

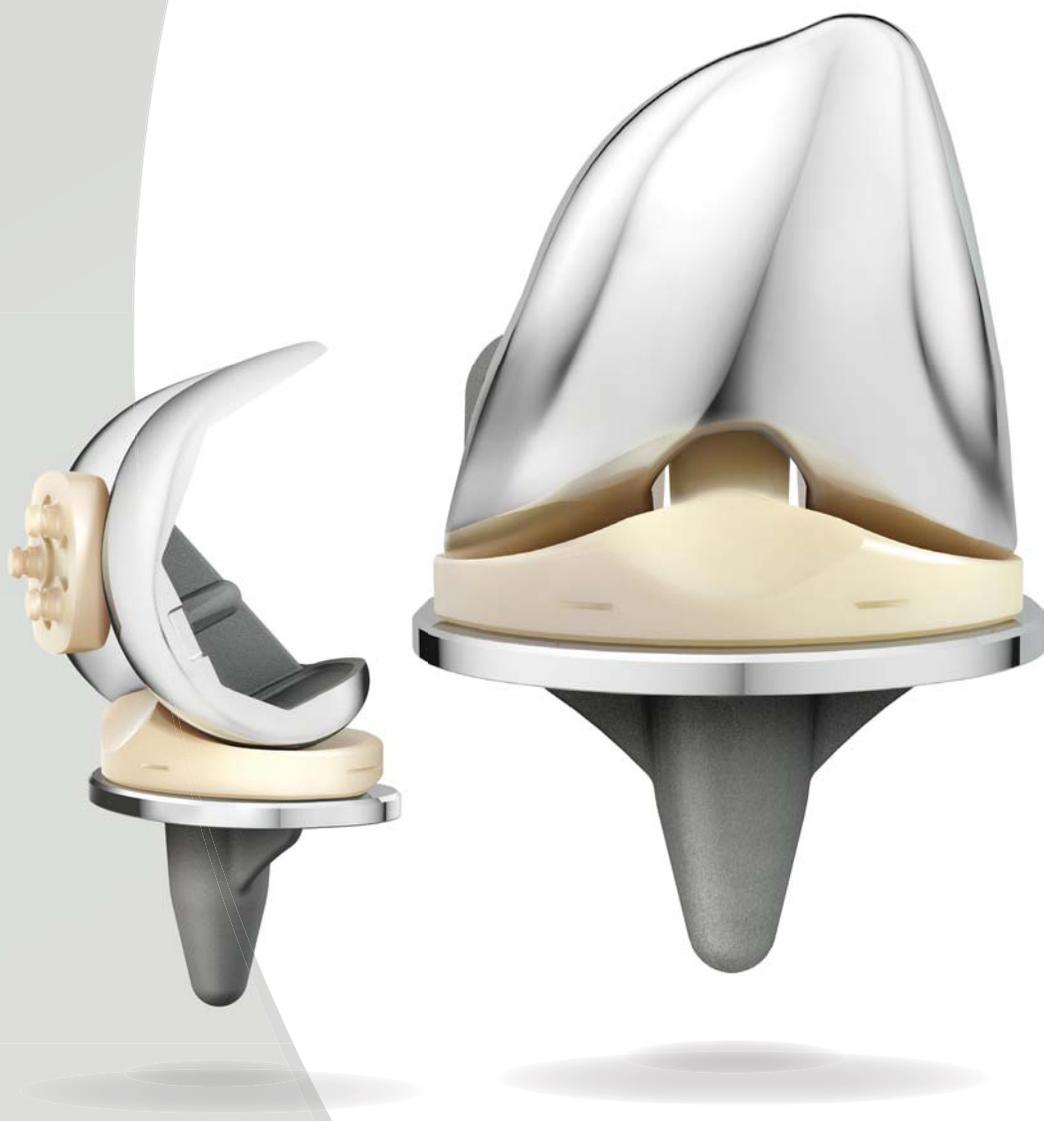
Supplement to

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SPOTLIGHT

## Improving Patient Satisfaction Through Total Knee Arthroplasty Design



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## Introduction

To provide patients with an ideal knee system, global thought-leader surgeons, engineers and experts in fields of study such as kinematics, anthropometrics, polyethylene wear and design convened to design and test the ATTUNE® Knee System (*DePuy Synthes Joint Reconstruction*), which was designed to improve function, stability and mobility after total knee arthroplasty. Surgical technique coupled with an ideal knee system can produce more efficient and high-quality outcomes and improve patient satisfaction as a result. This supplement provides expert perspectives from surgeons who have helped design and assess the ATTUNE Knee System and have experience implementing it in their practices.

This spotlight supplement is based on presentations given at a symposium sponsored by *DePuy Synthes Joint Reconstruction* at the 2014 American Academy of Orthopaedic Surgeons Annual Meeting. I thank the faculty for their participation and *DePuy Synthes Joint Reconstruction* for sponsoring this ORTHOPEDICS TODAY supplement.

Anthony A. Romeo, MD  
Chief Medical Editor  
ORTHOPEDICS TODAY

### TABLE OF CONTENTS

**Surgeons can help improve patient satisfaction with total knee arthroplasty outcomes..... 3**  
Robert T. Trousdale, MD

**Advanced implant designs improve total knee arthroplasty outcomes..... 6**  
David A. Fisher, MD

**Advanced implant designs improve knee instability ..... 10**  
David F. Dalury, MD

**Implant design and surgical technique affect patellofemoral complications ... 12**  
William P. Barrett, MD

**New implant design may help address ongoing debates in TKA ..... 15**  
Douglas A. Dennis, MD

**Early outcome study on the ATTUNE® Knee System ..... 19**  
Mark Clatworthy, MD

# Surgeons can help improve patient satisfaction with total knee arthroplasty outcomes

Robert T. Trousdale, MD



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As one of the most common orthopedic procedures, total knee arthroplasty (TKA) is regarded by orthopedic surgeons as an effective treatment for patients with knee osteoarthritis. Surgeons have increased their focus on function and patient satisfaction rather than just function and

survivorship, and have worked to identify the causes of patient dissatisfaction following TKA and manage it accordingly. Postoperatively, patients will often achieve good motion, and their radiographs will usually demonstrate a well-aligned, stable knee. Despite these positive results, some patients are dissatisfied with the outcomes of their procedure. To improve patient satisfaction with TKA results, the orthopedic surgeon must establish reasonable expectations for their patients, especially with regard to recovery time. Additionally, the surgeon must perform surgery on appropriate candidates using an effective surgical technique, along with a well-designed implant that optimizes motion and stability. These steps will ultimately increase the probability of patient satisfaction.

Over the past decade, research has shown that approximately one in five patients are dissatisfied with their TKA results. Data from one study showed that patient expectations were met in 70% of total knee cases.<sup>1</sup> Furthermore, in this study, 89% of patients receiving total knee replacements stated that they would undergo surgery again compared with 96% of patients in the total hip arthroplasty (THA) population. Compared with the THA patients, the TKA patients had smaller improvements in WOMAC scores, which assess pain, stiffness and physical function. They were also less satisfied with their level of pain reduction.

Other centers have reproduced these data. For example, one study found a similar level of dissatisfaction among patients who underwent TKA.<sup>2</sup>

**Figure 1:** Anteroposterior view of a patient 1 year following TKA. The knee is well aligned and stable, with motion from 0° to 120°. No infection is present. Although there is no radiological explanation, the patient has persistent periarticular soft tissue pain during activity. The patient was not satisfied with the results of his or her TKA.

Source: Trousdale RT



Between 2006 and 2008, researchers evaluated 1,217 consecutive patients before their TKA and 6 months after their TKA. One year postoperatively, 18.6% of patients were unsure of their satisfaction level or dissatisfied with their procedure. The best predictors of dissatisfaction were the preoperative SF-12 mental component score, the 6-month SF-12 score, depression, pain in other joints and less improvement in the pain element of the Oxford Knee Score. These studies demonstrate that several factors are involved in causing patient dissatisfaction with TKA.

## Pain often linked to dissatisfaction

The top indicator of patient dissatisfaction is pain.<sup>3</sup> One study showed that, at more than 1 year following TKA, 81.8% of patients were satisfied with the results of their surgery. Pain and lack of function were associated with the least satisfaction (Figure 1). Ongoing pain, female gender and a primary diagnosis of osteoarthritis were also associated with patient dissatisfaction in this study.

The differences in patient satisfaction due to pain after THA vs. TKA can be traced to the



**Figure 2:** (A) Radiograph showing bilateral knee arthritis in a patient who has activity-related pain but no periarticular soft tissue pain. This patient would likely respond well to TKA. (B) Radiograph of a patient who has mild degenerative disease. This patient is less likely to be satisfied with a successful TKA.

Source: Trousdale RT

fundamental differences between the hip and knee joints. A deep-seated joint, the hip is substantially covered with muscles and soft tissues, which may offer a better cushion against pain. In contrast, the knee is a subcutaneous joint and, because there is significantly less cushion around the knee joint, it may be subject to more periarticular pain. The kinematic differences between the hip and knee with regard to motion and stability may also influence patient satisfaction. Generally, patients who undergo a TKA experience more pain than patients who undergo THA, which largely contributes to dissatisfaction postoperatively.

### Patient selection

The first step surgeons can take to improve patient satisfaction is choosing to perform surgery on the appropriate patients. TKA is best suited for patients with severe pain, osteoarthritis or rheumatoid arthritis. A patient with bilateral arthritis and activity-related pain but no periarticular soft tissue pain should achieve positive results with TKA (Figure 2).

Certain patients have comorbidities that render them less than optimal surgical candidates. For instance, obesity negatively influences total joint arthroplasty results. Results of a systematic literature review demonstrated that patients who are morbidly obese had significantly lower rates of implant survivorship at a mean 5-year follow-up compared with obese and nonobese patients.<sup>4</sup> In addition, mean Knee Society objective and function scores, a measure of prosthesis and patient function after knee replacement, were lower in the morbidly obese patients in this study. Diabetes can also

influence total joint arthroplasty outcomes. According to Bolognesi and associates, the 64,262 patients with diabetes who had primary or revision THA or TKA in their study were at greater risk for pneumonia, stroke and transfusion.<sup>5</sup>

Other patients considered poor surgical candidates include patients who have infections, particularly in their ipsilateral foot or toe; patients with severe pain but minimal radiographic disease; patients who are on workers' compensation; and patients who use a significant amount of narcotics preoperatively. Zywiell and colleagues found that patients undergoing TKA who used opioids preoperatively had longer hospital stays, more postoperative pain and more complications, making their recovery more difficult.<sup>6</sup> The patients who took opioids preoperatively required additional procedures and pain management referrals and were more likely to have unexplained pain or stiffness, as well as less function and motion in the operated knee. Therefore, surgeons can narrow down the patients who would benefit from TKA and eliminate those who would not, thereby improving the likelihood that the patients they choose will be satisfied with their outcomes.

### Managing postoperative expectations

To improve patient satisfaction, surgeons can offer patients realistic expectations about their postoperative recovery. Patients should understand that it will take 1 year to completely recover from surgery. They will be able to return to many of their previous activities by 3 to 4 months postoperatively, but full recovery will take at least 1 year. Making this clear to patients preoperatively should prevent them from expecting to be healthy and active 4 to 6 weeks after surgery. When patients know what to expect postoperatively, it is more likely that they will feel content with their results.

### Surgical technique

It is critical to use the proper surgical technique to achieve a successful outcome. The surgeon must achieve effective alignment and stability in flexion, midflexion and extension. Fixation must be reasonable and durable. If the surgeon accomplishes each of these steps during surgery, then it will set the foundation for a successful outcome and patient satisfaction.

Choosing an implant with an optimal design that offers high-quality motion and stability is also essential. Advances in implant design,

such as those included in the ATTUNE® Knee System (*DePuy Synthes Joint Reconstruction*), may decrease the percentage of patients who are dissatisfied with their TKA results. The ATTUNE Knee implant design may eliminate or reduce the instability some patients experience during daily activities such as walking down stairs and bending. If surgeons combine a high-quality surgical technique with an advanced implant design like the ATTUNE Knee System, patients will likely be more satisfied with their outcomes.

Various studies have shown that patients experience less satisfaction after TKA procedures than THA procedures. Factors such as postoperative pain, patient selection, patient expectations and surgical technique affect patient outcomes following TKA. However, patient satisfaction is not out of surgeons' control. Surgeons can manipulate each of these factors to produce better outcomes for patients. When surgeons manage patient expectations and perform a successful surgery on the appropriate candidates using advanced implants, they can improve the likelihood that their patients will have a positive experience.

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*Dr. Trousdale is a professor of orthopedics at the Mayo Clinic in Rochester, MN. Dr. Trousdale receives research support from DePuy Synthes Joint Reconstruction.*

# Advanced implant designs improve total knee arthroplasty outcomes

David A. Fisher, MD



David A. Fisher, MD

Orthopedic surgeons have similar goals in mind when recommending that a patient undergo total knee arthroplasty (TKA). Surgeons aim to relieve pain, improve function and restore patients' mobility. Other essential goals include minimizing complications, monitoring results and, over time, making procedural and technological advancements to continuously improve the experience for patients. Despite surgeons' best efforts, problems associated with TKA, including pain, stiffness, infection, sizing issues, kinematic challenges, flexion instability, patellofemoral tracking, instrumentation issues and polyethylene

wear-related complications occur. In addition, the cost of this elective procedure, including the implants, can be an obstacle in this cost-conscious society.

Within the orthopedic community, differing views remain about both implant design and surgical technique. In surgeons' attempts to determine the best methods for achieving a successful TKA with minimal complications, there are ongoing debates on topics such as retaining or substituting the PCL, computer navigation, patient-specific "custom" instrumentation, gap balancing vs. measured resection surgical techniques, resurfacing the patella, and fixed vs. mobile bearing total knee designs. Although challenges with perfecting TKA remain, surgeons can continue to implement new systems and techniques to potentially help patients reach their goals.

## Establishing an initiative

To address the challenges associated with TKA, a world class team of experts along with various research specialists from leading academic institutions assembled to create the ATTUNE® Knee System (*DePuy Synthes Joint Reconstruction*). The goal for this new knee system was to produce measurable improvement in total knee outcomes through a process of engaging surgeons experienced in performing total knee replacement and engineers experienced in designing the implants. *DePuy Synthes Joint Reconstruction* recruited 35 such U.S. and international surgeons. The team was composed of surgeons who had used various products from different countries with different philosophies on instrumentation, surgical technique and implant design. Through collaboration, they identified potential areas for improvement in current implant technologies, as well as concepts that have stood the test of time (Figure 1).

The surgeon design team was assembled into four subteams to assist in the design and development of the many aspects of the ATTUNE Knee System. These teams included a cruciate retaining (CR) team, a posterior stabilized (PS) team, an instrumentation team and a revision team. Each surgeon provided valuable insight and guidance within his or her



**Figure 1:** Surgeons and engineers study issues related to TKA to create a new total knee system.

Source: Fisher DA

subteam, but also had the opportunity to provide input into other aspects of the system.

### An improved system

The surgeons, engineers and academic specialists wanted to create a fully integrated knee system that addressed pressing concerns in modern TKA. To do this, a new system would need to (1) provide motion with improved stability and kinematics; (2) improve patient fit; (3) improve patellofemoral joint function; (4) improve design and materials for implant durability with integrated fixed, mobile and revision options; and (5) provide accurate and reproducible instrumentation to advance the surgical process for implant positioning and operating room efficiency, which addresses a range of surgical philosophies and aids in operating room efficiency.

It was important for the collaborators to start with basic concepts and build a foundation in order to accomplish these goals. The surgeons and engineers started by asking simple questions with complicated answers: What features work in current implant designs? What are the current problems associated with total knee implants? How can we analyze the problems and create solutions to address these issues?

A number of international universities and research institutions collaborated to design studies to assess these queries in the laboratory. The design process began with the analysis of fluoroscopic studies of patients with various contemporary knee replacement designs. When the team observed issues with an implant, they simulated the motion of these knee systems in the Kansas Knee Simulator (University of Kansas), a six-axis, dynamic weight-bearing simulator designed to study the kinematics of existing designs during various activities such as gait, stair descent and deep knee flexion. Through these simulations and a complementary computational knee biomechanics model at the University of Denver, the team was able to correlate an implant's geometry to the type of motion patients experienced. Subsequent designs were developed based on the results and the system was retested and validated on cadavers.

Through these types of analyses, the engineering and surgical design teams developed a scientific method to assess and validate the design features of the ATTUNE Knee System (Figure 2). There have been over 100 patent applications, multiple premarket approvals and more than 30 scientific abstracts and journal publications that document



**Figure 2:** Steps of the development process for the ATTUNE Knee System.

Source: Fisher DA

the science behind the ATTUNE Knee design. As a result, the ATTUNE Knee System is one of the most researched, analyzed and tested implants ever designed in the field of orthopedics.

The ATTUNE Knee System includes several features that address the challenges observed during this testing. For example, it includes a new sagittal radius of curvature (ATTUNE GRADIUS™ Curve) designed to reduce instability and provide patients with a smooth transition from high conformity in extension to rotational freedom in deep knee flexion, as seen in the native knee. The GLIDERIGHT™ Articulation has a trochlear groove designed to accommodate patient variation and soft tissue interaction with patella components and to optimize patella tracking while maintaining bone coverage. The system also features a proprietary S-Curve (SOFCAM™ Contact) designed to provide smooth engagement between the PS femoral component and PS insert to enable rollback and reduce stress on the insert. Finally, the ATTUNE Knee also includes the LOGICLOCK™ Tibial Base with a patented central locking design that provides a way to optimize femoral-tibial bearing contact while reducing backside micromotion between the components. For the first time in fixed bearing total knee replacement, surgeons can match the insert to the femur every time, reducing compromises associated with upsizing or downsizing the femur to the insert. These new features highlight a few of the comprehensive developments in this advanced total knee system.

### Surgical technique

When performing TKA, I make the patellar cut first, followed by the proximal tibial resection, aiming for neutral tibial alignment in the anteroposterior

ATTUNE vs. SIGMA			
	ATTUNE (N = 315)	SIGMA (N = 379)	P Value
6-week ROM	2 - 115	2 - 113	NS
6-week knee score	85.4 (8.6 SD)	82 (12 SD)	NS
6-week function	59 (16.6 SD)	48 (16 SD)	<.05
6-month ROM	0.2 - 122	1 - 118	NS
6-month knee score	91 (5.7 SD)	89.2 (12 SD)	NS
6-month function	90.6 (14 SD)	73.2 (11.4 SD)	<.01
1-year ROM	0 - 127	0.48 - 120	NS
1-year knee score	91.5 (6.3 SD)	89.3 (12.2 SD)	NS
1-year function	94.4 (6.3 SD)	83.5 (12.2 SD)	<.05

**Figure 3:** Outcome data for the ATTUNE Knee System vs. the SIGMA® Knee System. ROM=range of motion; SD=standard deviation; NS=not significant.

Source: Fisher DA

(AP) plane. For CR knees, I cut the posterior tibial slope at 5° to 7° of slope, while I reduce the slope to 3° for a PS knee. I will then make a distal femoral resection of 9 mm using the intramedullary guide. The amount of valgus incorporated into the distal resection may vary from 3° to 6°. I use a modified measured resection technique using posterior referencing for femoral sizing and rotation. After sizing the femur, I typically choose 3° external rotation as a default position, insert the pins and remove the femoral sizing jig. I use two lamina spreaders to open the flexion space and check to see if the proposed position will create a rectangular flexion space. If I have not created a symmetrical flexion space and I need to add more external rotation, then I do so before attaching the femoral finishing cutting blocks. Approximately 60% of the time, 3° will be accurate, but I may need to make adjustments before committing to the femoral positioning. This can easily be accomplished by simply pulling the lateral pin with the cutting guide in place and rotating it into the appropriate amount of external rotation and repinning the lateral side. Once the bone cuts have been made, flexion and extension spaces can be assessed with the spacer blocks.

I perform the final testing with the trials in place. I want to make sure the knee achieves full extension. As I flex the knee up, I check the flexion space. The blunt Hohmann retractor is approximately 1 mm at the tip and it should slide between the femoral condyle and the tibial articular surface on both sides. I also check the stability in extension and typically like

to see 0.5 mm of opening with a firm varus and valgus stress. If the knee is unbalanced and opens more on one side while remaining tight on the other, then I may consider ligament releases or modification of bone cuts. Occasionally, the knee may remain tight on the medial side and pie-crusting of the medial collateral ligament will help to balance the extension space. If the knee has symmetrical laxity of 1 mm or more, then I simply insert a 1-mm thicker trial and reassess the stability. The combination of surgical steps and implant options provided by the ATTUNE Knee System allows surgeons to balance the soft tissue and control the implant position and fit for each patient.

I have implanted approximately 350 total knees with the ATTUNE Knee System using a combination of fixed bearing and rotating platform implants. When comparing this experience to my previous results with the SIGMA® Knee System (*DePuy Synthes Joint Reconstruction*), my work flow has been similar. I use the same ligament-balancing technique with both; however, I try to place them slightly tighter with the ATTUNE Knee System. I have learned that surgeons can more accurately control the flexion and extension spaces with 1-mm increments in the ATTUNE Knee System as compared with the 2-mm to 2.5-mm insert increments with the SIGMA System.

To compare my outcomes, I reviewed 315 patients who received ATTUNE Implants and 379 patients who received SIGMA Implants, all with comparable age, body mass index, preoperative range of motion, knee scores and function scores. The postoperative AP femoral-tibial alignment (4.2° valgus for the ATTUNE Knee vs. 4.1° valgus for the SIGMA Knee), the posterior tibial slope (85.9° vs. 86°) and the tibial AP position (89.7° vs. 89.65°) were similar for both groups. The average surgical time was comparable between the two groups.

Overall, the two knee systems are similar with regard to work flow options, instrumentation and surgical time. Some notable differences I found were that the ATTUNE Knee System's 1-mm bearing options provide greater flexibility when balancing the knee. The consistent incremental sizing of the ATTUNE Knee System femoral implants was superior and its anatomic trochlea and medialized patellae provide excellent patellofemoral contact and motion with little need for lateral releases.

#### Patient satisfaction

Clinical scores for the patients in the two cohorts were gathered at 6 weeks, 6 months and

1 year post-procedure (Figure 3). At 6 weeks, there was a noticeable difference between patients who received the ATTUNE Knee and patients who received the SIGMA Knee, with the ATTUNE Knee having improved self-reported Knee Society scores (59 vs. 48;  $P < .05$ ). At 6 weeks, many patients reported being able to walk up and down stairs without assistance or a railing, which was a capability that most patients had not previously reported with other implant designs.

At 6 months, there was a larger difference in Knee Society function scores with the ATTUNE Knee System (90.6 vs. 73.2;  $P < .01$ ), and these differences remained at 1 year (94.4 vs. 83.5;  $P < .05$ ). No statistically significant differences were observed for the Knee Society Knee scores; however, a trend toward greater range of motion was seen in the ATTUNE Knee group.

The most significant difference observed was that patients with the ATTUNE Knee Implants recorded higher activity levels and seemed to have more confidence in their knee function. Patients have returned to playing softball, tennis and snow and water skiing without any reported difficulty.

### Conclusion

Overall, in my experience, the ATTUNE Knee System has provided me with better tools and has improved the ease of use when performing TKA. The knee feels smoother and more stable through the flexion arc intraoperatively. Though not statistically different than the SIGMA Knee System, the



**Figure 4:** Six-week radiographs of the ATTUNE Knee System.

Source: Fisher DA

ATTUNE Knee System allows excellent return of early range of motion (Figure 4). At this point, over 2 years after its development, the surgeon design team is experiencing highly favorable results with enhanced patient satisfaction. Advanced systems like the ATTUNE Knee System may ultimately make it easier for surgeons to restore patients' knee mobility with improved stability and achieve higher levels of long-term patient satisfaction.

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*Dr. Fisher is an orthopedic surgeon practicing with the Ortho Indy group and is the director of the Total Joint Center of Excellence at the Indiana Orthopaedic Hospital in Indianapolis. Dr. Fisher receives research support from DePuySynthes Joint Reconstruction.*

# Advanced implant designs improve knee instability

David F. Dalury, MD



David F. Dalury, MD

Instability is a common cause of patient dissatisfaction following total knee arthroplasty (TKA) and is a leading cause of revision surgery. Instances of dislocation of the femur on the tibia are easily diagnosed, but subtle instability that patients experience can be more difficult

to identify and treat. Multiple studies have shown that total knee implants do not restore normal kinematics<sup>1</sup> and, in fact, video fluoroscopic studies of TKAs have documented a paradoxical anterior slide of the femur on the tibia as the knee bends rather than a posterior rollback, which is desirable for better motion and function. Achieving a knee design that both flexes and maintains stability throughout the flexion arc should be a primary aim of advanced TKA designs.

When the ATTUNE® Knee System (*DePuy Synthes Joint Reconstruction*) was being developed, many aspects of knee kinematics were investigated, but a significant amount of time was spent on the femoral-tibial articulation. From the beginning, the design team, made up of orthopedic surgeons, academic and research institutions, and design engineers from *DePuy Synthes Joint Reconstruction*, recognized and sought to address this frequent anterior sliding phenomenon seen in traditional knee replacements. The team postulated that patients could sense this subtle sliding and it could be a contributing factor to a lack of confidence and stability in their knee. This led to the testing of different sagittal curves, as well as the testing of different baseplates, to ensure the femur and insert could match size for size every time and in turn eliminate conformity compromises. By pursuing these enhancements, an ideal system that maintains stability throughout the flexion arc was designed to help improve patient satisfaction.

## Considering single and multiradius sagittal designs

During the development of the ATTUNE Knee, various sagittal curves, including single radius and traditional multiradius designs, were investigated in both cadaveric models, as well as computer simulations. While researching single radius knees, it was observed that, during a certain portion of the knee flexion arc, this concept worked effectively. However, in extension and early flexion, compromises had to be made; the polyethylene surface by necessity had to be made relatively flat and lack conformity. This allowed for paradoxical anterior sliding in early flexion activities, especially with increased load on the knee as seen during stair descent. The designers of the ATTUNE Knee System wanted to avoid having to make this type of compromise.

In addition to a single radius design, a traditional multiradius “J curve” of the femoral component’s sagittal profile was also investigated. These femoral designs, which have been widely used for years, incorporate a large distal radius, which is meant to provide stability in extension, as well as a smaller posterior radius, which is meant to allow for rotation during flexion. However, the transition point from the larger radius to the smaller radius can potentially lead to anterior sliding of the femur as the knee flexes (as identified in video fluoroscopy).

## Improved sagittal geometry

In contrast to both single and multiradius designs, the ATTUNE Knee System incorporates a unique sagittal geometry. Rather than one or two radii in early flexion, the ATTUNE Cruciate Retaining (CR) Femoral Component is designed with a series of multiple gradually decreasing radii between 5° and 65° of knee flexion. These gradual radii are meant to prevent abrupt transitions seen in many other designs. Beyond 65°,

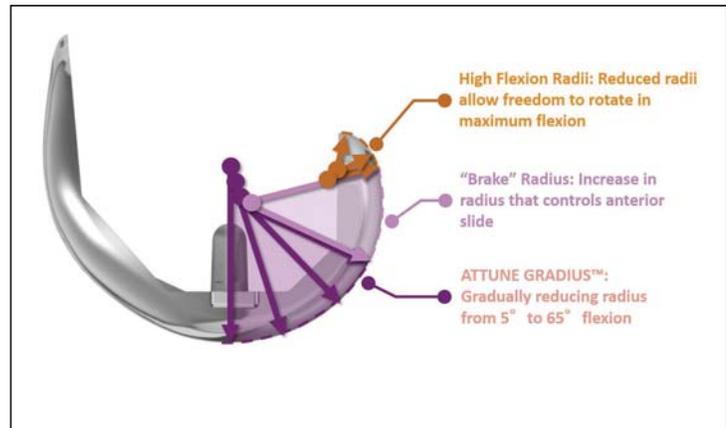
the femoral curve then slightly increases. This increase, in effect, acts as a brake as the knee flexes, leading to increased posterior rollback. Finally, at the most posterior aspect of the femoral component, there is a reduction of the radius to allow rotational freedom and manage tibiofemoral contact pressures in deep flexion (Figure 1).

The ATTUNE Posterior Stabilized (PS) Femoral Component is slightly different (Figure 2). It, too, incorporates a gradually decreasing radius that extends from 5° to 70°. At that point, it transitions to a slightly smaller transition as the cam and post engage. The more posterior aspects of the femoral curve feature further reductions to the radius to allow for better rotational freedom during flexion. In addition to the slight differences between the CR and PS sagittal curves, 1 mm of thickness is added to the posterior condyles of the PS femoral component as a means of addressing the increased flexion laxity seen when the PCL is removed.

These designs of the ATTUNE Knee System were rigorously tested in both cadavers and computer simulators.<sup>2</sup> In traditional multiradius designs, these simulators demonstrated anterior sliding of the femur on the tibia (both medially and laterally) when the femoral changed from a large radius to a small radius. In contrast, the medial condyle on the ATTUNE Knee was stable and the lateral condyle showed consistent rollback as the knee flexed, similar to what is seen in the native knee. This was found to be true for different activities like stair descent, stair ascent and walking.

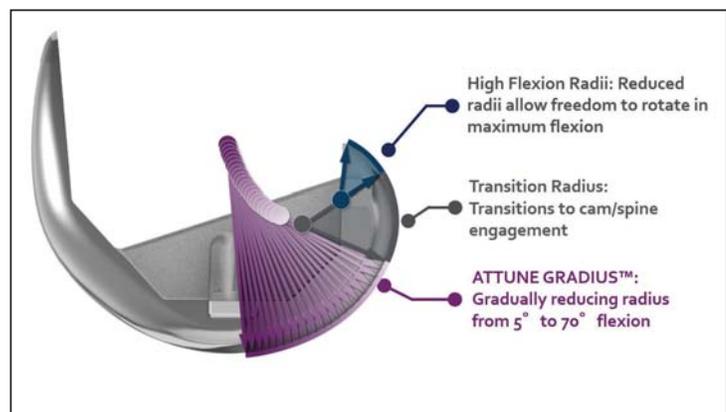
## Conclusion

Collectively, the early computational and cadaveric data have shown that the ATTUNE Knee design is performing differently compared to single and traditional multiradius designs. Robust cadaveric and computational simulator testing demonstrated that the design changes incorporated into the ATTUNE Knee produced a kinematic pattern that has less paradoxical anterior sliding and more consistent rollback with fewer abrupt transitions as the knee bends.<sup>2,3</sup> Overall, testing of this knee design showed that the ATTUNE Knee produced a smoother, more predictable range of motion with better stability throughout the flexion arc compared to other knee designs, which may help improve patient dissatisfaction due to instability.<sup>2,3</sup>



**Figure 1:** An explanation of the sagittal femoral geometry in the cruciate retaining ATTUNE Knee System.

Source: DePuy Synthes Joint Reconstruction



**Figure 2:** An explanation of the sagittal femoral geometry in the posterior stabilized ATTUNE Knee System.

Source: DePuy Synthes Joint Reconstruction

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*Dr. Dalury is a professor of orthopedic surgery at the University of Maryland Medical School and the Chief of Orthopedic Surgery at the University of Maryland, St. Joseph Hospital in Towson, MD. Dr. Dalury receives research support from DePuy Synthes Joint Reconstruction.*

# Implant design and surgical technique affect patellofemoral complications

William P. Barrett, MD



William P. Barrett, MD

Approximately 10% to 20% of patients who undergo total knee arthroplasty (TKA) report undefined anterior knee pain.<sup>1</sup> Most surgeons associate anterior knee pain with complications linked to patellofemoral instability, subluxation, painful patellar clunk and crepitance, or overstuffing

of the patellofemoral joint, which has been associated with increased tension in the retinacular tissue. By addressing complications related to the patellofemoral joint, orthopedic surgeons can improve outcomes in TKA.

## Defining the complication

As with the management of any surgical complication, the key to reducing anterior knee pain associated with TKA is to determine its cause, which, in this case, is the patellofemoral joint.

In 2012, Meftah and colleagues studied the patellofemoral joint and the effect of patellar replacement technique on patellofemoral complications and anterior knee pain.<sup>2</sup> The study included 100 consecutive fixed bearing posterior stabilized TKAs that were performed using the following technique: the articular surface of the lateral facet of the patella was excised to the depth of the subchondral bone, and the medial facet was cut parallel to the anterior surface. Patients were followed for a median of 3.7 years. Although the researchers reported no overt issues related to the patellofemoral joint and no lateral releases, a 3% incidence of patellar crepitus was reported, along with knee pain in 15% of patients and anterior knee pain in 11%. This study underscored the need to further understand the patellofemoral joint and its impact on anterior knee pain.

In North America, the majority of TKAs performed have a varus deformity and the patellofemoral joint is often relatively preserved. Typically, retinacular soft tissue is not inherently tight in these

knees, so the majority of patellofemoral soft tissue problems are related to the surgical technique, the implant design, or both. Therefore, in order to minimize anterior knee pain, surgeons must continue to learn from advances in implant design and surgical technique.

## Implant design

In the past, surgeons typically ignored the patellofemoral joint and made no accommodation for patellofemoral articulation. Some early accommodations were relatively primitive compared to current standards, like the total condylar knee which was designed with a symmetric femoral component. However, in the 1980s and 1990s, contemporary designs were made side-specific, had a variable amount of constraint at the patellofemoral joint and had variable acceptance of the native patella.

With these advanced designs, surgeons began to examine features of the implants and learn from design failures. Surgeons observed that, if implants had a narrow, shallow and short trochlear groove, then complications related to patellar instability often occurred (Figure 1).<sup>3</sup> In addition, excess constraint and a boxy design without a patellar recess led to overstuffing and anterior knee pain (Figure 2).

Within the last 30 years, researchers have noted that approximately 50% of complications associated with TKA were related to the patellofemoral articulation.<sup>4</sup> Beginning at the turn of the century, most major publications that focused on TKA included at least one article or chapter about patellofemoral complications and its corresponding impact on implant design. However, design advancements are only one of several factors that surgeons need to better understand to address anterior knee pain.

## Surgical experiences

In the past few decades, knowledge of the appropriate surgical technique related to the patellofemoral joint has improved. Surgeons have learned that it is necessary to completely expose the patella or view

the entire medial lateral facet to visualize the entire working area during surgery.

Surgeons have learned it is also necessary to measure the thickness of the patella and of the residual bony bed, and to leave a minimum of 12 mm of bony surface. Surgeons can then resect from chondral osseous junction to chondral osseous junction, medially and laterally, and from the quadriceps tendon to the inferior tubercle, superiorly and inferiorly. This technique will facilitate a level patellar cut. Surgical experience has also taught surgeons to avoid internal rotation of the femoral and tibial components, and to medialize the dome to recreate the midline raphe of a native patella.<sup>5,6</sup>

However, despite using this type of technique, surgeons are still faced with issues like subluxation and dislocation, patellar fracture, osteonecrosis, early loosening of the implant, excess polyethylene wear and crepitus and clunk. In addition, pain remains an issue even when the patient does not present with the previously described conditions.

For example, instability is often related to increased shear forces at the patellofemoral articulation, which can lead to excess wear or loosening. Usually, it is not due to tightness of the native retinaculum, but instead due to surgical error, such as implant rotation or position, or thickness of the overall construct. Generally, surgeons can take preventative measures during surgery to reduce the risk for complications related to the patellofemoral joint.

### Patellar, construct thickness

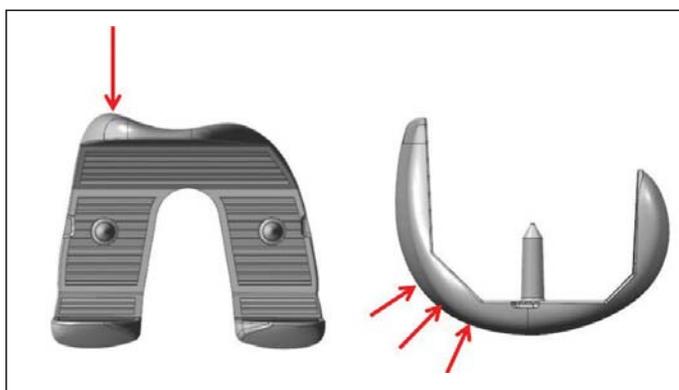
Patellar thickness is also an important factor in patellofemoral joint complications. When the patella is resurfaced, surgeon experience has shown that overstuffing the patella can be associated with increased patellofemoral force, tightening of the retinaculum and a higher incidence of anterior knee pain and loss of motion. On the other hand, excess resection can be problematic and can lead to patella fracture or a significant reduction in the force and mechanical advantage of the quadriceps tendon.

Surgeons have learned that the design of the femoral implant and its corresponding surgical instruments are also critical for restoring construct thickness. A bulky femoral component or improper resection of the anterior cortex can lead to some of the same issues described with patella thickness. Additionally, the femoral component design must also be able to appropriately restore the posterior condylar offset for gap balancing purposes without adversely affecting the patellofemoral joint or overhanging the femur. All of these factors affect the



**Figure 1:** Photos show examples of implants with narrow, shallow or short trochlear grooves.

Source: Barrett WP



**Figure 2:** In earlier joint designs, excess constraint and a boxy design without a patellar recess led to overstuffing and anterior knee pain.

Source: Barrett WP



**Figure 3:** The goal when addressing the patellofemoral joint is to replace resected portions of the joint without resecting too much, as shown in the image on the right.

Source: Barrett WP

patellofemoral articulation and must be taken into account to restore the tissue tension in the retinaculum. The goal then is to replace the same amount of resected bone with metal and polyethylene without notching the femur (Figure 3).

While restoring the patellofemoral joint space is acknowledged as critical, surgeons around the world remain mixed on whether this should be done utilizing a resurfaced or nonresurfaced technique.<sup>7,8</sup>

### Resurfacing the patella

Surgeon preference varies regarding whether to resurface the patella when performing TKA, and multiple studies have been undertaken to determine whether either method is superior. In 2009, Burnett and colleagues examined 118 TKAs that were equally divided between patellar resurfacing and nonresurfacing and followed them for a minimum of 10 years.<sup>1</sup> They found no difference in range of motion, knee scores or revisions between the two groups. However, 50% of patients had knee pain. Anterior knee pain was present in 16% of patients with nonresurfaced patellas and 21% of patients with resurfaced patellas.

In a meta-analysis published in 2012, Pilling and colleagues examined data from 3,465 TKAs equally divided between resurfaced and nonresurfaced procedures.<sup>9</sup> Again, they found no difference in knee scores. Anterior knee pain was present in 13% of patients with resurfaced patellas and 24% of patients with nonresurfaced patellas, but the difference was not statistically significant. However, they found that the complication rate and the reoperation rate for anterior knee pain or patellofemoral complications were significantly higher in the nonresurfaced group.

### Conclusion

As surgeons continue to learn more about implant design and surgical techniques related to TKA, the goal is to minimize anterior knee pain. This can be accomplished with the appropriate selection of patients for TKA and careful consideration of implant design and surgical technique.

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*Dr. Barrett is an orthopedic surgeon specializing in primary and revision hip and knee replacement and is the medical director for the Joint Center at Valley Medical Center in Renton, WA. Dr. Barrett receives research support from DePuy Synthes Joint Reconstruction.*

# New implant design may help address ongoing debates in TKA

Douglas A. Dennis, MD



Douglas A. Dennis, MD

Orthopedic surgeons performing total knee arthroplasty (TKA) typically have the same goal in mind: to provide patients with a knee implant that provides improved mobility and stability. However, debates currently exist within the field about the best tools and methods needed to

achieve that goal. Surgeons often disagree on subjects such as the use of fixed bearing vs. rotating platform implants and employing gap balancing or measured resection surgical techniques. Surgeons generally do not choose one implant design or surgical method exclusively but may have preferences for certain cases.

## Rotating platform vs. fixed bearings

Surgeons have the option to use a rotating platform or fixed bearing implant for primary TKA. In fixed bearing implants, a modular polyethylene insert is securely attached to the metal tibial tray. In rotating platform implants, the polyethylene insert can rotate at the polyethylene bearing-tibial tray interface.

### Rotating platform design

Orthopedic surgeons frequently see patients who have suffered traumatic injuries to their knees at a young age, subsequently requiring multiple operative procedures, and then present for a TKA at age 50 with advanced traumatic arthritis. This type of patient presents different challenges than a patient presenting at 78 years, who would typically be less active. The 50-year-old patient requires 30 to 35 years of function from his or her knee implant, typically at a much higher demand level necessitating TKA devices that promote a proper balance between anteroposterior (AP) stability and internal-external (IE) rotational freedom. Rotating platform knees provide one option to help these patients through more favorable loading conditions on cruciate-substituting posts and better tibial base rotational freedom.



**Figure 1:** A failed primary TKA due to polyethylene wear and extensive periprosthetic osteolysis.

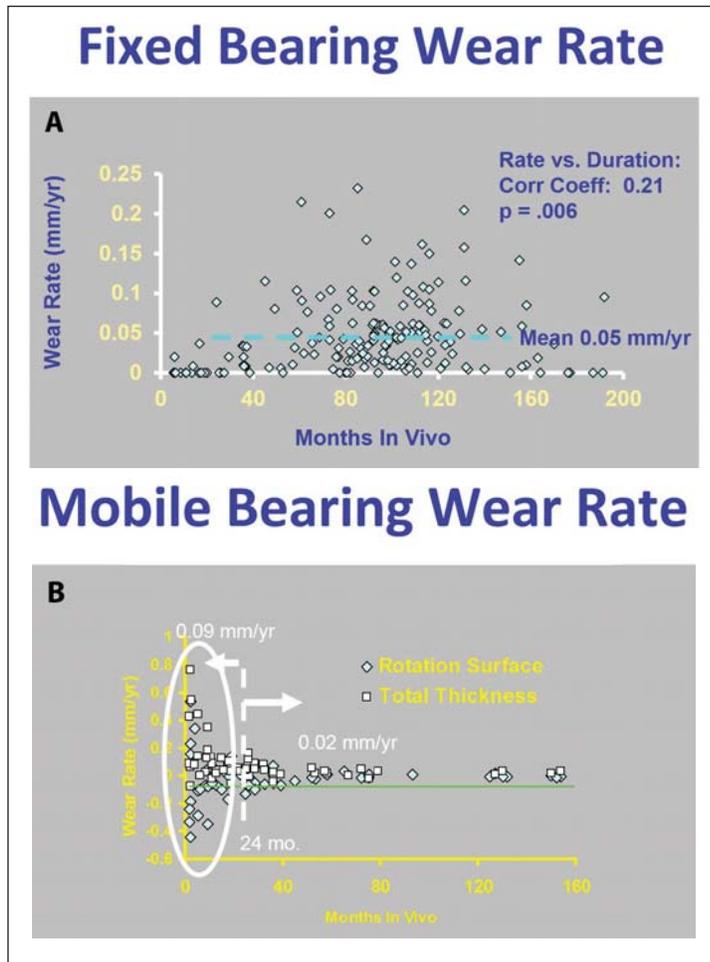
Source: Dennis DA

Rotating platform knees accomplish this through increased conformity and contact area in both the sagittal and coronal planes, while allowing rotational freedom to occur between the articulating surface and the tibial base plate. Due to this increased conformity, a rotating platform can reduce paradoxical anterior femoral sliding. Subsequently, this may help reduce cross shear forces and polyethylene stresses, which have historically led to wear and lysis (Figure 1).

My colleagues and I conducted research on cam-post mechanics in multiple posterior-stabilized TKA designs.<sup>4</sup> This study demonstrated that, if the knee gets any axial rotation, a majority of the contact and subsequent wear is on the posteromedial corner of the stabilizing post. If axial rotation occurs in a rotating platform design, the mobile polyethylene bearing tends to self-center with the femoral component so the cam-post contact is well centralized and eccentric post wear can be avoided. This improvement in cam-post contact and subsequent reduced post stress become even more important as one moves up the constraint continuum in revision knee arthroplasty.

### Fixed bearing design

A fixed bearing knee design can be modular with a polyethylene tibial insert attached to a metal-backed tibial tray or a nonmodular design manufactured exclusively from polyethylene. These designs require slightly less support from the supporting soft



**Figure 2:** (A) The wear rate for a fixed bearing implant. (B) The wear rate for a mobile bearing implant.

Source: Dennis DA

tissues compared with a rotating platform. Historically, wear simulator studies and retrieval analyses of fixed bearing implants have demonstrated increased wear rates as compared with rotating platform implants.

A 2005 study performed by McEwen and colleagues compared wear in both fixed and rotating platform implants under high kinematic conditions (more shear and displacement) mimicking kinematic conditions typically encountered in a younger patient.<sup>1</sup> The study showed that there was nearly a four-fold reduction in wear with the addition of bearing mobility. A retrieval analysis calculated wear rates by taking the backside wear depth and dividing it by the amount of time in vivo. The data demonstrated that wear increased as time passed (Figure 2A).<sup>2</sup> With rotating platform implants, the wear rate was higher in the first 12 to 18 months, but decreased to less than half of that observed in fixed bearing retrievals as time passed (Figure 2B). A recent retrieval analysis of 312 metal-backed tibial components was performed

comparing a rotating platform design vs. two different fixed bearing designs.<sup>3</sup> One of the fixed bearing designs was manufactured with a titanium material with increased surface roughness vs. another material created from cobalt-chromium with a polished surface finish. Results demonstrated higher wear rates in both fixed bearing designs as compared with the rotating platform cohort. The polished cobalt-chromium fixed bearing implant exhibited lower wear rates compared with polyethylene inserts retrieved from the titanium tibial components. Based on this evidence, some companies began polishing their tibial base plate and using cobalt chrome. In addition, new polyethylene materials were made available. These changes allowed for reductions in fixed bearing wear. Due to these improvements, implant loosening and instability have surpassed wear as the primary reason for TKA failure.

#### The ideal fixed bearing tibial component

When designing the ATTUNE® Knee System, improvements that promoted stability and rotational freedom were thoroughly examined. Many different types of locking mechanisms were considered and analyzed. As a result, the ATTUNE Knee Fixed Bearing Tibial Base has a combination of both peripheral-type capture and tongue-in-groove mechanisms. This design now allows the fixed bearing insert to match the femur in every case with the tibial base plate having the ability to upsize or downsize by up to two sizes. This consistent matching helps reduce the kinematic and stability issues seen in other fixed bearing devices. This design also enables a significant reduction in micromotion compared with other modular tibial bases currently available (Figure 3).

#### Gap balancing vs. measured resection techniques

There is also controversy within the field of knee arthroplasty on the use of gap balancing vs. measured resection surgical techniques to determine accurate rotation of the femoral component. Some surgeons believe that TKAs should be performed by measured resection, where bone landmarks such as the transepicondylar, the AP or the posterior condylar axes determine component position. Other surgeons choose to use gap balancing, where the femoral component is placed parallel to the resected tibia with equal collateral ligamentous tension.

My colleagues and I reviewed 212 consecutive TKAs that were performed using computer navigation, which provided the advantage of being able to compare femoral component orientation using a gap balancing vs. a measured resection operative

technique.<sup>6</sup> The chosen computer algorithm positioned the femoral component to achieve rectangular and balanced gaps. The component position was then compared to the femoral component position obtained using either the transepicondylar axis, the AP axis or the posterior condylar axis. We found a rectangular and balanced flexion gap was not frequently obtained with use of any of the measured resection axes. If the transepicondylar axis was used, on average, then the femoral component rotational orientation was within 0.9° of the gap balancing method. However, there was a wide variation in component position with use of this measured resection axis (Figure 4), and a rectangular flexion gap within ± 3°, equating to a 6° range, would have been achieved in only 41.5% of cases. If the AP axis was used, then a rectangular flexion gap would have been obtained in only 39% of the cases. If a fixed amount of external rotation relative to the posterior condylar line had been selected, then a rectangular gap would have been obtained in 58% of cases. These results demonstrate that measured resection techniques using bone landmarks to determine femoral component rotation infrequently resulted in a balanced, rectangular flexion gap as compared with use of a gap balancing methodology.

In an additional study, we compared a series of 60 TKAs, including both posterior cruciate retaining and substituting TKAs done with either measured resection or gap balancing techniques.<sup>7</sup> Stability was assessed by measuring the incidence and magnitude of femoral condylar lift-off. Femoral condylar lift-off greater than 1 mm occurred in 60% and 45% of posterior cruciate retaining and substituting TKAs performed using a measured resection technique and in none of the subjects performed using a gap balancing method ( $P < .0001$ ). In addition to having a higher incidence of lift-off, the TKAs performed using a measured resection approach had greater magnitudes with a mean maximum condylar lift-off greater than 2.5 mm in the two measured resection groups compared with 0.88 mm in the gap balanced cohort ( $P = .0002$ ). In summary, these results demonstrated that gap balancing led to a lower incidence and magnitude of coronal plane instability.

All technical methods of determining femoral component rotation can induce error. Therefore, it is unwise to depend on a single method. The disadvantage of placing the femoral component at a fixed amount of external rotation relative to the posterior condylar axis (typically 3° to 4°) is individual patient anatomic variability. While the average amount of external rotation, or the posterior condylar twist angle,

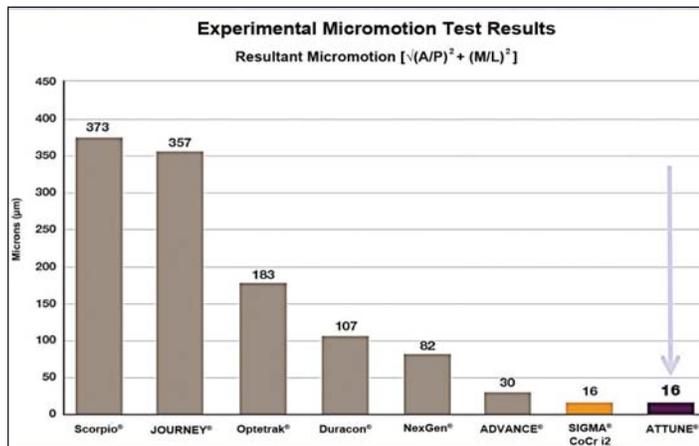


Figure 3: A comparison of micromotion in the ATTUNE Knee System and other implants.

Source: Dennis DA

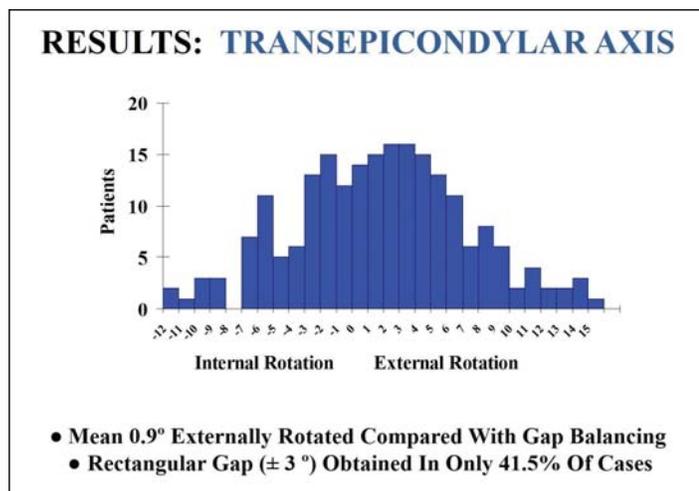


Figure 4: When the transepicondylar axis was used, the mean femoral component rotation was within 0.9° of the position obtained using gap balancing. However, due to wide variations, a rectangular flexion gap was obtained in only 41.5% of cases.

Source: Dennis DA

is 3° to 4°, anatomic studies have shown that the posterior condylar twist angle ranges from 1° to 10°. If the surgeon performs knee arthroplasty on a patient with a posterior condylar twist angle of 7° and selects a cutting angle of 3°, then the femoral component will be internally rotated 4° relative to the transepicondylar axis. The disadvantage of routine use of the AP axis is its absence in revision TKA and difficulty of precise identification in cases with substantial trochlear dysplasia or advanced patellofemoral arthritis. Kinematically, the transepicondylar axis is an effective landmark but can be difficult to accurately locate. Kinzel and colleagues demonstrated in a review of

74 TKAs that surgeons can accurately identify the transepicondylar axis only 75% of the time.<sup>10</sup> Gap balancing is also not a faultless technique; it is dependent on performing the proximal tibial resection accurately. If the surgeon places the AP cutting block parallel to the resected tibia and has cut the tibia in a varus orientation, then the femoral component will be placed in internal rotation. Conversely, if the tibia has been resected with a valgus error, then the femoral component will be positioned in excessive external rotation. Gap balancing is also dependent of ligamentous integrity on the medial (superficial medial collateral ligament) and lateral (lateral collateral ligament and popliteus) flexion gap stabilizers.

#### The ideal system

As previously stated, it is wise to use all techniques to obtain gap balance and stability. Based on the data presented above, I primarily gap balance by placing the AP cutting block parallel to the resected tibia with the flexion gap tensioned using two lamina spreaders. I then secondarily check the orientation of the AP cutting block relative to the transepicondylar and AP axes before performing the anterior and posterior femoral resections. The ideal system provides multiple instrumentation options that allow surgeons to perform TKA with their preferred method, which is a feature of the ATTUNE Knee System.

In addition to instruments that provide surgeons with multiple technical options, obtaining symmetric gap balance and good stability throughout the flexion range can be enhanced by providing more prosthetic size options, including more femoral component sizes, the availability of modular tibial inserts in 1-mm incremental thicknesses and the ability to fine-tune balance through precise adjustments of cutting instruments. Historically, many implant systems have provided femoral components that vary in AP diameter by 4 mm to 5 mm from size to size. A system with more sizes and a fixed 3 mm AP dimensional difference from size to size eases the difficulty of obtaining gap balance. Having tibial inserts with 1-mm incremental thickness and the ability to adjust the AP femoral cutting block in 1.5-mm increments allows more precise fine-tuning of ideal gap balance. These features have been incorporated into the ATTUNE Knee System.

#### Conclusion

Research has shown that there are several advantages and disadvantages for rotating platform and fixed bearing implants, as well as with measured resection vs. gap balancing techniques. Based on 6 years of extensive study and development, the goal of the ATTUNE Knee System was to provide improved implant options and feature an instrumentation system with multiple options to allow surgeons to select and perform their preferred technique in a precise manner.

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*Dr. Dennis is an adjunct professor in the Department of Biomedical Engineering at the University of Tennessee, an adjunct professor of bioengineering at the University of Denver and an assistant clinical professor in the Department of Orthopedics at the University of Colorado School of Medicine. Dr. Dennis receives research support from DePuy Synthes Joint Reconstruction.*

# Early outcome study on the ATTUNE® Knee System

Mark Clatworthy, MD

The ATTUNE® Knee System (*DePuy Synthes Joint Reconstruction*) incorporates several design improvements, including an improved trochlea geometry, a medialized dome patella and a medialized anatomic patella, an increase in the range of sizes and polyethylene inserts in 1-mm thickness increments. This design has allowed surgeons to experience improved early function and motion. However, there has been no clinical evidence to support these claims. Therefore, I initiated an early outcome study to measure the range of motion (ROM), functionality, pain and discharge time with the ATTUNE Knee System.

## Early outcome study

This early outcome study focused on a group of patients who received an ATTUNE Cruciate Retaining (CR) Rotating Platform (RP) Knee vs. a group of patients who received a PFC® SIGMA® Cruciate Retaining (CR) 150 Rotating Platform (RP) Knee (*DePuy Synthes Joint Reconstruction*).

Study design:

- 40 patients in each group
- Prospective study
- In-hospital data collection by physiotherapists (blinded data collection)
- ROM measured at 2 and 6 weeks (non-blinded data collection)

In our findings, 85% of the patients who received the PFC SIGMA CR 150 Knee achieved 90° flexion at discharge compared with 100% of the patients who received the ATTUNE Knee. There was also a statistically significant difference between the two implants regarding flexion at 2 and 6 weeks (Table 1).

I also measured various functional factors, such as the number of days to independence, straight leg raise (SLR), use of the exercycle, completion of a lap around the ward, ability to go up and down stairs and use of crutches (Table 2). The ATTUNE Knee showed improvement in each of these parameters. There was a statistically significant difference between the two systems regarding the number of days to crutches (2.3 days vs. 2.6 days), trending.

I also observed pain, functional score and discharge time in the two groups. The most statistically significant difference observed was the functional score (Table 3), where the ATTUNE Knee group scored 6.6 and the SIGMA Knee group scored 5.3.

## Conclusion

Overall, the ATTUNE Knee System showed significant improvement over the PFC SIGMA Knee System in each of the assessments. In particular, the ROM of the ATTUNE Knee was significantly better at 2 and 6 weeks. Patients who received the ATTUNE Knee were discharged earlier and, upon discharge, experienced less pain, had a better visual analogue scale functional score and were able to use crutches earlier than patients who received the PFC SIGMA Knee. All other parameters that were measured also showed that the

ATTUNE Knee System tested better than the SIGMA Knee System. This early outcome study data support anecdotal surgeon feedback that the ATTUNE Knee System has overall improved function and mobility.

*Dr. Clatworthy is an orthopedic knee specialist at Middlemore Hospital in Auckland, New Zealand. He is an early evaluator of the ATTUNE® Knee System. There was no research support for the study described herein and Dr. Clatworthy does not receive implant royalties.*

**Table 1. ROM Results**

	ATTUNE KNEE CR RP N=40	PCF SIGMA KNEE CR 150 RP N=40	Significance
Discharge flexion	101.4°	98.6°	P>0.05, not significant (NS)
Discharge ROM	100.4°	96.4°	P>0.05, NS
2-week flexion	113.0°	106.1°	P<0.001
6-week flexion	121.1°	115.0°	P=0.002
Days to 90°	2.1	1.9	P>0.05, NS
Unable to get 90° at discharge	0/40 knees	6/40 knees	P=0.026, trending

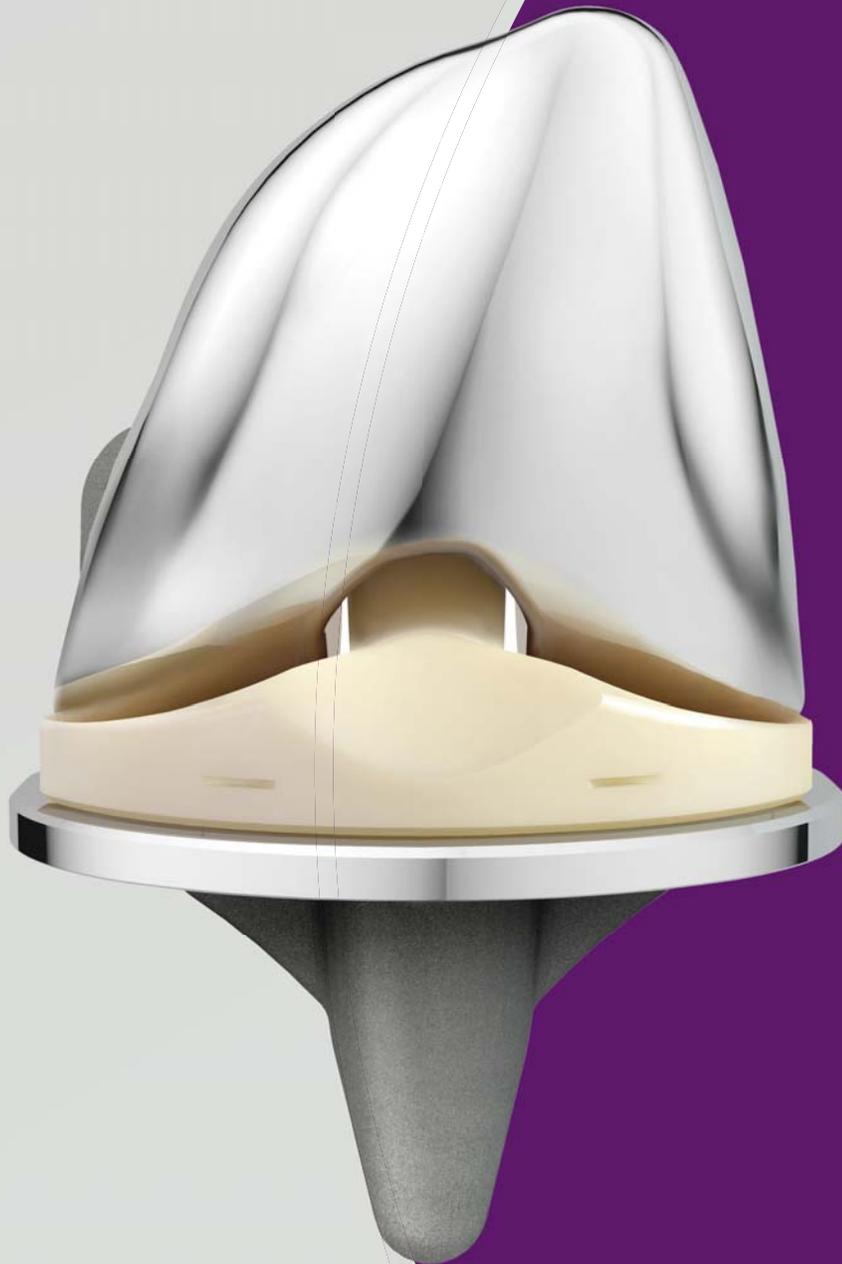
**Table 2. SLR, Exercycle, Crutches and Stairs**

	ATTUNE KNEE CR RP N=40	PCF SIGMA KNEE CR 150 RP N=40	Significance
Days to independence	2.4	2.4	P>0.05, NS
Days to SLR	1.8	2.0	P>0.05, NS
Unable to SLR at discharge	2/40 knees	3/40 knees	P>0.05, NS
Days to exercycle	3.3	3.1	P>0.05, NS
Unable to exercycle at discharge	2/40 knees	6/40 knees	P>0.05, NS
Days to lap ward	2.4	2.5	P>0.05, NS
Days to do stairs	2.9	3.0	P>0.05, NS
Days to crutches	2.3	2.6	P=0.018, trending

**Table 3. Pain, Functional Score and Discharge Time**

	ATTUNE KNEE CR RP N=40	PCF SIGMA KNEE CR RP N=40	Significance
Discharge pain at rest	0.4	0.8	P= 0.048, trending
Discharge pain with exercise	3.9	4.5	P>0.05, NS
Functional Score SF 1	6.6	5.3	P<0.001
Discharge days	4.3	4.5	P>0.05, NS
Days to reach criteria for discharge	3.3	3.6	P=0.048, trending

Source: Clatworthy M



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