Treatment of Osteoarthritis of the Middle-aged Athlete

Brian P. McKeon, MD and Jason D. Rand, PA-C

Abstract: Unicompartmental knee arthroplasty (UKA) has increasingly become an attractive alternative to total knee arthroplasty for early intervention. Clinical and biomechanical studies have shown that UKA offers advantages in early recovery, more natural function, and patient satisfaction. The literature has also shown that UKA exhibits a higher rate of revision than total knee arthroplasty, particularly in registry studies that include patients from outside of high-volume specialty centers. Patient-specific UKA offers the potential to close the gap between the known advantages of a partial knee solution and the documented risk of early revision. On the basis of the patient's own imaging data, patient-specific UKA allows for an anatomically matched implant design that provides personalized fit, full coverage of the tibial cortical rim, and preserves the femoral articulating geometry. These design advantages are paired with a patient-specific instrument system that provides reliable component placement and simplified balancing.

Key Words: unicompartmental knee arthroplasty, partial knee replacement, patient-specific knee replacement, patient-specific instruments, Confor MIS

The treatment of osteoarthritis (OA) in young and active patients has always been challenging. Despite best efforts with less invasive approaches such as bracing, viscosupplementation, and arthroscopic techniques that may help defer the onset of more debilitating symptoms, many patients eventually progress to needing a surgical solution. Unicompartmental knee arthroplasty (UKA) has become a increasingly popular choice for early intervention in the last 2 decades. In a 2008 study measuring the incidence of UKA in the United States over an 8-year period, Riddle et al1 reported that the incidence rate of partial knee replacement grew at 32.5%, 3 times the rate of total knee arthroplasty (TKA).

The growth in UKA procedures has been supported by a growing body of literature showing that a UKA, when performed well in appropriately selected patients, can offer the promise of a less invasive, long-lasting procedure with more natural kinematics and higher patient satisfaction. One recently published study involving 2235 primary TKAs and 605 UKAs performed at 3 institutions showed that UKAs had a significantly lower rate of postoperative complication, shorter length of hospitalization, and a higher percentage of patients discharged to rehabilitation facilities.2 Other studies also confirmed that UKA patients recover faster than TKA patients.3,4

Studies comparing UKA and TKA kinematics have shown that UKA patients report better range of motion and function5 and had fewer problems with activities that involved bending the knee.6 In patient preference studies involving patients with a unicompartmental implant in 1 knee and total knee implant in the other, patients have reported better early flexion, higher range of motion, and a more natural feel with their unicompartmental implant.7 Laurencin et al7 reported that of 23 patients who had a UKA in 1 knee and a TKA in the other, 44% stated that their UKA was the better knee, whereas only 12% chose their TKA knee as better. Dalury et al8 reported that of 12 of 23 patients in his series preferred UKA to TKA, whereas no one preferred TKA.

Revision rates reported for UKA have been more varied. In studies performed at high-volume centers by experienced surgeons, the clinical results of UKA appear durable and long lasting. Ten-year survivorship studies have approached 98% in single-center studies for both fixed-bearing and mobile-bearing systems. In the only published study of its kind, 1 center in the UK randomized unicompartmental OA patients into UKA and TKA arms and tracked them at 5, 8, 10, 12, and 15 years. The analysis showed that the results for UKA are as good as those for
TKA and show no greater tendency to fail at 15 years. In contrast, all comor registry studies have shown a survival rate for UKA that falls closer to 85% to 95% at 10 years. These results trail the survivorship of TKA by approximately 5%. The challenge of contemporary partial knee systems is to preserve the clinical and functional advantages of UKA while addressing the patient selection, design, and technique challenges that lead to less reproducible results.

**PATIENT SELECTION**

Patient selection for UKA is critical to success. The classic indication for UKA was established by Kozin and Scott in 1989. The indication included localized OA with minimal erosive changes in the opposite compartment, noninflammatory OA, mechanical axis deformity of < 15 degrees, intact ACL (anterior cruciate ligament) without medial to lateral subluxation, a preoperative arc of flexion of > 90 degrees, and flexion contracture of < 5 degrees. On the basis of the experience and data available at the time, the indication also guided patient selection toward those over 60 years of age, < 82 kg (181 pounds), with low-activity demands, and minimal erosive changes in the patellofemoral articulation. In 1 study, the indication narrowed the potential population to approximately 6% of patients, even though 15% of those in the study qualified based on unicompartmental OA pattern alone.

Improvements in implant design, surgical technique, instrumentation, and an improved understanding of the requirements of a UKA versus TKA have led to an expansion of the indication in contemporary practice. UKA can now be considered an attractive procedure for those under age 60 as well as a beneficial alternative to TKA for those over 70 due to the less invasive surgery. Other contraindications such as weight, patellofemoral disease, and anterior pain have also been shown to be poor predictors of early failure in UKA. Although many of these indication expanding studies were performed using mobile-bearing designs, studies comparing the outcomes of mobile-bearing to fixed-bearing systems have consistently shown less difference in clinical outcomes between these design approaches. Finally, UKA has also been shown to be a viable option for lateral compartment disease and in ACL ruptured knees when combined with an ACL repair.

Although patient selection remains an important contributor to success in UKA, the cumulative experience...
and published clinical results over the last 2 decades have greatly expanded the patient selection criteria for UKA.

PATIENT-SPECIFIC UKA

One of the newest advancements in knee replacement is the advent of patient-specific, imaging-based approaches to implant design and instrumentation. This section describes my experience with the iUni G2 (Confor MIS Inc., Burlington, MA), an Food and Drug Administration-cleared system that combines a customized unicompartmental knee implant with disposable, patient-specific instrumentation for use in medial or lateral UKA.

The iUni G2 is a cemented fixed-bearing system with a resurfacing femoral component and a modular metal-backed tibia. On the basis of the patient’s own imaging data, the manufacturer uses mass customization technology to design and manufacture an implant that is shaped and sized to fit that patient. The same imaging data are used to create a set of disposable, patient-specific surgical instrumentation. The entire system, including all implant components and instruments are delivered as a single-use package a few days before surgery.

Image to Implant Process

A candidate for a patient-specific unicompartmental knee replacement is sent for a diagnostic computed tomography scan. The imaging study is conducted according to a protocol that requires full capture of the knee and partial views of the femoral head and talus. The imaging center uploads the imaging study to a secure web server, from which they are imported into proprietary image processing and design software. Automated design software generates a virtual 3-dimensional model of the knee, from which the patient-specific implants and instruments can be designed (Fig. 1).
The patient’s condylar dimensions determine the size and shape of the femoral component, so that the fit is precise and matched to the patient. Unlike many systems where the component is straight and symmetrical, requiring positioning compromises to cover the anatomy, the iUni G2 follows the anatomic curvatures and dimensions to resurface the entire medial or lateral condyle (Fig. 2).

The sagittal curve follows the patient’s natural articulating geometry, corrected for deformities. The implant undersurface mirrors the topography of the subchondral bone, allowing the femoral component to fully resurface the condyle after residual cartilage is removed. At approximately 3.0 to 3.5 mm thickness, the femoral component approximates the thickness of healthy cartilage, restoring the patient’s natural articulating surface. A minimal posterior bone cut is incorporated into the design to facilitate implant placement on the patient’s posterior condyle.

The profile of the metal-backed tibial component is also derived from the patient’s anatomy, so that it can cover the entire resected tibial surface without overhang or undercoverage. Because the implant dimensions are individualized for a particular patient, it provides complete tibial coverage, a result that cannot be achieved with off-the-shelf implants. The insert is highly finished for low backside wear and designed with an interference fit resulting in extremely low micromotion. Fully assembled, the tibial components are 8 or 10 mm in total thickness, including both the metal-backed tray and polyinsert (Fig. 3).

Once the implant design is complete, the manufacturer designs a set of disposable, patient-specific instruments and cutting jigs. The instruments are designed to fit the patient

![Balancer chip in position.](image)

**FIGURE 9.** Balancer chip in position.

![Flexion/extension gap trialing.](image)

**FIGURE 11.** Flexion/extension gap trialing.

![Sagittal (A) and axial (B) tibial resections.](image)

**FIGURE 10.** Sagittal (A) and axial (B) tibial resections.
precisely at only 1 location and in 1 orientation, enabling
tactile and visual feedback to drive efficient placement
of the guides. The cut planes and drill holes are prenavigated
to the anatomy and matched to the equivalent features on
the patient-specific implant, reducing the number of steps
required for intraoperative sizing and positioning.

The entire system, including all instrumentation, is
delivered in a small, lightweight kit. All items in the kit
come presterilized, requiring no additional processing or
sterilization before coming into the operating room. All
instrumentation can fit on 1 tray and are either implanted
or disposed of after the surgery, creating highly efficient
operating room turnover (Fig. 4).

**Advantages of Patient-specific UKA**

Patient-specific UKA is relatively new and will need
long-term clinical results for full evaluation. But there are
several distinct advantages that are already apparent re-
tative to other contemporary UKA systems.

First, customized implants based on the patients’
anatomy provide unparalleled fit and a more anatomic
shape. Studies have shown that tibial component overhang
of just 3 mm can result in long-term painful outcomes,
whereas undercoverage raises concerns about tibial sub-
sidence.29 Issues of fit can be particularly problematic in
certain subpopulations30 and in the lateral compartment.31
Patient-specific UKA provides highly conforming designs
that can be personalized for each patient to allow maximum
coverage without overhang.

![FIGURE 12. Final preparation of the femur. A, Creation of anterior recess. B, Drilling holes through cortical bone for cementation.](image1)

![FIGURE 13. Final preparation of the tibia.](image2)

![FIGURE 14. Components cemented with trial poly.](image3)
Second, customized implants and jigs allow for simplified ligament balancing. The author’s experience has been that maintaining the patients’ natural sagittal curve allows for consistent balancing through the range of motion. Most standard implants require separate balancing in extension and flexion, with the potential for some mid-flexion instability depending on the fit between component geometry and the patient’s native articulating surface. A patient-derived implant shape and preservation of the patient’s natural posterior slope allows for simplified balancing.

Third, the iUni G2 combines a patient-specific jig system with a fixed-bearing design that enables a simplified, precise surgical technique. One published evaluation study showed reproducible implant positioning and alignment accuracy that is comparable to published results for robotic-assisted unicompartmental knee replacement. These results were achieved without the capital expense of a robotics system that approaches $1M in cost and the potentially longer surgical times required for a robotically assisted technique. In addition, the fixed-bearing design enables a less demanding surgical technique with lower potential for bearing dislocation than mobile-bearing systems.

Fourth, the disposable, patient-specific jig system enables a very efficient operating room process. All system-required instruments are provided as disposables in the delivery package, presterilized, and ready to go into the operating room (OR). There are no reusable instrument trays that require processing by central supply, and everything in the kit is either implanted in the patient or disposable. This not only saves the hospital in direct labor and management costs associated with instrument handling and sterilization, but also enables faster OR turnover.

**SURGICAL TECHNIQUE**

The surgical technique for a patient-specific UKA system consists of 5 steps. With the prenavigated jigs and customized implants, certain traditional steps such as intramedullary rod placement to establish alignment and sizing trials are eliminated altogether.

1. **Femoral preparation and resection.**
2. **Balancing the knee.**
3. **Performing tibial resections.**
4. **Trialing and final preparation.**
5. **Cementing implants.**

**Step 1: Femoral Preparation and Resection**

After intravenous antibiotics and a single-shot femoral nerve block, the patient is placed under general anesthesia and positioned supine on the table with the leg resting on a foot support at approximately 90-degree flexion. After a short midline skin incision a medial arthrotomy is performed (for a lateral case, perform a lateral arthrotomy). The medial (or lateral) sleeve is not released, but all femoral and tibial osteophytes, including those in the intercondylar notch are removed.

A patient-specific femoral cutting block, shaped to fit the condyle and representing the size and geometry of the femoral implant, is placed on the condyle with its anterior edge seating about 2 to 3 mm inferior to the Sulcus terminalis (Fig. 5).

The anterior margin of the femoral cutting block is outlined to provide a reference point for removal of cartilage. Cartilage removal is necessary as the implant is designed to fit the subchondral bone surface—any cartilage posterior to the Sulcus terminalis not already worn away must be removed to obtain precise fit. Cartilage removal is completed using a ring-curette (Fig. 6).

Once removal of all residual cartilage on the femur has been completed, replace the femoral cutting block on the femur and verify its position. The femoral cutting block is designed with patient-specific flanges on the medial and lateral sides to conform to the femur in only 1 location and facilitate proper positioning. In addition, a supplementary patient-specific guide and target resection values are provided to assist with confirming final anterior-posterior positioning. Once final position is obtained, the femoral cutting block is drilled and pinned into place. The posterior femoral condyle resection can then be performed with an oscillating saw using a cut guide surface as a reference for the saw blade (Fig. 7).

**Step 2: Balancing the Knee**

Once femoral preparation is complete, the meniscus is resected and the tibial plateau surface is cleared of any remaining cartilage and osteophytes. Once the tibial plateau is cleared, soft-tissue balancing is performed to set the desired ligament tensioning and degree of joint play using patient-specific navigation jigs, also referred to as “balancer chips” (Fig. 8).
These balancer chips are provided with varying thicknesses in 1 mm increments and provide confirmation, before any bone resections are performed, of what the balancing will be once the implants are placed. Each chip has an underside that matches the exact shape and topography of the patient’s tibial surface. When inserted into the compartment, the chip will self-seat into a stable position because of its conformity with the anatomic landmarks (Fig. 9).

Balancer chips are inserted in turn, from thinnest to thickest, with the knee in extension and then brought into slight flexion to check balancing. The balancer chip providing optimal ligament tensioning is then selected. An opening under valgus stress of about 1 to 2 mm is recommended for the medial compartment and 2 to 3 mm for the lateral compartment. Successful UKA is dependent on this important step. Restoring proper ligament tension is the key to proper alignment and restoring native kinematics.

**Step 3: Performing Tibial Resections**

Once optimal knee tensioning is set, the balancer chip is left in position and a patient-specific tibial cutting block is attached with the knee placed in extension. This tibial cutting block is seated flush against the anterior of the tibia to provide a precise fit. All 3 planes of the tibial cut including the horizontal cut, sagittal cut, and the posterior slope are determined in this step. An alignment rod is provided to confirm alignment with the tibial eminence and verify proper position. The tibial cutting block is then drilled and pinned into position and the tibial resections are ready to be performed (Fig. 10).

**Step 4: Trialing and Final Preparation**

A femoral trial component and balancing block are utilized to assess balancing. With the femoral trial in place, a 8-mm spacer block representing the thickness of the tibial construct is inserted to evaluate the balance (Fig. 11).

If the knee is too tight, a provided recut guide can be attached using the original tibial fixation holes to resect an additional 2 mm from the tibia. If the knee is too loose, a 10-mm spacer block that corresponds to a provided 8-mm tibial poly can be inserted to evaluate balance in flexion and extension. Once the optimal flexion/extension gap is confirmed, final preparation of the femur and tibia can be performed.
To complete final preparation of the femur, an anterior recess is created using a 5-mm burr. The most anterior edge of the component submerges 3 to 4 mm below the subchondral bone plate with a taper beginning approximately 8 mm inferior to the intact cartilage. This ensures a smooth taper at the implant/cartilage transition zone. In addition, a series of interdigitation holes are drilled on the cortical surface of the femoral condyle with a perforator drill bit for cement fixation (Fig. 12).

Final preparation of the tibia is performed using a patient-specific tibial template jig. The tibial implant is designed to match the patient anatomy exactly and should cover the entire tibia cortex without overhang or under-coverage. The outline of the tibial template is based on the anatomy and provides visual confirmation of the match. Position of the peg holes and keel holes are preset by the tibial template jig and created with provided drill bits and keel punch (Fig. 13).

**Step 5: Cementing Implants**

The tibial tray is cemented first, then the femoral component, taking care to remove all excess cement. An impactor kit is provided with the system to facilitate this step. Once both the tibial and femoral components are in place, the knee can be brought to 45 degrees and a patient-specific trial representing the thickness of the tibial poly can be inserted to allow equal pressurization of the femoral component while cement is setting (Fig. 14).

The trial insert can then be removed and the real polyethylene component inserted (Figs. 15, 16).

**After Care/Rehabilitation**

After sterile dressing is placed a knee immobilizer is applied to the extremity. The patient is admitted for pain control and intravenous antibiotics for 24 hours. Unless there is a predisposition for deep venous clotting, patients are given 2 adult aspirin a day for 6 weeks. Typically, the nerve block will wear off the following morning and the patient gains protective quadriceps function to allow for full weight bearing with walker or crutch assistance. The knee immobilizer is optional and continuous passive motion is initiated for up to 6 h/d. On postoperative day 1, the majority of patients are discharged to home after their afternoon hospital physical therapy training session. The author sends the patients home with a continuous passive motion (2 wk) with visiting nurse and physical therapy home sessions.

Unrestricted weight bearing and motion are permitted on postoperative day 1. Quadriceps sets and straight leg raises are initiated and patients are instructed to be as aggressive as tolerated. A wound check at 2 weeks is performed and most patients are instructed to begin outpatient therapy. Patients can drive a car when comfortable and off narcotics. Recumbent or upright stationary cycling with progression to elliptical trainer over the next several weeks is observed. At 4 weeks, the author allows pool therapy. By 12 weeks, the majority of patients are fully ambulatory and well into a strengthening phase. With the exception of impact all activities are permitted. Patients can expect continued improvement up until even 2 years postsurgery in the author’s experience. Radiographs are recommended at 1-, 3-, 5-, and 10-year intervals.

**CONCLUSIONS**

Advances in imaging, 3D design software, and digital manufacturing methods have enabled the cost-effective creation of anatomic, patient-specific resurfacing implants, and single-use instrumentation. Patient-specific UKA allows for a degree of precision in shape and fit that can lead to a bone preserving resurfacing design on the femur and enhanced cortical bone support on the tibia. In addition to the implants, personalized instrumentation simplifies surgical technique, providing image-based placement of all cuts and implant components without the need for navigation systems or robotics. This novel approach to orthopedic implant design and system delivery creates opportunities for great efficiency in the OR and cost reduction in central supply.

**REFERENCES**


