Kinematically aligning the tibial component involves several steps unlike the femoral component placement. The first step is to align the anterior-posterior axis of the tibial component perpendicular to the transverse axis of the femoral component.11 The second step is to align the tibia to the tibial component, which is based on the assumption that the internal–external rotational relationship between the femur and tibia is normal. The final step is aligning the center of the tibia under the center of the tibial component. This is planned with the help of a software which creates a 3-dimensional model of the arthritic knee from a non-weight bearing MRI or computed tomography arthrogram of the knee. Additional software programs help to transforms the arthritic knee model of the patient to a normal knee model. Then it kinematically aligns the components by shape-matching the best-fitting femoral and tibial components to the normal knee model. The 3-dimensional position of each component is then transferred by the software, from the normal knee to the arthritic knee model. Finally the patient-specific cutting guides are made to fit the patient's femur and tibia accordingly.12, 13

By comparing the symmetry of the thickness of the bone resections the kinematic alignment of the femoral component can be confirmed intra-operatively. Then restoration of motion and balancing the TKA is simplified by a stepwise algorithm of removal of osteophytes, adjusting the plane of the tibial cut, releasing the posterior capsule from the femur, and lateralizing or medializing the tibial component. Here the undesirable consequences are lessened by customizing the position of the implants with kinematic alignment.

Coronal alignment is definitely a factor in deciding the outcome of TKA, though it may not be the most important factor but may serve to compound failure from other causes.14 The principle of mechanically aligned TKA is to restore the neutral mechanical axis which will help to improve the implant durability and patient's function following surgery.15 In a study by Fang et al.,16 three alignment groups were selected and it was found that patients who had alignment between 2.4° and 7.2° of valgus had the best overall survivorship. They also noted that varus knees might failed due to medial tibial collapse, and valgus knee failed commonly because of ligamentous instability.

Jeffery et al.17 radiographically assessed the mechanical axis of TKA and reported that when the axis passed through the middle one-third of the prosthesis, which resulted in a 3% rate of loosening. While as the axis shifted either medial or lateral, the loosening rate was increased to very high value (24%). There are many reports that, patients who achieved mechanical alignment within 3° of the mechanical axis had a significant increase in International Knee Society Score and Short-Form 12 physical scores compared with patients who did not. Despite the common belief among orthopedic surgeons that a mechanically well-aligned TKA will results in improved outcomes. But many studies have challenged this concept.

The conventional and computer navigated system uses mechanical alignment TKA have no bearing on the kinematics of the knee.18 Even among the perfectly mechanically aligned TKA groups have a 20% prevalence of patient dissatisfaction.19 Studies show following mechanically aligned TKA with conventional instruments, one out of five patients is not satisfied because of continued pain and poor function.19

There was no functional or patient satisfaction correlation between the two functional arc alignment groups of 3° or less and 3° or more.20 However, they observed that in patients who had more than 3° of alignment has significantly increased difficulty with activities of daily living. Another interesting observation in 15-year follow up study between the prostheses place within 3° of varus or valgus compared with the prosthesis aligned outside this range that there were no differences in the estimated survivorship.21

Several studies have shown that there are a significant number of healthy asymptomatic adults do not have a neutral mechanical axis but mechanical alignment TKA believes on this non-existing zero axis.

So the mechanically aligned TKA will kinematically mal-aligns the knee and ultimately causes early failure.7 Although there is a wide belief that a neutral mechanical axis will result in better longevity of TKA, the mid- or long-term scientific support for this contention is surprisingly weak.9 Recently many reports have been highlighted challenging the superiority of neutral mechanical alignment.

Regarding the survival of implants, Morgan et al. reviewed the outcomes of 197 Kinemax™ TKAs and found no difference in revision rate among those in neutral, varus or valgus alignment postoperatively.22 Hence many researchers have explored the cylindrical axis of the knee23 and then came the concept of kinematic alignment.24 This is considered to be a 3-dimensional alignment of components, whereas the other two were 2-dimensional only.25 The goal of this alignment method is to achieve a “more natural” knee kinematics.26 The kinematic alignment reestablishes the normal obliquity and the pre-arthritic level of joint line. This is considered as the reasons for the good improvements in clinical outcomes, greater ranges-of-motion, and better patient satisfaction.26 A change in the natural angle and level of joint line causes abnormal kinematics; consequently there will be instability, stiffness, wear and component loosening.27 In kinematically aligned TKA the bony cuts restore the natural angle and level of joint thereby minimizing the complications.

The kinematic alignment concept is traced to Hollister and colleagues’ were done a lot of classic research on the kinematics of the knee and who highlighted the biomechanical rationale for kinematic alignment.8 Before the practice of kinematic alignment, the TKA were performed mainly on the mechanical alignment principles. Kinematic alignment works on different principles for placing the components. Here, co-aligning the transverse axis of the selected best-fitting femoral component with the primary transverse axis in the femur, removing osteophytes to restore ligament length motion and stability, and placing the tibial component perpendicular to the transverse axis in the femur. Loss of flexion and extension, pain, stiffness, instability and prolonged recovery associated with mechanical alignment are not seen with kinematically aligned knee […/…/Users/yathra/Desktop/doubts/KINEMATICS/Mechanical, Anatomical, and Kinematic Axis in TKA Concepts and Practical Applications.htm – CR347). Studies have shown that releases of the collateral ligaments are not needed with kinematic alignment, which could be the reason why kinematically aligned TKA restores more normal contact kinematics than mechanical counterpart.28

A level I prospective randomized control study which compared the function, patient satisfaction and flexion by Dossett et al. shows significantly better results in kinematically aligned TKA.25 There was a significantly better WOMAC and KSS scores in kinematic alignment group compared with the mechanically aligned counterpart. Although the kinematic alignment group demonstrated significantly better overall results, more outliers with poor outcomes were also seen in this group.29 This study also shows that, restoring the pre-morbid flexion-extension axis offers a better overall functional results and the kinematic alignment is a favorable technique for TKA. It is found that the contact mechanics in kinematically aligned TKA had normal motion hence have high function.28

The added advantages of kinematically aligned knees are shorter operating and recovery time and earlier return to the daily routines. Moreover blood transfusions are infrequent, probably because the collateral and retinacular soft tissues are not released. Fat embolic incidents have not been occurred because intramedullary rods are not at all used.

**7. Conclusion**

The goal of a successful TKA is to achieve good alignment of the femoral, tibial, and patellar components. Faulty joint alignment can result in increased implant stress, poor functional outcomes, and early failure. The better survivorship of the mechanically aligned TKA might be the result of better balancing of the knee and restoration of normal kinematics rather than the modern implant design or instrumentation. Kinematic alignment does not mal-align the natural hip–knee–ankle axis of the patient. Kinematically aligned TKA stand as a superior alternative to the mechanically aligned TKA because it offers a better patient satisfaction and joint function. As of now, the kinematically aligned knee restored high function with no catastrophic failure because it has less abnormal kinematic contacts. All these factors promote this wonderful concept as a worthy alignment option for a better TKA.

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1. **RIVIÈRE C, HARMAN C, LEONG A, COBB J, MAILLOT C.**

**KINEMATIC ALIGNMENT TECHNIQUE FOR MEDIAL OXFORD UKA: AN IN-SILICO STUDY. ORTHOP TRAUMATOL SURG RES. 2019 FEB;105(1):63-70.**

### Abstract

#### BACKGROUND:

Mobile bearing unicompartmental knee arthroplasty (UKA) Oxford™ components are recommended to be systematically and mechanically aligned (MA) for restoring the constitutional lower-limb alignment. Good long-term clinical outcomes have been generated with the medially implanted MA Oxford™, but some sub-optimal biomechanical-related complications still remain. Kinematic Alignment (KA) is a personalised technique for anatomically and kinematically implanting components (total knee, fixed bearing partial knee, total hip) aimed at creating more physiological prosthetic joint biomechanics. Interestingly, for decades the principles for implanting fixed bearing UKA components were consistent with those promoted by the KA technique, but differently formulated. We initiated this computational study to assess the feasibility of this technique with the Oxford™ components, as we thought this more anatomical implantation may be clinically advantageous.

#### HYPOTHESIS:

We surmised that kinematically aligning the Oxford™ medial UKA would maximise the prosthesis-bone interface through maximising the implants' size used (question 1), and alter, within an acceptable limit, the components' orientation (question 2) compared to conventional mechanical alignment.

#### METHODS:

A cohort of 40 consecutive medial osteoarthritic knee patients scheduled for UKA had a preoperative CT scan that was segmented to create 3D knee bone models. MA and KA of medial UKA Oxford® components (Zimmer-Biomet, Warsaw, Indiana, USA) were simulated. Component sizing and positioning were compared between the two techniques.

#### RESULTS:

We found no difference in component size, but significantly fewer occurrences of borderline fit with the KA simulation. KA technique oriented the femoral component 3.6° more valgus (from 1° varus to 7° valgus) and the tibial component 2.9° more varus (from 8° varus to 0°) compared to the MA technique. The tibial component slope in KA simulation was 6.4° posterior (from 0 to 12°) compared to a systematic 7° posterior for MA positioning.

#### DISCUSSION AND CONCLUSION:

Kinematic alignment of the medial Oxford™ generated a different, albeit still acceptable (Oxford group recommendations), implant orientation, in addition to a likely better shape-fit between components and the supportive bone cut, compared to the MA technique. The potential to improve the implants' interaction and to restore a more physiological bone loading makes the KA of Oxford™ an attractive, potentially clinically beneficial option. Clinical investigations are needed to assess its true value.

#### LEVEL OF EVIDENCE:

I, computational study.