

Article Review: Case series report of navigation-based *in vivo* knee kinematics in total knee arthroplasty with a gradually reducing femoral radius design¹

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SUMMARY

Total knee arthroplasty is performed in patients who have severely damaged knee joints mainly as a consequence of osteoarthritis. Range of motion and stability are important factors used to determine the success of total knee arthroplasty (TKA). Despite advances in restoring function, instability in flexion remains a problem with some TKA implant designs.

In this retrospective study, two knee systems were compared (SIGMA[®] CR Knee System and the ATTUNE[®] CR Primary Total Knee System) in twelve Japanese female patients. Knee kinematic patterns were assessed intra-operatively.

Paradoxical anterior movement was observed in both the medial and the lateral condyle from 40 to 70 degrees of knee flexion intra-operatively in patients receiving the SIGMA Knee System. Smooth roll-back movement without abrupt change at mid-flexion was observed in patients receiving the ATTUNE Knee System.

Based on this retrospective case series, it appears that the ATTUNE Knee System performs better in Japanese female patients undergoing navigation based TKA, providing more stability and minimising the paradoxical anterior slide than the SIGMA Total Knee System.

Total knee arthroplasty is performed in patients who have severely damaged knee joints mainly as a consequence of osteoarthritis.² The primary purpose of surgery is to reduce pain and restore function, by providing an aligned and stable joint.^{3,4} The style of prosthesis chosen affects the kinematics of the implant.² Other factors that influence kinematics include, conformity, surgical procedure, ligament integrity, muscle function and loading activities.^{5,6}

Range of motion and stability are important factors used to determine the success of total knee arthroplasty (TKA). Typically, patients achieve between 110 and 115 degrees of knee flexion,^{7,8} and while this is sufficient for ascending and descending stairs (90 to 120° of flexion), it may not be sufficient for transferring in and out of a bath (up to 135° of flexion), or squatting, kneeling and cross-legged sitting (111 to 165° of flexion).^{7,8} Instability has been reported in these high demand activities.^{9,10} Thus, despite TKA, many patients are unable to return to their normal activities.

Range of motion must be weighted against the stability of the joint. Post-operative instability is one of the major causes of TKA revision.¹¹ After TKA, medial stability and lateral rollback may be replaced by anterior-posterior sliding and reversed rotation. This can lead to significant wear on the implanted joint, and may reduce range-of-motion.¹¹

Therefore, implant design is a determinant factor of knee instability.¹² The SIGMA CR Knee System (SIGMA Knee) and the ATTUNE CR Primary Total Knee System (ATTUNE Knee) are commonly used semi-constrained (CR) knee replacement

systems. The SIGMA Knee System has a traditional multi radius design, while the ATTUNE Knee System has a gradually reducing radii design (*Figure 1*). The gradually reducing design aims to provide a smooth transition throughout the gait cycle to enable a gradual reduction in tibio-femoral conformity. This would provide high stability in lower flexion angles, and increased mobility in higher flexion angles.⁵ In addition, the ATTUNE Knee System has been developed with the objective of minimizing the paradoxical anterior movement seen in other designs (*Figure 2*).¹³

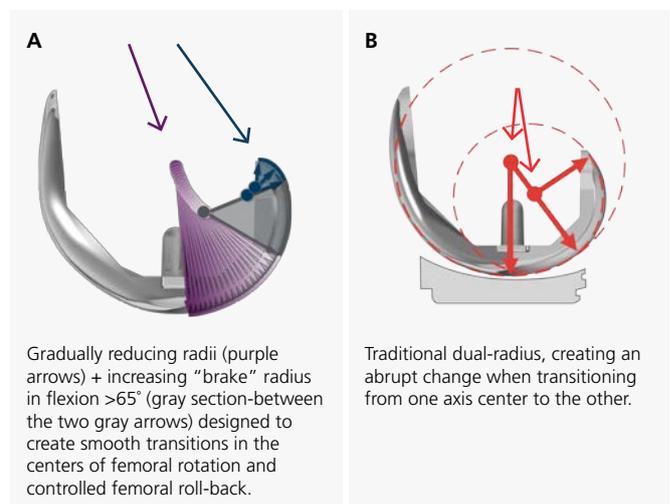


Figure 1: Illustrations of ATTUNE GRADIUS™ Curve radius system (A) and the multi-radius design used in SIGMA Knee System (B)

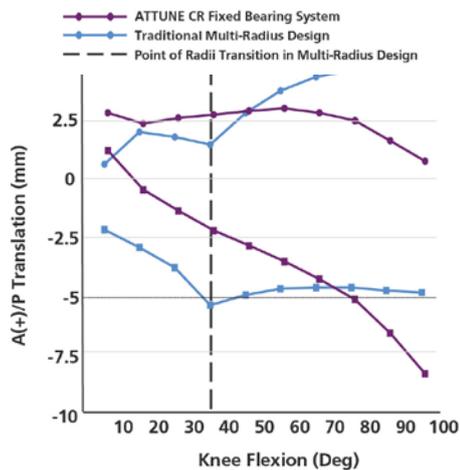


Figure 2: In vitro evidence (experimental and finite element analysis) of paradoxical anterior sliding seen by Clary and colleagues in the traditional multi-radius knee implant design such as SIGMA Knee (blue) compared to ATTUNE Knee (purple). Medial condyle, top line, lateral condyle, bottom line. Adapted from Clary *et al.*⁵

This anterior movement is clinically important as relative sliding can cause wear on the implant (Figure 3).¹⁴

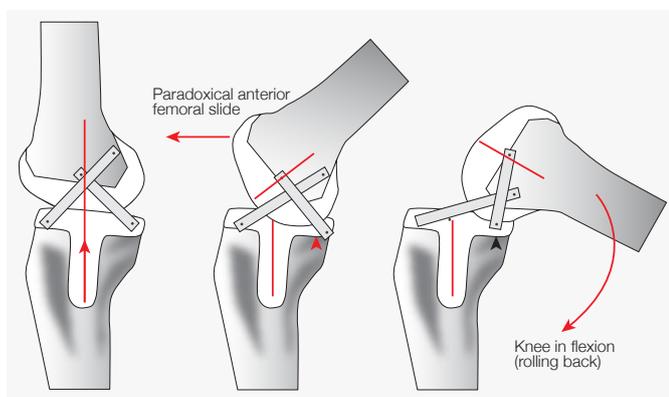


Figure 3: Paradoxical anterior sliding: the femur slides forward instead of the normal roll-back as the knee flexes, adapted from *The Unhappy Total Knee Replacement: A comprehensive Review and Management Guide*, MT Hirschmann, R Becker (ed.) Springer 2015¹⁵

Some of the differences in paradoxical sliding between posterior stabilized and cruciate retaining implants can be overcome with implant design. The ATTUNE Knee System is designed to work in harmony with the PCL in deeper flexion to ensure proper rollback. This requires the proper tibial slope. Computer navigation, which can optimize knee kinematics during surgery,¹⁶ can aid the surgeon in achieving the proper tibial slope. Adequate kinematics and functional outcomes of the implanted knee is required in order to maintain the patient's quality of life, and reduces the need for revision TKA which is costly.³

The purpose of this study was to compare the kinematics of the gradually reducing radii design TKA (ATTUNE Knee) with the traditional multi radius design TKA (SIGMA Knee) in navigation based TKA.

METHODS & RESULTS

Dr Takagi *et al.* performed a retrospective case series report of twelve Japanese female patients, with average age of 75.3 years (51 to 87 years) and a 10.3 ± 2.3 year history of knee osteoarthritis (7 to 15 years).¹ It is worth noting that approximately 82% of TKA patients in Japan are female.¹⁷ All patients underwent TKA using a computed-tomography free navigation system resection technique (Kolibri BrainLAB

AG, Germany). This system for software-guided surgery gives visual guidance allowing less invasive surgery and better alignment of implants.

Patients (n=12) receiving either the SIGMA CR FB Primary Total Knee System with re-surfaced SIGMA Patella (SIGMA Knee, DePuy Synthes, USA; n=6) or the ATTUNE CR FB Primary Total Knee System with re-surfaced medialized dome patella (ATTUNE Knee, DePuy Synthes, USA; n=6) were randomly selected for chart review of their surgical procedure. The surgical technique was identical for both implants, with measured resection, 5 degrees of CR tibial posterior slope. All patients were under general anesthesia.

Knee kinematics were measured intraoperatively during passive range of motion from full extension to 130 degrees of knee flexion.

SIGMA® Knee System

Paradoxical anterior movement was observed in both the medial and the lateral condyle from 40 to 70 degrees of knee flexion in patients receiving the SIGMA Knee System (Figure 4,5). Both condyles moved in parallel.

ATTUNE® Knee System

No paradoxical anterior movement of either condyle was observed in patients receiving the ATTUNE Knee System (Figure 4,5). A medial pivot pattern from extension to 90 degrees of flexion was observed with the ATTUNE Knee System, beyond which there was rollback to 130 degrees of knee flexion.

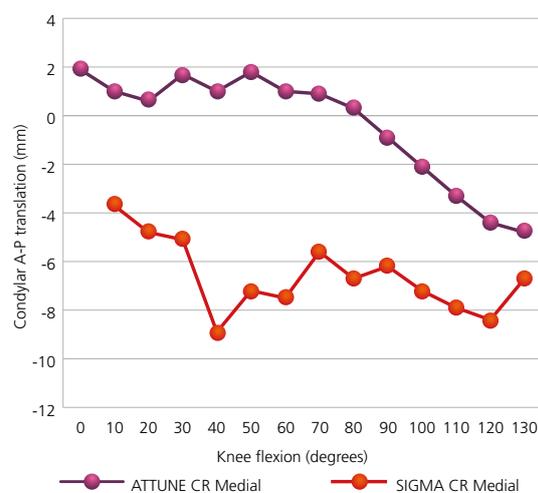


Figure 4: Average A-P displacement of the ATTUNE and SIGMA Knee Systems, adapted from Takagi *et al.*¹

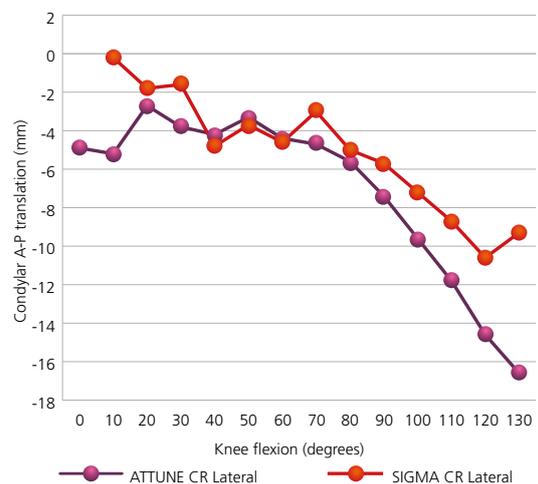


Figure 5: Average A-P displacement of the ATTUNE and SIGMA Knee Systems, adapted from Takagi *et al.*¹

DISCUSSION

In this small case series, the ATTUNE Knee implants were not associated with paradoxical anterior movement, while patients with SIGMA Knee implants did exhibit anterior sliding. Others have also reported excellent medial stability in mid flexion for patients with the ATTUNE Knee System.⁵ This *in vivo* data is consistent with the computational and experimental results of Clary and colleagues,⁵ who suggested that the rate at which the femur rolls posteriorly is correlated to the size of the distal radius, with larger distal radii rolling more rapidly. The overall magnitude of the slide would be affected by the tibial conformity.⁴ Thus when a multi-radius femoral component changes from its first radius to its second radius, the medial condyle moves forward and the lateral condyle stops rolling back. They suggested that replacing the instantaneous transition to a gradually reducing radius could attenuate the magnitude of the paradoxical anterior slide,⁵ as was observed in our case-series. Clary *et al.* also reported the ATTUNE Knee System could attenuate the paradoxical anterior slide due to the inclusion of a brake radius beyond 65 degrees of flexion, along with increased femoral roll back beyond the 65 degrees.⁵ This is similar to the rollback observed in our study beyond 70 degrees.

Clary *et al.* postulated that the differences in patient factors or surgical technique could influence the kinematic variations reported in his study more than the implant design itself,⁵ although he noted that others have suggested the dominant drivers of knee kinematics depend on whether the knee is in extension (where patient factors are more important) or in flexion (where implant design is more relevant).⁶ In the present study, the same surgical technique was employed for all cases, therefore we postulate differences are likely due to differences in the design of the two implants, especially when considering the kinematics in flexion.

Lifestyle and anatomical differences can make choosing and fitting implants more challenging. The additional sizes and refined shape of the ATTUNE Knee System design helps the surgeon optimize the selection and fit of the implant. Asian patients, along with other patients with a floor based lifestyle, have higher flexion needs. Cross-legged sitting, squatting and kneeling require the full range of motion of the human knee joint.⁷ Lifestyle factors such as frequent squatting or kneeling also require stability of the implant. Avoiding paradoxical anterior translation, as the ATTUNE Knee System was designed and experimentally shown to do,⁵ is essential to maintaining range of motion and stability. Instability of the implanted joint accounts for just under 1 in 10 revision TKAs in Japanese patients,¹¹ therefore choosing an implant that provides the appropriate stability is particularly important.

There are several limitations to this study: firstly, only a small number of patients underwent TKA with the two implants in a non-randomised fashion undertaken by a single surgeon; secondly, the knee kinematics were observed intra-operatively, and as such, the influence of load-bearing on the kinematics of the implant could not be assessed; and finally, the chart review included only female patients.

Despite these limitations, it appears that the ATTUNE Knee System performs better in Japanese female patients undergoing navigation based TKA, providing more stability and minimising the paradoxical anterior slide versus the SIGMA Knee System.

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