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# The Promise of Kinematic Alignment in TKA: Game-changer or Gimmick?

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## Abstract

**Introduction:** Total knee arthroplasty (TKA) is a proven solution for end-stage knee arthritis, yet traditional mechanical alignment (MA), which aims for a neutral mechanical axis, leaves up to 20% of patients dissatisfied postoperatively. Kinematic alignment (KA) has emerged as an alternative, focusing on restoring the patient's native anatomy and joint line orientation, achieving balance without extensive soft-tissue releases.

**Methods:** This article examines the principles of KA and compares it with MA regarding safety, outcomes, and biomechanical balance through a literature review comprising various retrospective studies, randomized controlled trials, and systemic reviews. KA relies on the patient's unique femoral morphology to guide bone cuts, achieving natural alignment and ligament balance. Evidence suggests that KA offers comparable if not superior, functional outcomes, with higher Oxford knee scores and forgotten joint scores while maintaining similar implant survivorship. Studies also show KA leads to better compartmental balance, reduced knee adduction moments, and more natural gait mechanics. The compartmental pressure alignment knee classification highlights KA's ability to balance the knee across various lower limb phenotypes.

**Conclusion:** Although KA shows promise, challenges remain. Concerns about tibial varus have been addressed, with studies confirming no compromise in implant stability or survival. However, long-term data are needed to validate KA's durability and define its role for specific patient groups.

This article provides a comprehensive overview of KA's benefits and limitations, offering guidance for surgeons seeking evidence-based alignment strategies. It underscores KA's potential as a personalized approach in TKA, bridging gaps in satisfaction and functional outcomes while maintaining safety.

**Keywords:** Kinematic alignment, mechanical alignment, arthroplasty, osteoarthritis.

## What is Kinematic Alignment (KA)?

The concept of KA in total knee arthroplasty (TKA) finds its origins in the foundational work of Dr. Hungerford, who first proposed the idea of an "anatomical alignment" against Dr. Insall's "mechanical" one. However, it was not until 2005 that Dr. Stephen Howell formally developed and popularized the approach, lending it structure and precision through what is now termed "caliper-verified kinematic alignment." This approach represents a paradigm shift from conventional mechanical alignment (MA) in TKA, focusing instead on replicating the individual's pre-arthritic knee anatomy and natural joint line (Fig. 1).

Caliper-verified KA is meticulously designed around three primary kinematic axes, each essential for restoring native knee movement and function. The first axis enables the tibia to flex and extend over the femur. The second axis facilitates patellar tracking over the femur, allowing for physiological patellofemoral articulation. The third axis is the rotational pivot on which the tibia rotates relative to the femur, vital for ensuring proper joint congruity during dynamic movements.

By calibrating alignment to these axes, KA restores the patient's natural knee anatomy without requiring soft-tissue release. It maintains the original, pre-arthritic resting lengths of the surrounding ligaments, preserving the natural balance and tension in the joint that traditional MA approaches often disrupt. This technique thus holds the potential to deliver a more anatomical, individualized reconstruction of the knee joint, promoting improved kinematics, patient satisfaction, and potentially, implant longevity.

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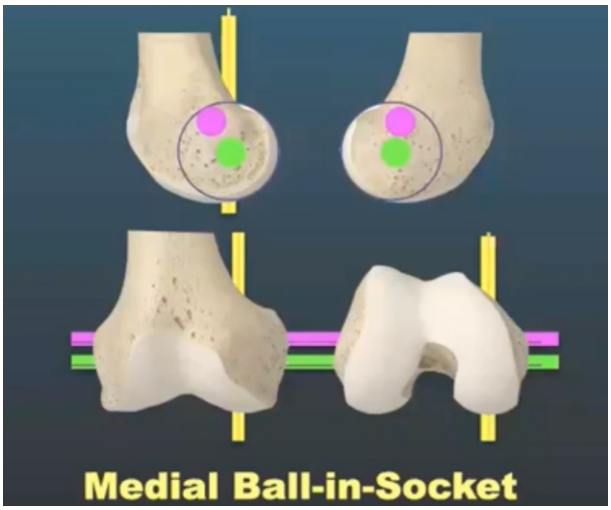


**Figure 1:** Three kinematic axes for kinematic alignment total knee arthroplasty.

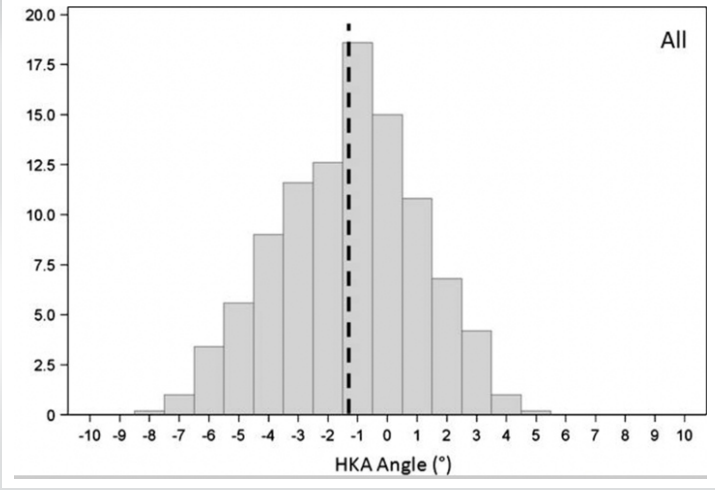


**Figure 2:** Histogram depicting alignment as studied by Bellemans et al, showing alignment distribution in 500 non-arthritic knees, with mean 1.2° varus. HKA: Hip-knee-ankle.

## Why this Debate?

The emergence of KA as an alternative approach to TKA is not without reason; it addresses several inherent limitations of the long-established MA methodology. MA, though traditionally the gold standard, has demonstrated significant drawbacks, with up to 20% of TKA patients annually reporting dissatisfaction with their outcomes. This dissatisfaction is widely documented, supported by a substantial body of literature underscoring limitations in the mechanical approach's ability to deliver consistently optimal results [1].

Even Dr. John Insall, father of mechanical TKA, highlighted these challenges, noting in his seminal work on soft tissue balancing that "even with meticulous attention, soft tissue balance is not always achieved in TKA." [2].

One prominent issue linked to MA is its propensity to compromise the patellofemoral mechanism, often resulting in lateral overstuffing of the extensor mechanism, which can lead to patellofemoral complications and diminished function. This misalignment impacts the delicate biomechanics of the patella, causing functional and symptomatic issues in a subset of patients [3].

Furthermore, a recent article in the *Journal of Arthroplasty*, titled "Ten Flaws of Systematic MA in Total Knee Arthroplasty," critically addresses the conceptual flaws in MA. It asserts that the approach incorrectly assumes a neutral alignment is universally suitable, oversimplifying the knee's complex three-dimensional anatomy and ignoring variations in individual patient anatomy. The article also challenges the assumption that the diseased compartment is always tight and must therefore be released, a notion contradicted by evidence indicating the importance of nuanced, individualized ligament management. In addition, MA presupposes that achieving mediolateral and flexion-extension isometry is paramount, an idea refuted by recent biomechanical insights showing that such uniformity does not always correlate with optimal outcomes [4].

In sum, MA's standardized, "one-size-fits-all" approach fails to accommodate the intricate, unique anatomical variations in individual patients, often leading to suboptimal outcomes. This realization has fueled the pursuit of alternative methods like KA, which seeks to address these limitations by respecting the native joint anatomy and individualized biomechanics of each patient.

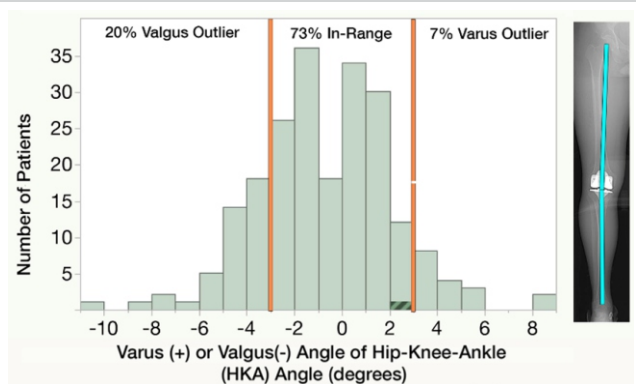


**Figure 3:** Histogram depicting alignment distribution by Howell et al., 73% of patients within 3° of neutral alignment.

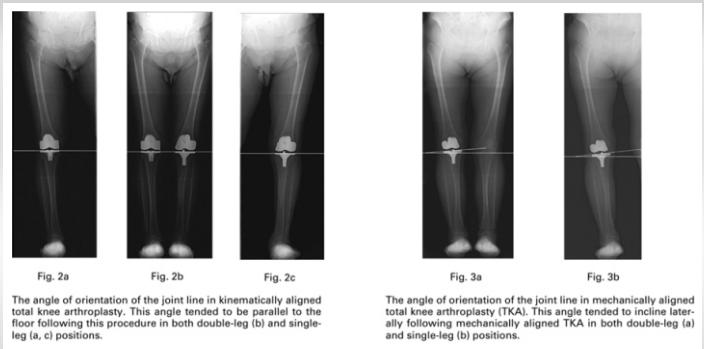


**Figure 4:** Matsumoto et al., single joint weight-bearing radiographs of Kinematic alignment total knee arthroplasty versus Mechanical alignment total knee arthroplasty.

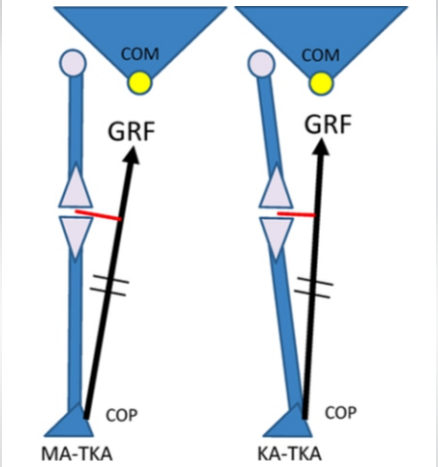


**Figure 5:** Niki et al., Kinematic alignment total knee arthroplasty reduces adduction moment more than Mechanical alignment total knee arthroplasty.

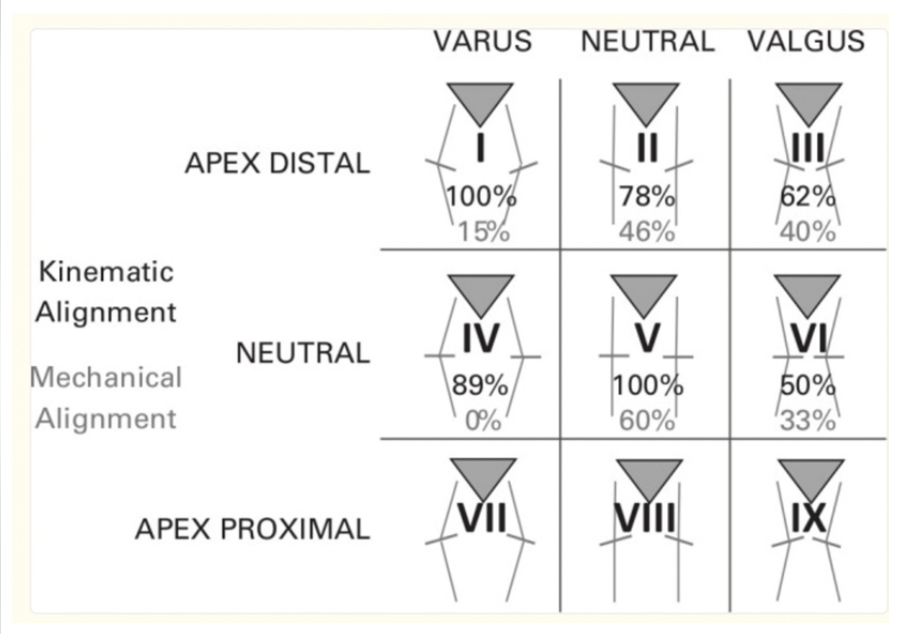


**Figure 5:** MacDessi et al., compartmental pressure alignment knee classification, with intraoperative compartmental balance in different alignment phenotypes.

## Are we All Aligned in Neutral?

Are we all naturally aligned in neutral? Far from it. A 2012 study by Bellemans et al., titled "Is Neutral Mechanical Alignment Normal for All Patients?," revealed that 32% of the population exhibits a constitutional varus of 3 degrees or more by the end of skeletal growth [5]. This finding underscores that a neutral MA is not the anatomical norm for a significant portion of individuals, challenging the assumption that a uniform neutral alignment is universally appropriate in knee arthroplasty (Fig. 2).

## How is it Done?

In MA TKA, the tibia and femur are cut at 0° relative to the mechanical axis in extension. The femoral component is rotated to align parallel to the transepicondylar axis, with the tibial component following suit. Soft tissue "balancing" is then achieved by creating rectangular flexion and extension spaces, effectively making the tibial cut the primary driver of the surgery.

In KATKA, the distal femoral cut is made parallel to the native joint line, accounting for approximately 2 mm of articular wear, a consideration supported by multiple studies. The posterior femoral cut is similarly performed to achieve an equal posterior resection. The tibial cut is then aligned parallel to the femoral cut, requiring little to no soft tissue balancing [6]. Thus, in KATKA, the femoral cut drives the surgical approach. Contrary to common misconceptions, KA does not aim to place the tibia in varus; instead, the tibial osteotomy is guided by the femoral morphology, which dictates the natural alignment.

In KATKA, the goal is to achieve a tight, rectangular gap in extension, while in flexion, a more trapezoidal gap is desirable. This effect is not intentional but arises organically due to the native differences in knee ligament laxities at 0° and 90° of flexion. Attempting to equalize the flexion and extension gaps by altering these natural ligamentous laxities can result in overtightening the soft tissue restraints relative to the native knee. Such overtightening may lead patients to experience symptoms of pain, stiffness, and restricted flexion [7].

## Is there Any Evidence?

In a landmark 2014 study, Dossett et al. conducted a randomized controlled trial (RCTs) comparing 88 knees using conventional MA TKA instruments versus KA with OtisMed patient-specific guides. With a minimum follow-up of 2 years, the study found statistically significantly higher scores in the KA group across the Oxford Knee Score, western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and Combined knee society score (KSS) [8]. However, these promising results were not consistently reproduced in subsequent studies (Table 1).

In a 2017 study by Calliess et al., a RCTs involving 200 patients compared patient-specific instrumentation (PSI) ShapeMatch KA with standard MA instruments. The results showed that the combined KSS was significantly higher in the KA group (KA) compared to the MA group (MA) [9].

In a comprehensive 2018 study by Howell et al., a cohort of 222 knees was analyzed with a minimum follow-up of 10 years to assess the long-term outcomes of KA in TKA. The study reported an impressive survivorship rate of 97.5%, highlighting the durability and success of this alignment technique over a decade. At the 10-year follow-up, patients exhibited favorable functional outcomes, as reflected by the Oxford Knee Score, which averaged 43. This score indicates a significant improvement in pain relief, function, and overall quality of life

**Table 1:** Dosset *et al* ., knee scores, KATKA versus MATKA

| Knee Score | KA | MA | Difference | *P*-value |
|---|---|---|---|---|
| Oxford | 40 | 33 | 6.2 | 0.05 |
| WOMAC | 15 | 26 | −10.7 | 0.05 |
| Combined KSS | 160 | 137 | 23.3 | 0.05 |

KATKA: Kinematic alignment total knee arthroplasty, MATKA: Mechanical alignment total knee arthroplasty, WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index, KSS: Knee society score

for the majority of patients. In addition, the WOMAC score averaged 7, which further supported the long-term effectiveness of KA in reducing symptoms associated with knee osteoarthritis [10] (Fig. 3).

The 2023 study by Howell et al., in which 216 patients (220 knees), were followed to evaluate the outcomes of KA in TKA demonstrated a robust 93% implant survival rate, reflecting the longevity and durability of the procedure. Interestingly, 35% of the tibial components were implanted in a varus alignment >3°, with some reaching up to 8°. Despite this alignment variation, the functional outcomes were positive, with a median Oxford knee score (OKS) of 43, indicating significant improvements in pain relief and knee function. Furthermore, the median forgotten joint score (FJS) was 88, suggesting high levels of patient satisfaction and an excellent level of knee function, with patients reporting little to no awareness of their knee implant during daily activities. These results highlight the effectiveness of KA in achieving long-term implant survival and favorable patient outcomes, even with some degree of tibial varus [11].

In a 2023 meta-analysis by Van Essen et al., which included 12 RCTs and 14 observational studies published between 2014 and 2022, the results showed that KA outperformed MA in terms of OKS and FJS. However, both KA and MA were found to have similar outcomes for the WOMAC and KSS [12].

## Tibia in varus – Aseptic Loosening?

### Objective evidence

In a 2019 RCT by Laende et al., tibial migration was compared between MA and KA using radiostereophotometric analysis. The study found that both MA and KA showed similar tibial migration patterns at 1 and 2 years post-surgery, with minimal movement and stability in both groups. These results suggest that both alignment techniques provide comparable tibial component stability in the first 2 years after TKA [13].

In a 2017 RCT by Matsumoto et al., 60 patients underwent computer-navigated TKA with either KA (KATKA) or MA (MATKA). Using single-stance weight-bearing imaging, the study found that KATKA resulted in better joint line orientation and mechanical axis positioning compared to MATKA. In addition, knee flexion was greater in the KATKA group (122° vs. 116°) [14] (Fig. 4).

In a 2017 study by Niki et al., KA (KATKA) was found to reduce the knee adduction moment more than MA (MATKA). This reduction in knee adduction moment suggests that patients who undergo KATKA consume less energy during walking, potentially leading to improved functional efficiency and less strain on the knee joint [15] (Fig. 5).

In a 2021 RCT by MacDessi et al., the authors introduced the compartmental pressure alignment knee classification, which categorizes lower limb alignment into nine distinct phenotypes. This classification system provided a framework to assess and understand the variations in alignment and their impact on knee mechanics. The study then evaluated intraoperative compartmental balance at 10° of flexion, defining balanced compartments as those with an intercompartmental pressure of <15 PSI. The findings revealed that KA was more effective in achieving better knee balance across all nine alignment phenotypes when compared to MA. This suggests that KA is superior in restoring soft tissue balance, regardless of the patient's native lower limb alignment [16] (Fig. 6).

## Conclusion

TKA still presents some unresolved challenges. However, KA has emerged as an established alignment philosophy, supported by a growing body of evidence. KA has been shown to be safe, with strong implant survival rates. Clinical outcomes are comparable to, if not better than, MA, with improved scores in metrics such as the FJS and OKS. In addition, KA leads to better knee balance, as demonstrated by improvements in gait and the maximum adduction force during movement.

However, further studies are needed to confirm the long-term results and benefits of KA.

**Declaration of patient consent:** The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

**Conflict of Interest:** NIL; **Source of Support:** NIL

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