# ATTUNE™ Knee System: Stability in Total Knee Replacement

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Young and active total knee replacement (TKR) patients demand a knee that feels stable and restores confidence in their movement. This demand will continue to grow as more than 50% of TKR patients will be under the age of 65 by 2016.[1]

According to the literature, gross knee instability remains one of the leading causes for short-term knee revision, accounting for up to 21% of revisions within the first two years of implantation.[2] However, these failure rates don't speak to the more subtle forms of instability patients experience. For many patients, while their knee is not unstable to the point of revision surgery, they remain unhappy with the way their knee feels. According to patient reported outcome studies, up to 20% of patients are not satisfied with their knee replacement despite having good survivorship.[3,4] These TKR patients frequently struggle with activities of daily living, like going up and down stairs or walking on uneven terrain where a stable knee is most important.[3]

Many factors contribute to providing a stable knee, including both surgical technique and implant design. Balancing flexion and extension gaps, setting proper femoral rotation, and restoring posterior condylar offset are critical steps to provide knee stability.[5] In addition, the design of TKR geometry should enhance the stability of the joint provided by the soft tissue envelope, particularly in mid-flexion. Recent fluoroscopic evidence has elucidated the relationship between implant design and knee stability, highlighting the need to address "paradoxical anterior femoral translation" in TKR design.[6]

Some authors have speculated that utilizing a "single radius of curvature" to define the sagittal femoral profile instead of a traditional multi-radius "J Curve" leads to a more stable joint by providing collateral ligament isometry through the functional range of knee flexion.[7,9] However, clinical and engineering based studies provide a great deal of evidence to the contrary.[7,8,9,10]

## THE INFLUENCE OF IMPLANT DESIGN

From a historic perspective, stability has been engineered into TKR designs in two ways: by providing constraint to anterior-posterior translation through insert conformity and by enabling consistent tensioning of the knee ligaments through the flexion range.

### "Single Radius" versus "Multi-Radius" designs

Traditional knee replacement designs utilize multiple discrete radii to define the sagittal plane curvature of the femoral component (Fig. 1). This geometry was derived to replicate the function of the natural knee joint. The broader distal radius articulating against a relatively congruent tibial insert provides increased constraint and reduced contact stress in the range of flexion used for high demand, high frequency activities such as gait. By transitioning to a smaller posterior radius in knee flexion, the conformity of the implant is reduced and the femur becomes more mobile on the tibial insert. This enables the necessary knee rotation and rollback to facilitate deep knee flexion.

While the nomenclature of "single radius" design implies that no sudden radius transition exists, this isn't the case. In fact, the transition from the distal to posterior radius for the Stryker® Triathlon® "single radius" design just occurs earlier in the flexion cycle at 10°, where other traditional designs transition between 15° and 35° of knee flexion. While the discrete-radius "J Curve" femoral shape has a long and successful clinical history, the mid-flexion stability of the knee is adversely affected at the instant the knee flexes across the transition from the distal to posterior radius. In this instant, the constraint of the implant drops and the knee suddenly has more freedom to move. Because the transition from distal to posterior radius occurs earlier in the flexion range for Stryker® Triathlon® "single radius" design, the loss of stability occurs at a very inopportune time, during the stance phase of gait.

### ATTUNE™ Knee System

To address the unmet clinical need of mid-flexion stability, *DePuy Synthes Joint Reconstruction* designed the ATTUNE™ Knee System. This system's sagittal plane curvature of the femur harkens to the successful clinical history of knee replacements with a broad distal radius and a smaller posterior radius, but is designed to eliminate the sudden transition between the two. To do this, the ATTUNE Knee System features a gradually-reducing radius-of-curvature, (ATTUNE GRADIUS™ Curve) from 5° to 65° knee flexion (Fig. 1). This enables a gradual reduction in implant constraint, steadily increasing the mobility of the knee with increasing knee flexion to prevent any sudden changes in knee stability.

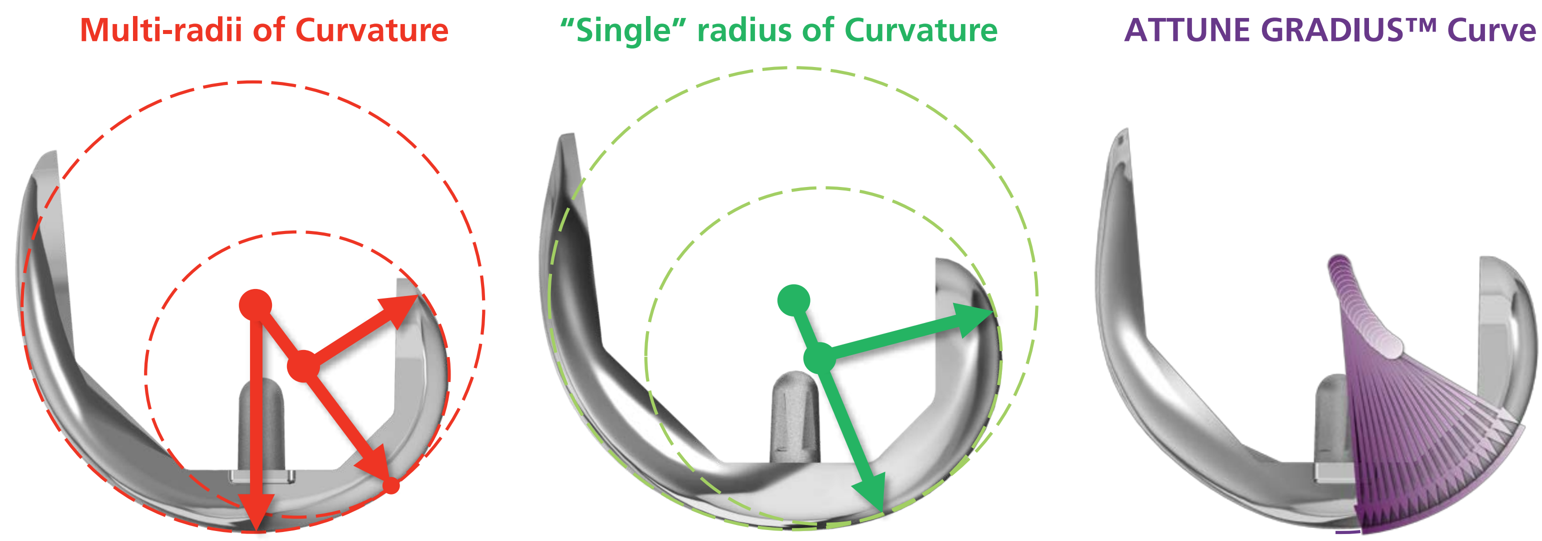


Figure 1: The sagittal plane curvature of "traditional" knee replacements are comprised of multiple discrete radii. While the Stryker® Triathlon® is formed by a single radius of flexion, the ATTUNE Knee incorporates a gradually reducing radius with knee flexion (ATTUNE GRADIUS Curve)

## DIFFERENCES IN IMPLANT CONSTRAINT: ATTUNE GRADIUS CURVE VS. STRYKER® TRIATHLON®

Due to the ATTUNE GRADIUS Curve, the ATTUNE Knee System is stable in extension, providing a large stabilizing force if the femur wants to slide anterior on the tibia. The implant conformity or stability then gradually reduces with increasing flexion, enabling a steady increase in knee mobility moving into deep flexion (Fig. 2). By contrast, the Triathlon® implant provides considerably less constraint in extension, and then has an abrupt loss of stability once the femur begins articulating on the single radius-of-curvature at 10° of knee flexion. By design, the implant has the same level of constraint at 10° knee flexion (in the middle of the stance phase of gait) as it has in deep knee flexion, when the knee needs the freedom to rotate. Compounding this issue further is the use of their "Rotary Arc" tibial insert design.[10] Carving out rotary troughs to enable knee rotation is one way of increasing the rotational freedom of the joint, but comes at an additional cost to anterior-posterior (A/P) stability.

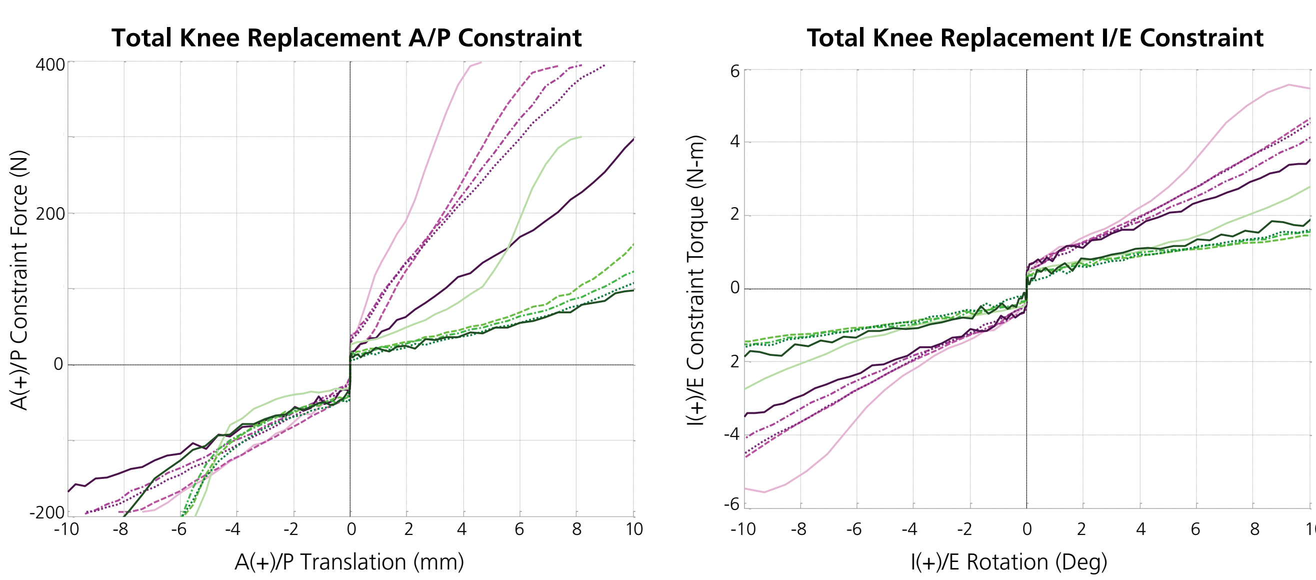


Figure 2: The anterior-posterior (A/P) and internal-external(I/E) stability of the ATTUNE Knee (purple) and Triathlon® (green) CR total knee replacements through the flexion range. The ATTUNE Knee provides considerably more anterior stability than the Triathlon® knee while maintaining the freedom to rotate in deep flexion.

Researchers have corroborated these findings when comparing the mid-flexion stability of the Triathlon® implant to the stability of the native knee (Fig. 3). In a series of cadavers, researchers from the Imperial College of London demonstrated that the Triathlon® knee implant had significantly less A/P stability than the native knee from full extension to 40° of knee flexion.[7] Without the anterior cruciate ligament, the remaining collateral ligaments and knee capsular structures do not have the appropriate line of action to resist anterior-posterior translations. The lack of A/P constraint built into the Triathlon® tibial bearing results in a knee that is under constrained in extension, when patients need it most.

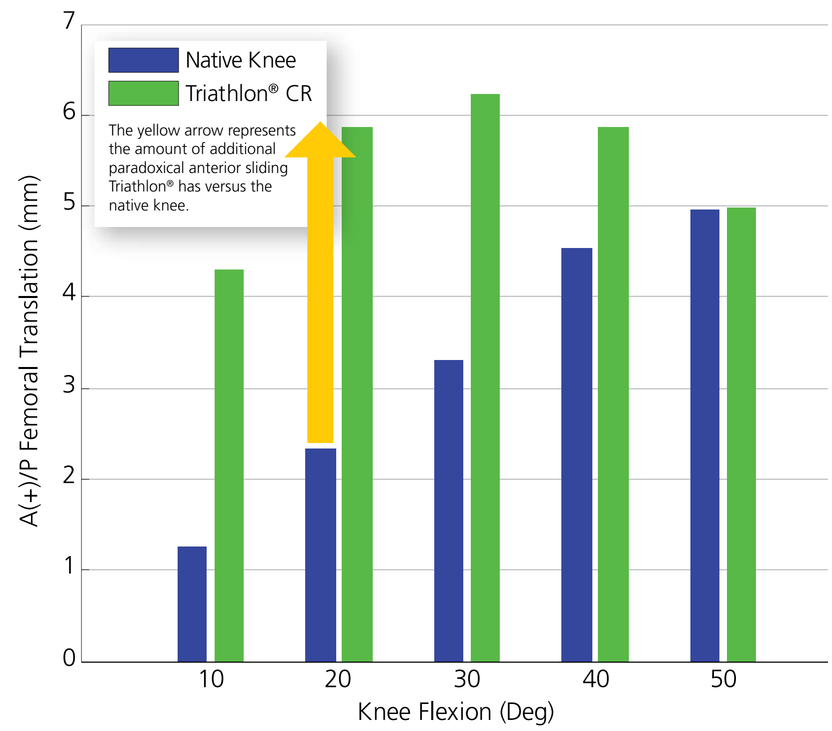


Figure 3: The overall A/P range of motion for the native knee and the Triathlon® total knee reported by Stoddard et al, demonstrating that the Triathlon® has significantly less constraint in knee extension and mid flexion.[7]

While laxity tests illustrate design differences, mid-flexion instability can only be observed during weight-bearing dynamic activities. When comparing Triathlon® and the ATTUNE Knee in a deep knee bend simulation,[8] Triathlon® experiences a sudden and rapid anterior translation of the medial condyle, which initiates at 10° knee flexion (Fig. 4), whereas the motion of the medial conydyle with the ATTUNE Knee is stable through the flexion range.

This behavior of the Triathlon® knee has been observed in vivo. In fact, a fluoroscopic study found that 27% of the patients with a fixed bearing Triathlon® and 63% of patients with a mobile-bearing variation of Triathlon® exhibited paradoxical anterior translation of both femoral condyles with knee flexion.[9]

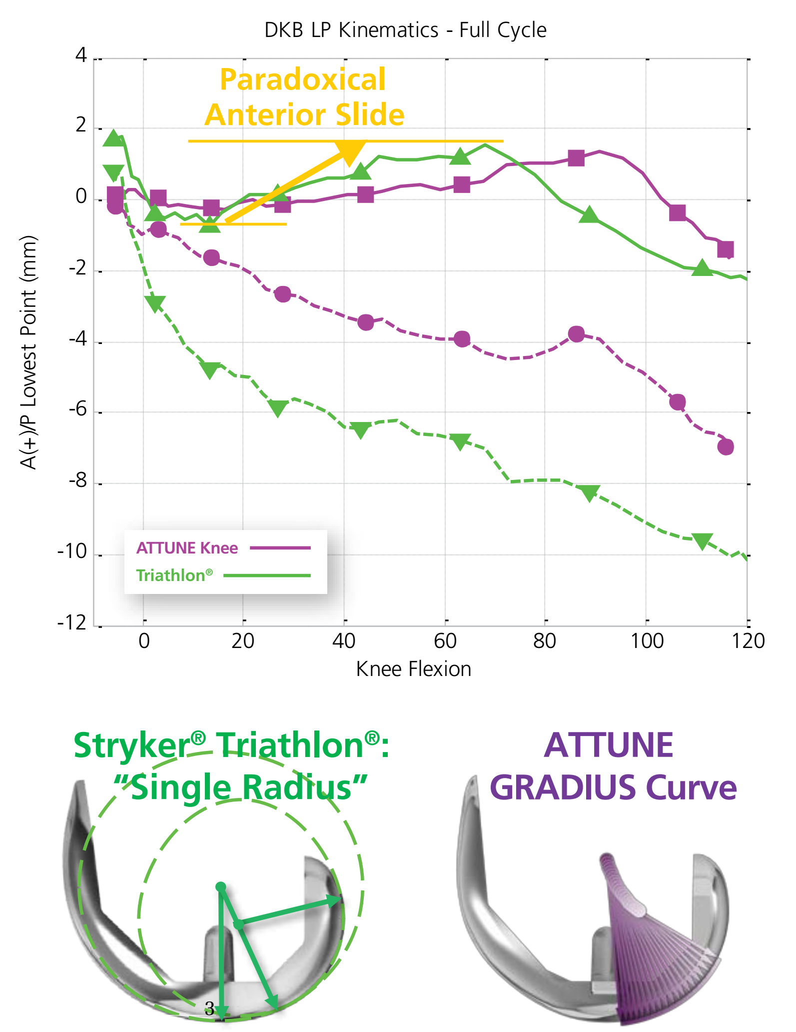


Figure 4: The results from the cadaveric testing at the University of Kansas clearly demonstrates the paradoxical anterior slide which occurs at the transition from the distal to posterior radii in traditional knee replacement. The anterior slide was significantly reduced in the cadaveric knees implanted with the ATTUNE Knee.

When subjected to the large loads seen during the stance phase of gait (Fig. 5) or stair descent (Fig. 6), the effect of implant stability becomes even more apparent.[10] The less stable Triathlon® knee replacement exhibits considerably larger condylar translations than the ATTUNE Knee under identical loading conditions, which may lead to a patient feeling unstable during these types of activities.

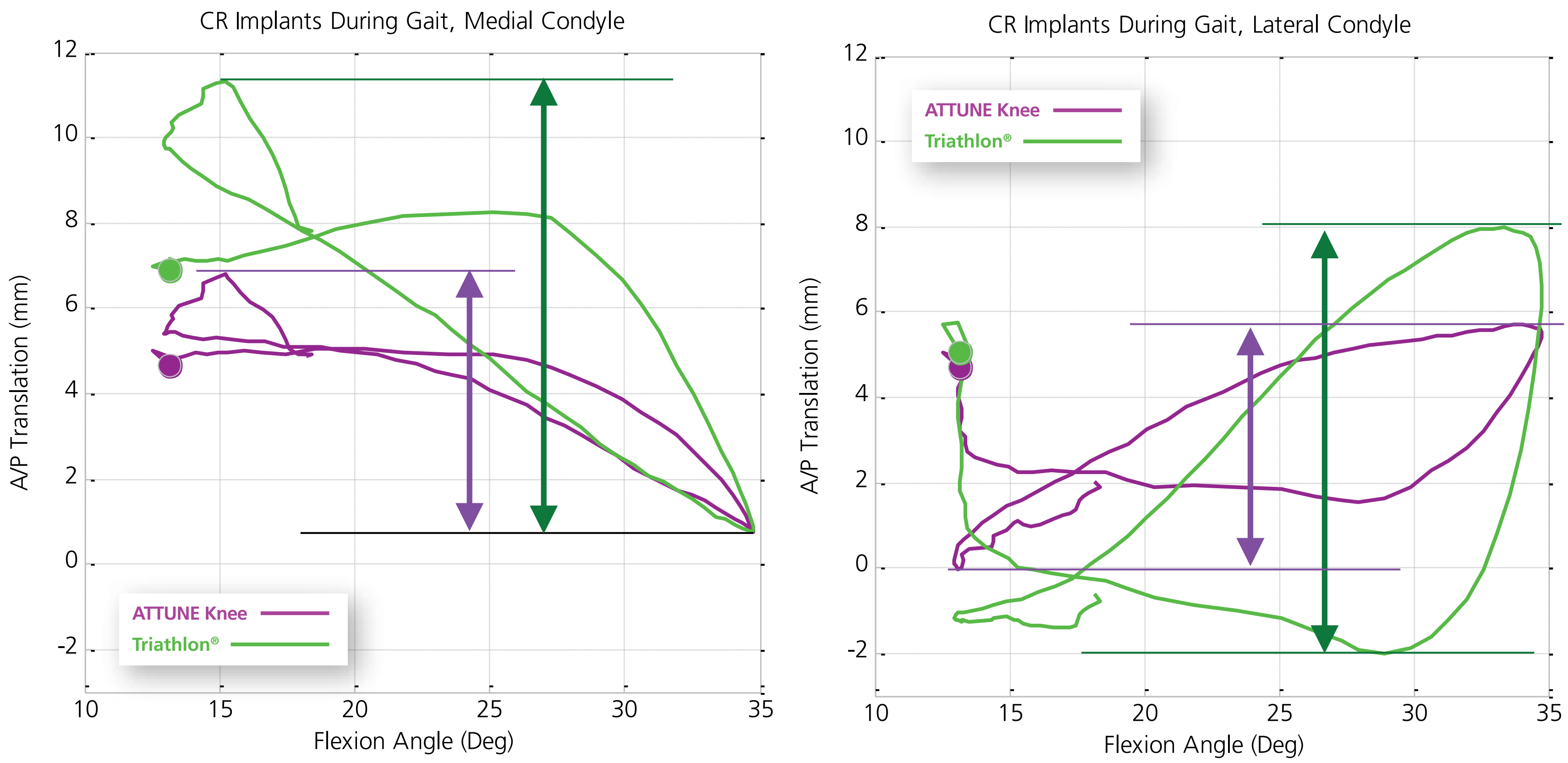


Figure 5: The overall condylar translation of the ATTUNE Knee and Triathlon® implants during the stance phase of gait. The optimized articulation of the ATTUNE Knee reduces the overall A/P condylar translations and provides more stability during this high demand activity.

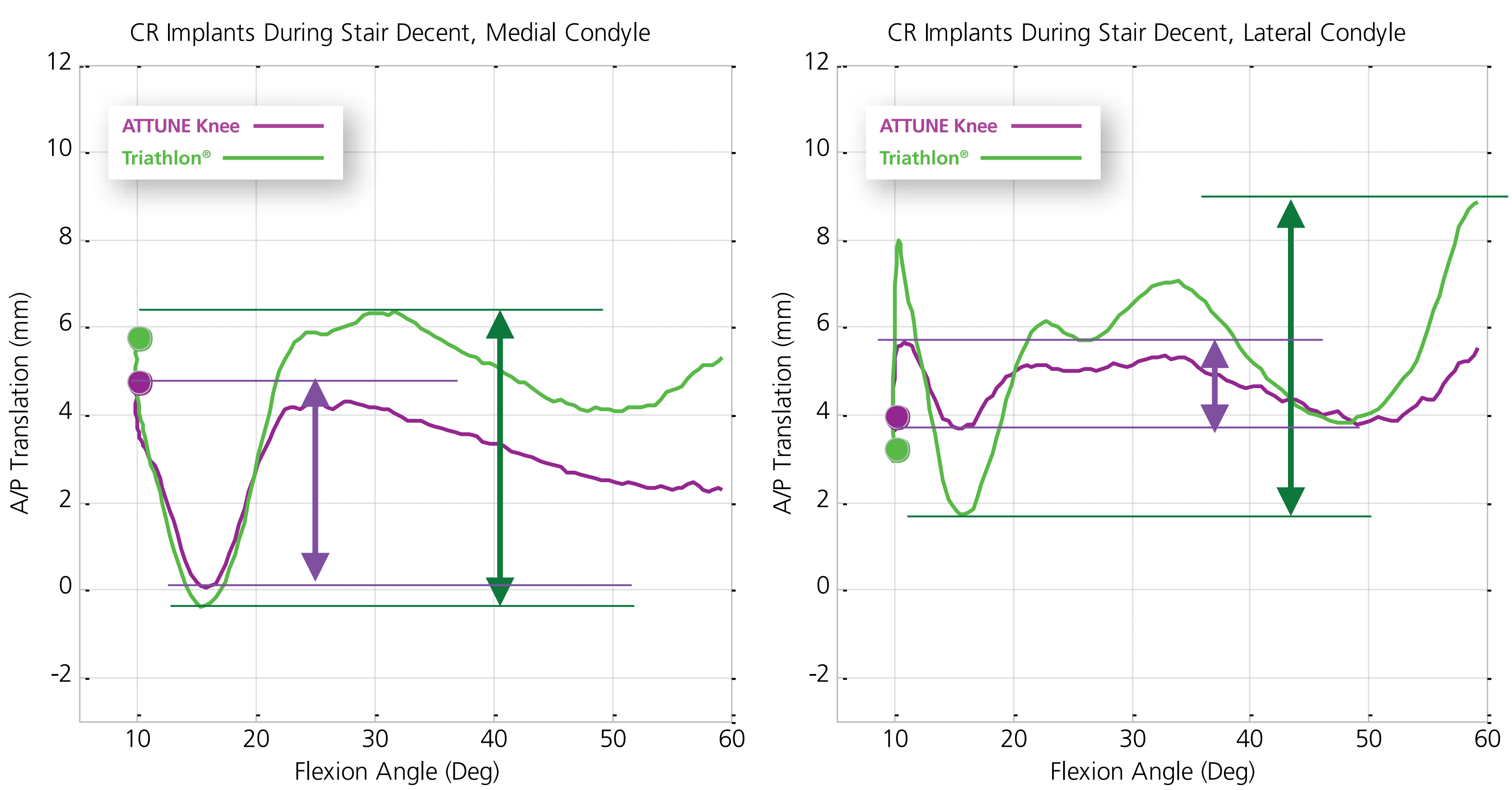


Figure 6: The overall condylar translation of the ATTUNE Knee and Triathlon® implants during the stair decent. The optimized articulation of the ATTUNE Knee reduces the overall A/P condylar translations and provides more stability during this high demand activity.

In addition to the lack of stability, the lack of conformity in the Triathlon® design leads to significantly higher contact stress across a broader percentage of the articulating surface (Fig. 7).[10] Increased stress on the tibial insert, coupled with a non-oxidatively stable polyethylene could lead to an increased risk of polyethylene failure.[11]

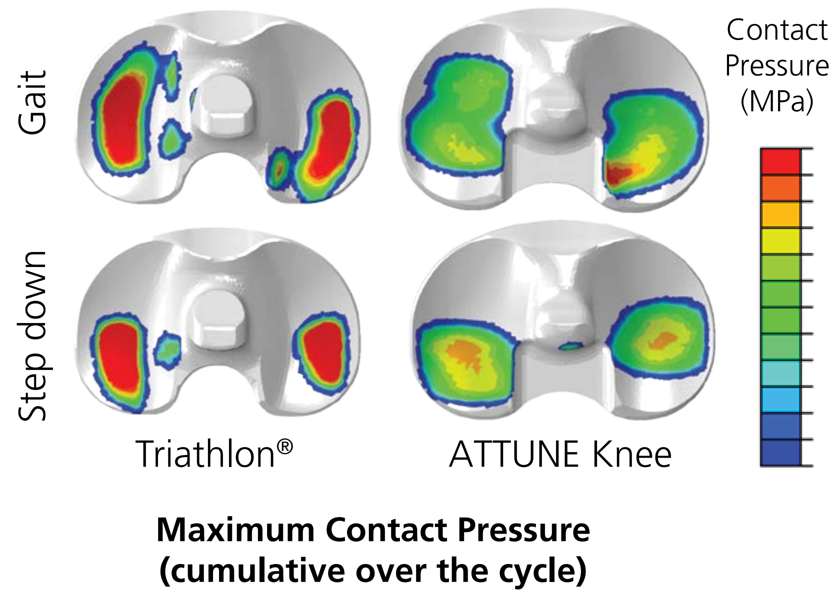


Figure 7: The peak contact pressures experienced by Triathlon® during stair decent and gait was considerably higher than the ATTUNE Knee under identical loading conditions.

## CONCLUSIONS

Reducing-radius femoral condylar shapes in TKA enable the implant designer to optimize the A/P stability of the tibia-femur construct to the activities which occur in a specific flexion range. By utilizing a larger distal radius through the arc of flexion experienced during the stance phase of gait (0 degrees to ~30 degrees) coupled with an optimized tibial articulation, the A/P stability of the joint during this high-demand activity can be maximized. Then, by transitioning to smaller radii during deeper flexion activities, the conformity ratio is reduced and the joint has more freedom of rotation.

In contrast, utilizing a single radius through flexion necessitates the same tibia-femur conformity in both extension and in flexion, while the functional demands in these flexion ranges are quite different. Bench top testing, cadaveric comparisons, and in vivo fluoroscopy all confirm that the Triathlon® femoral componenet and its single radius-of-curvature leads to a less stable knee joint. In contrast, the optimized shape of the ATTUNE Knee femoral component, which incorporates a gradually reducing radius, coupled with a tibial insert optimized to provide A/P stability while enabling rotational freedom, provides patients with an excellent level of knee stability throughout their range of motion.

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