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Commentary

Ten Flaws of Systematic Mechanical Alignment Total Knee Arthroplasty

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ABSTRACT

Mechanical alignment (MA) and its tenets have been considered essential for total knee arthroplasty (TKA) success since they were introduced in 1973. However, over time, there have been colossal advances in our knowledge and understanding of the anatomy and kinematics of the knee, as well as in surgical precision and implants. However, the MA systematic principles of prosthetic arthroplasty and implant position related to the lower-extremity mechanical axis, have only recently been called into question. The high rates of dissatisfaction and residual pain reported after MA TKA prompted this questioning, and that leaves plenty of room for improvement. Despite the general consensus that there is great variability between patients' anatomy, it is still the norm to carry out a systematic operation that does not consider individual variations. Evolving to a more personalized arthroplasty surgery was proposed as a rational and reasonable option to improve patient outcomes. Transitioning to a personalized TKA approach requires questioning and even disregarding certain MA TKA principles. Based on current knowledge, we can state that certain principles are erroneous or unfounded. The aim of this narrative review was to discuss and challenge 10 previously accepted, yet we believe, flawed, principles of MA, and to present an alternative concept, which is rooted in personalized TKA techniques.

Mechanical alignment (MA) was introduced in 1973 by Michael Freeman, who proposed systematically performing the femoral and tibial bone cuts perpendicular to their mechanical axes [1]. At the time, instrumentation and implants were rudimentary, and this "one size fits all" technique was a promising approach to simplify and standardize the procedure. Applying a systematic technique to variable bony anatomies with different alignments and phenotypes, resulted in varying degrees of collateral ligament imbalances [2,3]. To address this issue, John Insall proposed balancing the joint spaces through soft tissue releases and external rotation of the anterior and posterior femoral cuts. Total knee arthroplasty (TKA) performed with MA has an excellent reported long-term survival rate of 82% at 25 years, is the gold standard, and is perceived as essential for TKA success [4,5]. However, 75% of patients do not experience a natural joint [6], 50% have residual symptoms [7], and 25% would not undergo the same surgery again [8], indicating substantial room for improvement. Multiple implant design modifications and improved surgical precision with sophisticated tools such as computer or robotic-assisted surgery, did not provide better patient satisfaction and function [9,10]. In the face of such

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limitations, one must return to the fundamentals and shake the pillars of the temple. The objective of this commentary was to challenge 10 well-accepted principles of MA TKA and to present a potential alternative solution to these flaws.

Ten Flaws of Mechanical Alignment Total Knee Arthroplasty

Neutral Lower Limb Alignment for all (Mechanical Alignment Is Systematic, While Patients' Anatomy Is Variable)

The MA technique is a systematic, "one size fits all" technique that disregards individual native joint anatomy and physiological soft tissue laxities. Analyzing 4,884 computed tomography (CT) scans of individuals with knee pathology scheduled for TKA, Almaawi et al [11] found that while the mean hip-knee-ankle (HKA) angle was near neutral (mean 0.1 degrees in varus), significant variations were observed (24 degrees of valgus to 25 degrees of varus). The HKA values above 3 and 5 degrees were found in 40% and 19% of patients, respectively. Only 4% of patients exhibited a neutral tibial joint surface (0 degrees to the mechanical axis). Similarly, only 5% displayed a neutral distal femoral joint surface orientation to its mechanical axis (0 degrees). Moreover, <1% of patients had neutral (0 degrees) joint surfaces for both the tibia and femur, the MA goal. With MA, the mean modification of the distal femur frontal orientation is 2.7 degrees, with an important variability (11 degrees varus, 16 degrees valgus). Similarly, a modification of 2.9 degrees (21 varus to 21 valgus) of the proximal tibial joint surfaces is necessary [11]. Hirschmann et al reported similar results in 308 nonosteoarthritic knees with a mean proximal tibia angle of 2.8 degrees in varus and a mean distal femur angle of 3.4 degrees in valgus [12]. Therefore, MA, aiming for neutral femoral and tibial implant orientation, will modify the femoral flexion axis, the joint line orientation, and the entire 3-dimensional (3D) orientation of the knee joint surfaces for most patients. Although one can understand the reasons why it was proposed by Freeman at that time, from a current perspective, applying a systematic technique to the variable human bony knee anatomy is the first flaw of MA.

Mechanical Alignment Coronal Bases Simplify a Complex 3D Anatomy Geometry

Mechanical alignment TKA goals simplify and neglect the complex knee anatomy and variability. Native knee kinematics are created by an interaction between the joint surface geometry, soft tissue laxity, muscular contraction, and joint surface orientation in the coronal, sagittal, and axial planes. For example, MA neglects the sagittal plane alignment and an arbitrary posterior tibial slope is replicated in every patient. The concept of "one size fits all" is questionable as there is a great interindividual variability in native tibial slope [13]. It seems obvious that modifying the anatomy in the sagittal plane will disrupt the knee kinematics and natural soft tissue tension. While increasing the posterior tibial slope is associated with a higher maximum flexion angle and potential improvement in the extensor mechanism forces, it is also associated with higher anteroposterior instability [14]. However, decreasing it, increases stresses on the collateral ligaments and the anterior subchondral bone, risking component subsidence [14]. Howard et al found that restoring native tibial slope within 3° resulted in higher gain in range of motion and better knee functional outcome scores [15]. Farooq et al reported similar results in 2 studies investigating the optimal target of component position in the sagittal plane in 1,091 and 1,311 consecutive TKA, respectively [16,17]. They found that restoring the native posterior tibial slope with slight to moderate femoral flexion correlated with more knees "feeling normal", greater patient satisfaction, and superior patient-reported outcome measure scores [16,17].

Mechanical alignment also aims for an anterior implant flange flush with the anterior femoral cortex, neglecting the patient's anterior compartment anatomy. Using implant designs with a fixed anterior flange thickness, may impact patellofemoral kinematics [18]. Mechanical alignment systematic femoral axial external rotation will be discussed specifically in Flaw #6. Also, replicating the complex knee joint surface geometry would require implant customization and is not included in the MA technique [19]. When trying to replicate prearthritic knee kinematics, it seems essential to consider a more personalized 3D implant orientation.

The Diseased Compartment Is Frequently Tighter and Requires Soft-Tissue Release to Obtain a Neutral HKA Angle: Total Knee Arthroplasty Is a Soft-Tissue Operation

The distal femoral and proximal tibial cut orientation creates gaps in the medial and lateral compartments in extension. There is great variability in the knee, but on average, the femoral joint line is approximately 3 degrees in valgus and the tibial joint line is 3 degrees in varus [12]. Therefore, for many individuals, MA induces major anatomical modifications. Extension space imbalance will result from noncorresponding bone thickness removal on both bones for each compartment (Figure 1). Blakeney et al demonstrated that MA TKA surgical technique creates extension space imbalances ≥3 mm for 25% of varus and 57% of valgus knees, and ≥5 mm for 8% of varus and 19% of valgus knees [20]. Imbalance may contribute to stiffness, instability, and early loosening [21,22]. Better clinical scores were achieved when the mediolateral gap difference was ≤2 mm [23,24]. Therefore, the anatomical changes linked to MA systemic neutral tibial and femoral cuts will create imbalances that are difficult and potentially impossible to correct with soft tissue releases in many cases [25,26].

A study by Blakeney et al simulated measured resection MA bone cuts on a 3D bone model created from CT scans of 1,000 patients undergoing TKA to evaluate the impact on gap sizes [20]. In most cases, both for varus and valgus knees, the medial and lateral extension gaps were reduced (Figure 2). Furthermore, they found that in extension, for varus knees, the insufficient lateral bone cut distalizes the lateral bone surface by a mean of 2.1 and 4.4 mm, and the insufficient medial tibial plateau resection proximalizes the medial joint surface by a mean 3.3 and 1.2 mm, for varus and valgus knees, respectively [20]. These changes are directly linked to the MA surgical technique setting level of resection on the most prominent bone surface, the medial femur, and the lateral tibia in a majority of patients. Consequently, when systematic MA-induced gap imbalance is created, if strict mechanical alignment is to be maintained through bone cuts, such gap and ligament imbalance can only be corrected by ligament releases on the tighter side [27–29].

Over-Resection of the Distal Femur With Posterior Capsular Release Is Essential to Obtain Full Extension in Fixed Flexion Contraction

Fixed flexion contraction (FFC) is frequently observed in end-stage osteoarthritis (OA) and most authors agree that full extension should be obtained during surgery to ensure optimal clinical results [30,31]. In MA, a common method to address FFC is through medio-lateral ligament balancing with resection of all osteophytes, distal femur over-resection, and posterior capsular and gastrocnemius release [32,33]. However, pursuing the latter leads to longer surgical times, and increased risk of bleeding and infection [34]. Furthermore, a potential deleterious consequence of over-resection of the distal femur and raising the joint line in extension is the induction of mid-flexion instability.

A cadaveric study by Luyckx et al revealed that raising the medial joint line by 2 and 4 mm increased the coronal mid-flexion laxity by 64 and 111%, respectively, and that restoring the native

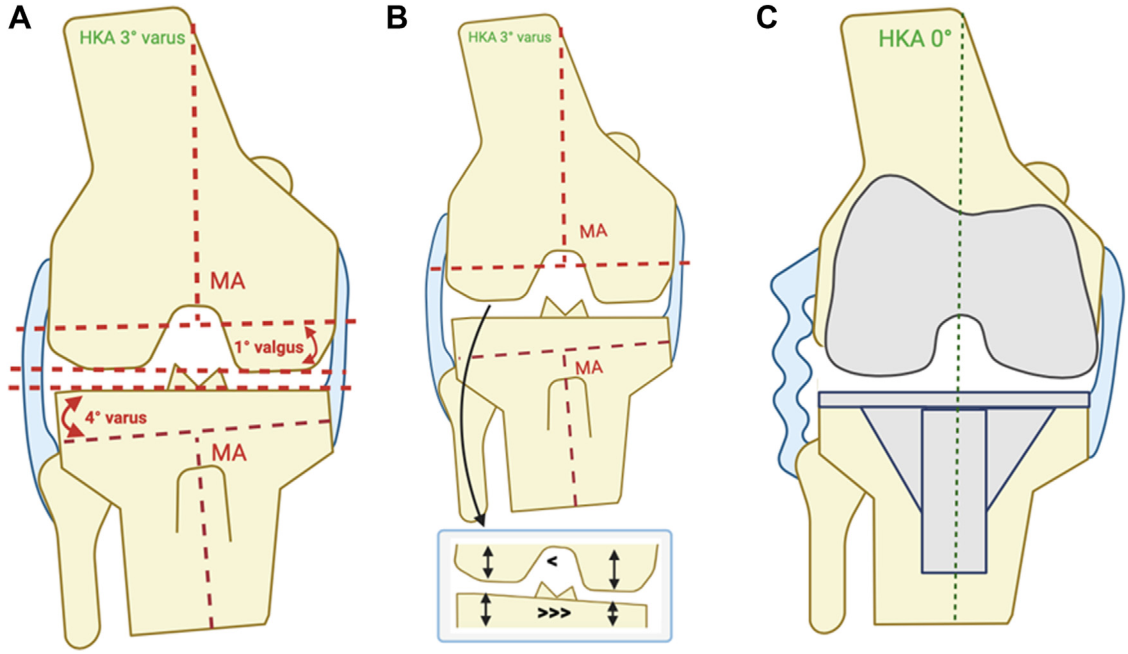

Fig. 1. (A) Example of a patient with a hip-knee-ankle angle of 3 degrees of varus (femur: 1 degree valgus, tibia: 4 degrees varus) before total knee arthroplasty. (B) Bone resection planning for mechanical axis total knee arthroplasty. In this example, a cut perpendicular to the mechanical axis of the femur and tibia will result in increased bone resection on the lateral compartment. (C) The result is imbalanced medial and lateral compartments in extension (medial tighter than lateral), requiring medial soft tissue release to balance the compartments.

joint line reproduced normal joint laxity throughout the range of motion [35]. Mid-flexion instability is deleterious as it leads to higher risks of revision [36]. A study by Moya-Angeler et al [30] demonstrated that FFC could successfully be addressed in kinematic alignment (KA) TKA, while avoiding the need for increased femoral resection and subsequently raising the joint line. In KA TKA, full extension can be achieved by minimally increasing the tibial cut thickness (<1 mm) with less soft tissue release [30]. Combined with the understanding of Flaw #3, restoring the prearthritic anatomy should provide TKA full extension without additional procedures,

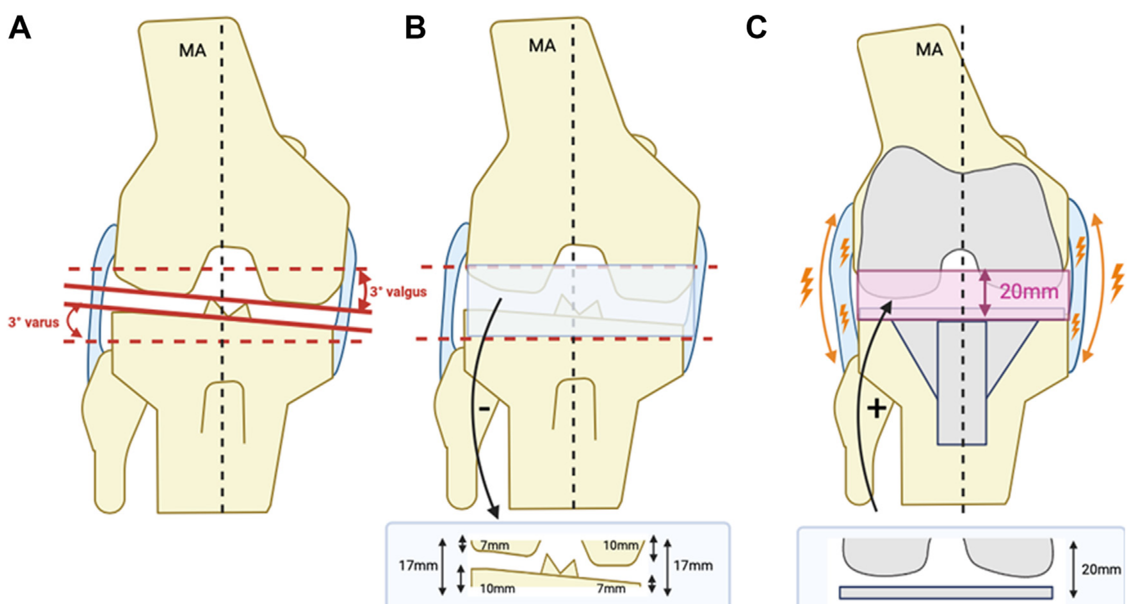

Fig. 2. Figure illustrating the results of Blakeney et al [20] simulating mechanical axis bone resection using standard instruments, setting the resection depth to 10 mm (implant thickness) from the most distal femoral condyle (usually medial with a valgus epiphysis) and the most proximal tibial plateau (usually lateral in varus epiphysis). (A) Example of knee joint with a 3-degree valgus femur and a 3-degree varus tibia. (B) Bone resection planning: the total resection of 17 mm is inferior to implant size (20 mm). (C) Insufficient bone resections create reduced medial and lateral extension gaps. To avoid soft tissues tightness, bone over-resection (+3 mm recut in that case) and/or soft tissue releases would be required. Additional femoral resection would elevate the joint line. Addressing the tightness with a tibial over resection alone, distalizes the lateral condyle, tightening the lateral retinaculum, and impacting the patella-femoral tracking.

such as proximalizing the joint line and releasing the posterior capsule.

Mediolateral and Flexion-Extension Ligament Isometry Should Be the Goal

Obtaining a rectangular gap after bone resection, with balanced medial and lateral ligament tension, in both knee flexion and extension has long been regarded as a fundamental requirement for successful MA TKA. Ligament tension during the arc of motion depends on the attachment zone of the ligaments. Kinematic testing and 3D motion analysis of cadaveric knee specimens by Gardiner et al [37] revealed that the anterior superficial bundle of the medial collateral ligament (MCL) remains tight during flexion and that its posterior fibers tighten in extension. Anatomical studies have shown that the distance between fibular and femoral attachment decreases with flexion. In full extension, the lateral collateral ligament (LCL) is tight, and as the knee flexes, there is a posterior translation of the lateral femoral condyle. The LCL becomes more vertical as the flexion increases, with the ligament becoming visibly slack at 90 degrees. With flexion to 120 degrees, the LCL further relaxes as the femoral condyle drops and rolls over the posterior round surface of the tibia (ie, posterolateral "rollback"), creating a medial pivot motion [38]. Tension of collateral ligaments, as well as gap widths and gap differences, are subject to individual variability and their specific phenotype [27,39]. Furthermore, there is more laxity in women, collateral ligaments are not isometric throughout the arc of motion, the MCL is tighter than the LCL, and both collateral ligaments are tighter in extension than in flexion [39]. Kamenaga et al [40] studied the relationship between postoperative knee stability and patient satisfaction. They found that preserving medial stability while permitting lateral laxity was significantly correlated with higher patient satisfaction and better clinical scores at 1-year follow-up. These findings were supported by 2 recent studies by Meneghini et al [41,42], where more physiological and native lateral compartment laxity relative to the tight medial compartment in flexion is associated with optimized patient-reported outcome measures after TKA. As these more recent data suggest, restoring the native knee collateral ligament balance and laxities is more likely the goal than aiming for perfect ligament isometry.

Systematic Femoral External Rotation Is Essential to Balance the Flexion Gap and for Adequate Patellar Tracking

The medial and lateral compartment flexion gaps depend on tibial and posterior femoral cut orientations. In the majority of varus cases, cutting the tibia at 90 degrees (mechanical) reduces its anatomical varus (by an average of 3 degrees) [11,12]. With MA, such tibial anatomy modifications require complementary adjustments on the femoral side (external rotation) to achieve a balanced flexion gap. There are several techniques to externally rotate the femur: anatomical landmarks, the antero-posterior axis, the transepicondylar axis, and the posterior condyles. First, the relationship between these anatomical landmarks is highly variable between individuals. For example, the transepicondylar axis angle to posterior condyles varies from 0.3 to 9.7 degrees, making standardized methods suboptimal [20]. Second, any modifications in the rotational alignment of the femoral component will alter the patient's native anatomy, affecting the femoral flexion axis and tibial and patella-femoral kinematics [11,43]. In a CT scan evaluation of 1,000 patients, using the transepicondylar axis, created a mediolateral flexion gap imbalance $\geq$3 mm in 23% of varus and 61% of valgus knees, while less imbalance was seen using 3 degrees of external rotation to posterior condylar reference (11% of varus and 23% of valgus knees) [20]. Furthermore, a study by Bonnin et al on 110 preoperative CT scans of arthritic knees, revealed that externally rotating the femoral component by 3 or 5 degrees induces a height asymmetry >3 mm in 25 and 46%, and a width asymmetry >3 mm, in 21 and 30% of patients, respectively [44]. The condylar asymmetries induced by the externally rotated femoral cut, are a cause of lateral prosthetic overhang and medial under coverage [44].

Restoring posterior condyle joint surface orientations and levels will subsequently maintain native flexion compartment gaps (as mentioned in Flaw #5) and the native patella-femoral relationship. One should note that in a patient without preoperative patella-femoral tilt or subluxation, externally rotating the femur is likely not warranted. However, in the presence of a pathological patella-femoral articulation, additional procedures may be warranted to optimize patella-femoral function, such as resurfacing the patella and medializing the button, lateral retinacular release, lateralizing the femoral component, etc [45]. Moreover, we should remember that actual femoral implants have been designed to be implanted with MA [45]. The trochlea has a fixed orientation designed to be implanted in neutral varus/valgus, and the lateral trochlear ridge may be too thick as it was designed to be externally rotated.

To Achieve a Neutral HKA Angle, Ligamentous Releases Are Required

Since the mid-1970s, releasing the medial or lateral soft tissues in severe varus or valgus deformities has been common practice with MA TKA [46]. It is generally agreed that soft tissue balance is essential to achieve favorable results in TKA [47]. Alternatively, there are conflicting reports in the peer-reviewed literature regarding coronal plane contracture or laxity in end-stage varus OA knees. A study by McAuliffe et al measured individualized neutral axes referenced against previously published medial and lateral laxity in 78 varus knees at maximum extension and 20 degrees of flexion [48]. It demonstrated that 74.4% of patients with varus knees up to 15 degrees had coronal laxity equivalent to that of subjects with healthy knees (neither medial contracture nor abnormal lateral laxity). Medial contracture combined with normal lateral laxity and abnormally increased lateral laxity combined with normal medial laxity was observed in 6.4 and 12.8% of cases, respectively. A total of 6.4% of patients displayed both increased lateral laxity and medial contracture.

A study of 30 valgus OA knees undergoing TKA by McAuliffe et al [49] reported that 50% of the subjects had medial and lateral laxity measures within limits of previously recorded values in the healthy population. Lateral contracture was present in 26.6% of patients, of whom 23.3% had concomitant abnormal medial laxity. The valgus knee at the time of TKA demonstrated major mediolateral and flexion-extension imbalance. In full extension, medial tissues demonstrate more laxity, while in flexion, this reverses with the lateral tissue being more lax [49]. Considering these facts, ligament releases should be uncommon. We should then question why we need to perform frequent soft tissue release when performing MA TKA. The answer lies in the MA surgical technique itself and relates to MA Flaw #4. In all varus knees with a varus oriented proximal tibial joint surface, neutralizing the tibia will proximalize the medial plateau and reduce the medial compartment gap. In all valgus knees with a valgus oriented distal femoral joint surface, neutralizing the femur will distalize the lateral femoral condyle and reduce the lateral compartment gap.

Respecting joint anatomy with KA, we frequently see important arthritic varus knees, deformed by the disease process (cartilage and bone loss on the medial compartment). Restoring these patients' joint surface anatomy in many cases restores the HKA near neutral without the need for ligamentous release. Hence, it is a fundamental flaw of the MA technique that an arthritic varus or valgus knee will inevitably require soft tissue release.

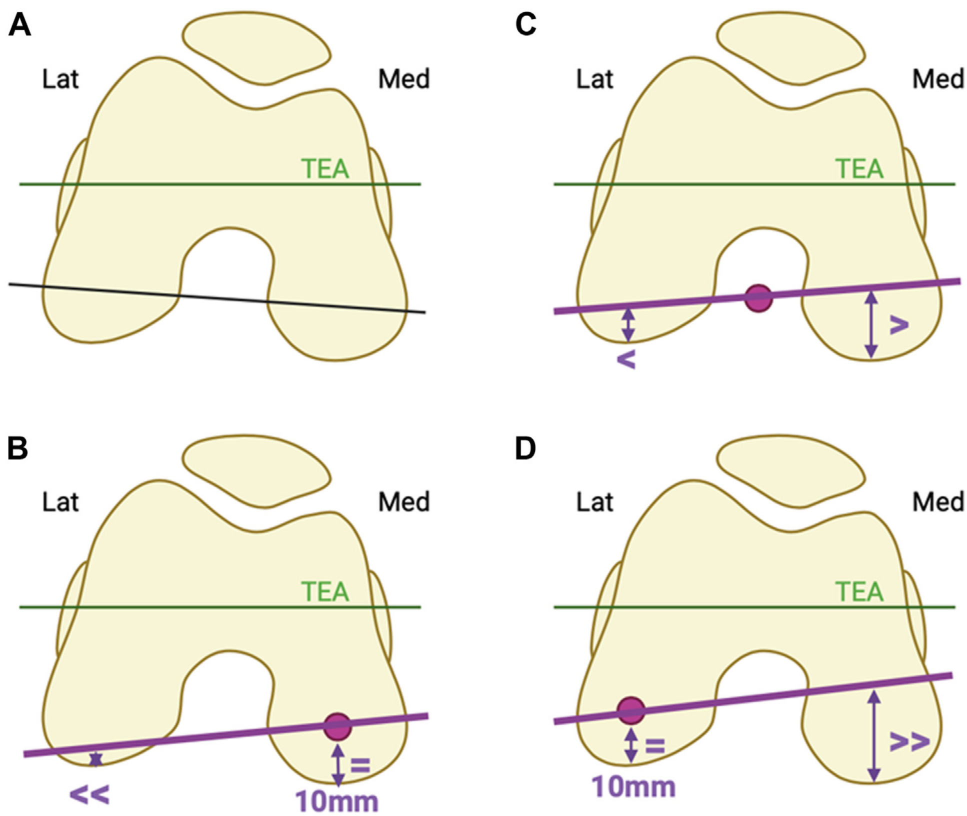

Fig. 3. Figure showing the impact of systematic external rotation on the posterior femoral condyles' resections according to the selected pivoting point (implant thickness of 10 mm). (A) Posterior reference without any external rotation. (B) External rotation using a medial pivot point preserves medial compartment flexion gap but reduces lateral flexion gap. (C) External rotation using a central pivot point impacts both compartments, increasing medial flexion gap and reducing lateral flexion gap. (D) External rotation using a lateral pivot point maintains lateral flexion gap but loosens the medial side. Since valgus knees' tibias are frequently neutral or valgus [55], (C and D) may cause medial flexion instability. Lat, lateral; Med, medial; TEA, transepicondylar axis.

Valgus Knees Have Lateral Condyle Hypoplasia

In valgus knees, it is commonly accepted to increase the external rotation of the femoral component to compensate for "hypoplasia of the lateral condyle" [50,51]. However, in knees with native valgus alignment, MA modifies the femoral flexion axis, tightens the lateral flexion compartment, and alters the physiologic knee kinematic [52]. However, we must question whether the lateral condyle is truly hypoplastic. To calculate the difference in radii between the medial and lateral femoral condyles in both varus and valgus knees, it is important to take into consideration the 3D orientation and interrelationship of the 3 axes of the knee about which the motion occurs. Howell et al studied 155 and 44 varus and valgus OA knees, respectively, scanning with magnetic resonance imaging both condyles in a plane perpendicular to the femur's flexion axis [53]. Interestingly, the lateral femoral condyle was 0.1 and 0.2 mm larger than the medial femoral condyle in varus and valgus knees, respectively [53]. In a larger study involving 6,829 knees examined with magnetic resonance imaging, Shah et al [54] found that the medial condyle was on average 1.4 mm smaller than the lateral condyle, confirming the findings of Howell et al [53].

To properly align the femoral component, the most important kinematic axis of the knee is the one about which the tibia flexes and extends and is called the femur's flexion axis (cylindrical or transepicondylar axis). It passes through the center point of the best-fit circle of the medial and lateral femoral condyles. The small asymmetry between the radii of the medial and lateral femoral condyles questions the methods of setting the rotation of the femoral component in a valgus knee. External rotation of the femoral component can be performed with different pivot points (Figure 3) [55].

- Medial, will maintain the medial compartment flexion gap, but tighten the lateral one ++, and increase implant anterior-posterior (AP) size.
- Central, will loosen the medial compartment flexion gap +, tighten the lateral one +, and maintain the implant AP size.
- Lateral, will loosen the medial compartment flexion gap ++, maintain the lateral one and increase the implant AP size.

In all 3 options (pivot points), the femoral flexion axis and joint surface orientation are modified in space. Moreover, none is ideal as we want to avoid destabilizing the medial compartment in these knees where the MCL may have been stretched or we do not want to tighten the lateral compartment, which may already present lateral soft tissue contractures.

Static HKA Angle is a Good Representation of the Dynamic Articular Load

To simplify preoperative evaluation and planning, and postoperative assessments, antero-posterior static standing long-leg radiographs have been used in clinical practice. The HKA can be easily measured, allowing comparisons between preoperative and postoperative values, or between different follow-up assessments. With MA, the goal was to obtain a neutral HKA with a rationale that a static neutral alignment on a long-leg radiograph was representative of the knee adduction moment during gait. A neutral static HKA would be linked to a reduced medial load, polyethylene wear, and improved long-term implant survivorship.

However, as more recent data suggest, the lower-limb alignment and subsequent tibiofemoral loads are quite different during

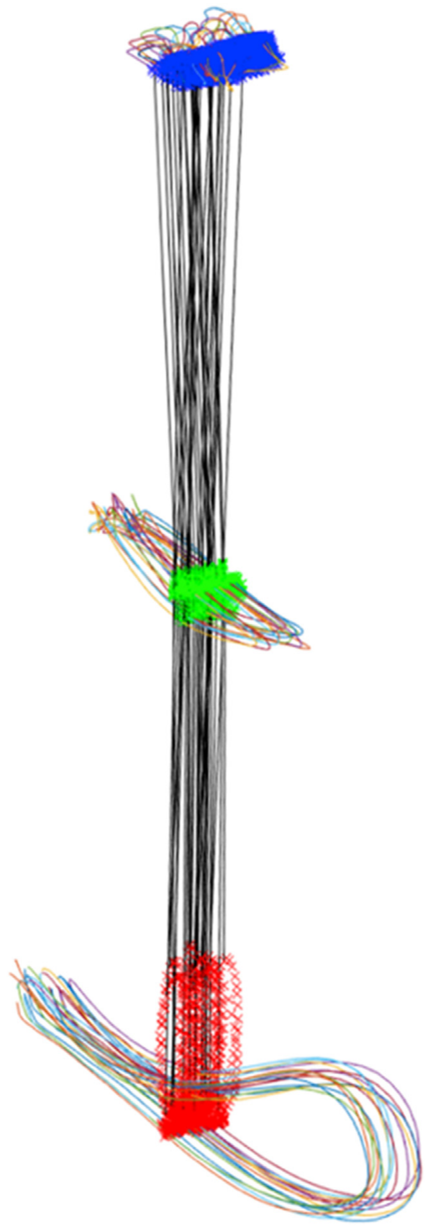

Fig. 4. This graph represents the movements of the hip, knee, and ankle joints of a healthy subject recorded using the KneeKG™ system (Emovi Inc., Montreal, Qc, Canada) during multiple gait cycles [56]. As shown in this example, the dynamic hip-knee-ankle angle varies during the gait cycle and may differ from the bipodal static hip-knee-ankle.

dynamic gait, as opposed to the static situation of a long-leg radiograph. Using a specific knee brace, Clément et al [56] analyzed and compared the static and dynamic HKA throughout the gait cycle in a healthy population (Figure 4). They found a low to moderate correlation for varus knees, and no correlation for valgus knees, between static and dynamic HKA [56]. Furthermore, 22% of the knees demonstrated a switch from static varus to dynamic valgus or vice versa during gait. Similarly, Rivière et al evaluated a group of 35 TKAs radiographically classified as neutrally aligned, valgus-aligned, or varus-aligned [57]. Using motion captured gait analyses, they found no significant correlation between static HKA and dynamic HKA during the stance phase. Static HKA only had a moderate correlation with mean and peak adduction moment. They reached the same conclusion, that the standing HKA after TKA was of little value to predict dynamic behavior of the limb during gait [57]. During gait, the dynamic HKA will be affected by the following:

- pelvic motion
- pelvic width and amount of hip adduction/abduction
- femoral internal/external rotation (proximal femoral offset and neck angle)
- knee flexion and femorotibial rotation.

These results demonstrate that the static HKA poorly reflects the dynamic HKA, and show the limited value of static bipodal coronal alignment for predicting lower limb alignment and joint load during gait [56]. This could explain why static HKA, used for MA TKA, poorly reflects long-term implant survivorship, fixation, and wear [58–60]. Interestingly, a study by Blakeney et al demonstrated that TKA using KA achieved gait parameters more closely aligned to those of healthy subjects when compared to TKA using MA [61]. Although KA cases had a higher mean static varus HKA than MA TKAs, the KA TKAs had a lower adduction moment during gait.

Deviating From a Neutral HKA Angle Compromises Implant Long Termer-Define Survivorship

A long-standing MA TKA principle to improve the implant survival rate is to achieve postoperative limb alignment to a neutral mechanical axis of 0 ± 3 degrees [62]. Broadly accepted by surgeons, this tenet has been challenged in recent years. Parratte et al, in a study of 398 TKAs, found no statistically significant difference in the 15-year survival of TKAs that were within 0 ± 3 degrees of the mechanical axis postoperatively compared to those that had alignment outside of 0 ± 3 degrees [58]. At 20 years of follow-up on the same patient cohort, the implant survival rate did not improve with the aligned group [63]. Bonner et al reviewed 501 TKAs and compared the 15-year implant-survival rate between the aligned (HKA = 0 ± 3 degrees) and malaligned (HKA >3 degrees) groups and found no statistically significant difference, concluding that the relationship between mechanical axis alignment and implant survival is weaker than that in previously published research [59]. However, several studies show that MA surgical errors >3 to 5 degrees of varus/valgus were associated with increased polyethylene wear and higher rates of revision [64–66].

The tenth flaw of MA TKA is considering the static HKA value deviation from neutral as a tenet of implant survivorship and clinical outcome. In MA, deviation from neutral is a surgical error, it was not planned, nor is it a reproduction of the prearthritic patient's anatomy. For example, an HKA of 4 degrees of varus after surgery may be the result of a femoral implant oriented in 3 degrees of varus when the patient's anatomy was 3 degrees of valgus (anatomical modification of 6 degrees on the femur) combined with a 1-degree tibial varus cut when the tibia anatomy was neutral. This patient had a prearthritic valgus knee of 3 degrees and ended up with a 4-degree varus knee after surgery with potential medial instability. Another example is shown in Figure 5.

Howell et al, using KA to reproduce the prearthritic joint orientation and HKA without any limits, reported a 10-year survival rate of 97.5% for 222 TKAs implanted using patient-specific instrumentation [67]. This is comparable to the published literature on MA TKA. Similarly, analyzing the combined results from the Australian and New Zealand Joint Replacement Registries, Klasan et al reported similar revision rates between KA patient-specific instrumentation TKA and all other TKAs [68]. Moreover, using radiostereometric analysis on 47 patients to compare component migration between MA and KA aligned TKA, Laende et al found no difference or correlation between non-neutral alignment and tibial component migration [69]. These studies shows that we need to

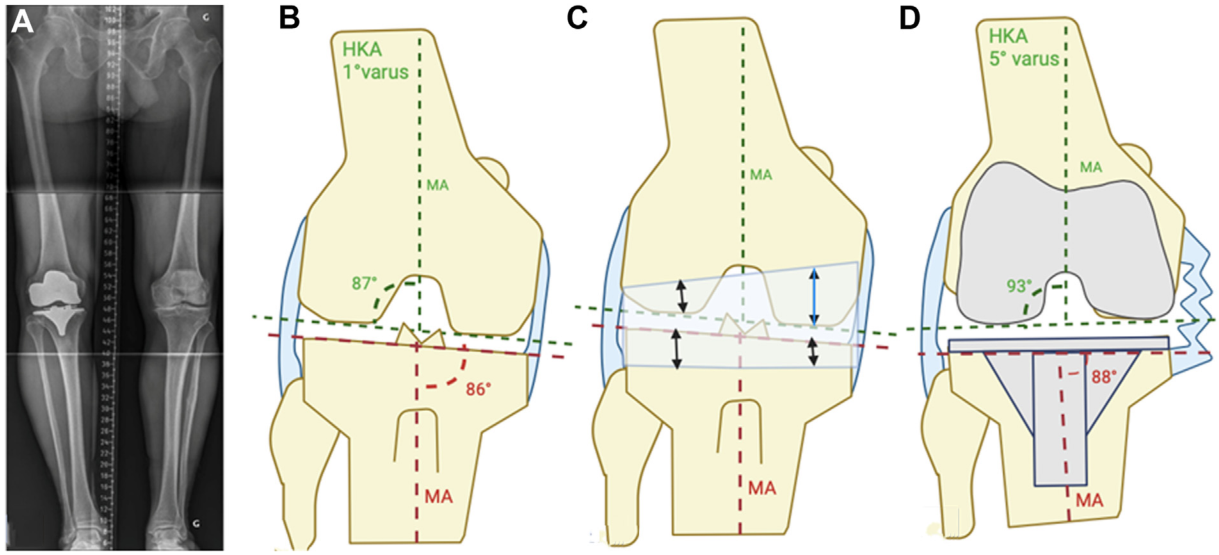

Fig. 5. (A) A standing radiograph of a man with persisting joint effusion and pain 3 years after a mechanical axis total knee arthroplasty. Femoral component has been implanted with 3 degrees of varus (other side has 3 degrees of valgus) and tibial component was implanted with 2 degrees of varus (other side has 4 degrees of varus). Resection errors both on the femur and tibia contribute to the medial instability. (B to D) illustrate the example above. HKA, hip-knee-ankle angle.

reconsider our point of view and understand that while surgical errors with MA are certainly detrimental, intentionally deviating from neutral HKA when performing a joint resurfacing, might be favorable, or at least not problematic.

Conclusions

Facing suboptimal TKA outcomes in clinical practice should bring us back to the drawing table and question previously held dogmas, such as traditional systematic MA. Looking at the human anatomy, joint kinematics is essential to avoid repeating the same errors. Understanding the flaws of our practice is essential to determine the solutions. Due to deficiencies in both knowledge and technology, in the past, we were far from replicating normal knee kinematics. Personalizing our TKA surgical technique can potentially improve patient satisfaction and function. Resurfacing the joint surfaces and restoring the prearthritic anatomy and soft tissue laxities make sense. Personalized knee arthroplasty techniques may allow faster recovery [70], better functional scores and pain relief, with similar survival rates [71]. It is now the time to shift from MA to personalized alignment [72].

Acknowledgments

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