A Review Paper

Indications for Unicompartmental Knee Arthroplasty and Rationale for Robotic Arm–Assisted Technology

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Abstract

Unicompartmental knee arthroplasty (UKA) is an effective surgical treatment for focal arthritis when appropriate selection criteria are followed. Although results can be optimized with careful patient selection and use of a sound implant design, two of the most important determinants of UKA performance and durability are how well the bone is prepared and components aligned. Study results have shown that component malalignment by as little as 2° may predispose to implant failure after UKA. Conventional cutting guides have been relatively inaccurate in determining alignment and preparing the bone surfaces for unicompartmental implants. Computer navigation has improved component alignment to an extent, but outliers still exist.

The introduction of robotics capitalizes on the virtues of computer navigation but couples the planning and mapping of navigation with robotic techniques for bone preparation. Robotic technology is fostering substantially improved precision and component alignment in UKA, even when using minimally invasive soft-tissue approaches.

Using a procedure in clinical practice has several prerequisites—an understanding of its appropriate application and alternative therapies, adequate training, familiarization with contemporary results using contemporary implants, and, eventually, critical analysis of one's experience with the treatment method to make sure that its results warrant its use. The history of unicompartmental knee arthroplasty (UKA) is certainly a reflection of that kind of analysis. Twenty-five to 30 years ago, some physicians dismissed UKA out of hand because of limited personal success with particular designs.[1,2] However, several physicians continued to pursue well-designed UKAs and to refine the indications for their use, ultimately achieving results not dissimilar from those of total knee arthroplasty (TKA), leading to a gradual change in attitude toward UKA. As long-term data become available, UKA is being more universally embraced as a clear and definable treatment option for unicompartmental arthritis.

Superb clinical data and desirable kinematic performance support the role of UKA. Berger and colleagues[3] found that the implant survival rate for 62 consecutive UKAs performed by a skilled surgeon with a design still in use today was 98% after 10 years and 96% after 13 years, using revision and radiographic loosening as the respective endpoints. Emerson and Higgins,[4] reporting their personal experience with 55 mobile-bearing UKAs, noted a 90% rate of 10-year implant survival with progression of lateral compartment arthritis as the endpoint and 96% with component loosening as the endpoint. Price and colleagues[5] reported 10-year all-cause implant survival with a mobile-bearing medial UKA of 91% in patients younger than 60 and 96% in patients 60 or older. However, these results have not all been replicated, even by skilled surgeons with reasonable implants.[6,7] The data highlight the importance of good surgical technique, appropriate patient selection, and use of a soundly designed implant to achieve satisfactory results after UKA.

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Expanding Role of Unicompartmental Knee Arthroplasty

There are practical reasons for the resurging interest in UKA and growing intrigue with robotic assistance for an increasing number of patients with isolated medial or lateral compartment arthritis. UKA preserves the articular cartilage, bone, and menisci in the unaffected compartments, as well as the cruciate ligaments, thus preserving proprioception and more normal kinematics in the knee than TKA does. Knees treated with UKA feel more normal than those treated with TKA.[8] For some patients, it is a bridging procedure before TKA becomes necessary; for others, it is the definitive procedure that will last their lifetimes.

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Patients who may be candidates for knee arthroplasty are often reluctant to undergo TKA because they fear a painful and lengthy recovery.[9] As such, the great potential for knee arthroplasty to relieve pain and improve quality of life often goes unrealized. In some geographic regions, no more than 15% of patients with advanced hip or knee arthritis are willing to undergo total joint arthroplasty (TJA).[10] In an unpublished study conducted at Duke University, only 8% of men and 12% of women whose physicians had recommended total hip arthroplasty or TKA for advanced arthritis elected to undergo the procedure. Typically, a patient's reluctance to consider TJA is related to misperceptions about and overestimation of the pain and disability needed to warrant TJA. The procedure is more likely to be chosen by patients who perceive their arthritis severity to be worse, who consider TJA an appropriate option for moderate arthritis, and who are willing to accept the risk for eventual revision arthroplasty.[11] The other patients declined surgery because of fear of pain or worsened mobility, misperceptions about the challenges in the rehabilitation process, and lack of a full understanding of the potential benefits of TJA. Additional education regarding the merits of UKA can be an effective tool in increasing the number of patients who undergo UKA, which may benefit a larger segment of the population with knee arthritis. This notion is particularly germane when considering the staggering growth in the portion of the population with progressive arthritis of the knee. Kurtz and colleagues[12] projected an increase in demand for primary TKA of 673% during the next 25 years, estimating an annual volume of 3.48 million primary TKAs in the United States by 2030.

Estimates vary regarding the penetration of the market share by UKA in the United States, but a conservative estimate is that 8% to 10% of knee arthroplasties performed are UKAs.[13] The range may be as high as 11% to 15% in other countries.[14,15] The potential for growth in the UKA market is large given the growing number of patients with progressive but isolated unicompartmental arthritis (10%-25% of patients with painful knee arthritis[16,17]) and the percentage of patients who undergo TKA but may be candidates for UKA. In the United States between 1998 and 2005, UKA use increased by a mean of 32.5%, whereas TKA use increased by a mean of only 9.4%.[13] In addition, as UKA precision improves, techniques become more refined, and traditional barriers are broken down—as patients and the medical community become better informed regarding the potential for improvement with diminished postoperative pain with robotic assistance—the growth of robotically assisted UKA may increase rapidly.

General Indications and Contraindications for Unicompartmental Knee Arthroplasty

The classic indications and contraindications for UKA[18] are equally appropriate when considering use of robotic arm technology, though expanding indications for UKA, in general, continue to be evaluated.[19-21] The classic recommendations are attributed to Kozinn and Scott,[18] who advocated restricting UKA to low-demand patients who are older than 60 and have unicompartmental osteoarthritis or focal osteonecrosis (Figure 1). They also recommended weight less than 82 kg (181 pounds), minimum 90° flexion arc and flexion contracture of less than 5°, angular deformity not exceeding 10° of varus or 15° of valgus (both of which should be correctable to neutral passively after removal of osteophytes), intact anterior cruciate ligament (ACL), and no pain or exposed bone in the patellofemoral or opposite tibiofemoral compartment.

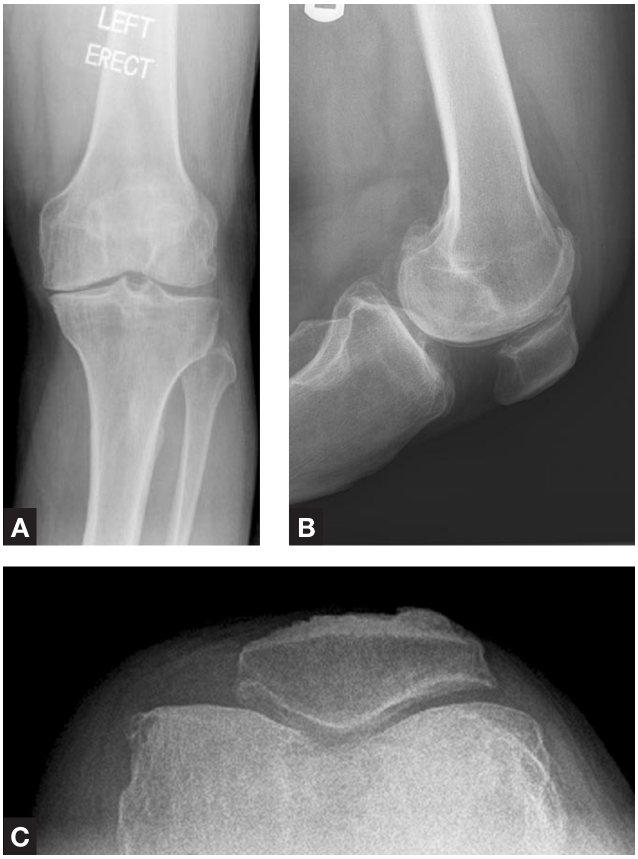

Figure 1. Standing anteroposterior (A), lateral (B), and sunrise (C) radiographs show arthritis localized to medial compartment of knee. Small patellar osteophytes are present, but articular cartilage is intact, and patient had no patellofemoral pain before surgery.

More recently, the indications for UKA have expanded to include younger and more active patients, without substantial compromise in outcomes or implant survival,[19-21] making UKA a legitimate alternative to periarticular osteotomy or TKA in younger patients. Obese patients have been shown to have compromised outcomes, though UKA is a reasonable option for patients who are only mildly obese.[19] I would not advocate the procedure in morbidly obese patients. Incompetence of the ACL may cause abnormal knee kinematics, and anterior tibial subluxation will typically result in posterior tibial wear. However, whereas ACL insufficiency historically had been considered an absolute contraindication to UKA, it is now considered a reasonable option when there is limited functional instability and the area of femoral contact on the tibia in extension and the location of the tibiofemoral arthritis are anterior.[21] Minimizing the tibial slope in the ACL-deficient knee during UKA is critical, however, to ensure durability.[22]

Figure 2. Anteroposterior radiograph shows malaligned femoral component implanted with conventional instrumentation.

Substantial subchondral bone loss, caused, for instance, by a large cyst or extensive osteonecrosis with structural compromise, may predispose the knee to component subsidence and thus should be considered a contraindication to UKA. In addition, UKA should be restricted to patients without inflammatory arthritis and crystalline arthropathy (eg, gout), as these conditions can increase the risk for pain and accelerated degeneration of the remaining compartments of the knee. Patients with areas of grade IV chondromalacia in other compartments of the knee should not be considered candidates for UKA. However, less advanced chondromalacia should not be considered a contraindication unless the patient reports pain in those compartments.

Whether patellofemoral arthritis is a contraindication to UKA is a point of debate. The classic indications suggest not performing UKA when patellofemoral chondromalacia is worse than grade III. However, results from recent studies with a mobile-bearing medial UKA design have suggested that patellofemoral arthritis and patellofemoral symptoms are not contraindications and do not adversely affect outcomes.[19,23] This has not been corroborated with fixed-bearing designs or in other studies, and more investigation is needed to determine the role of patellofemoral symptoms or arthritis in UKA outcomes.[3,21]

There are no specific contraindications to use of robotic assistance for UKA, though the increased duration of surgery early in the learning curve may make robotic assistance less appealing for some patients in whom briefer anesthetic time is desirable. Anesthetic times are typically approximately 2 hours during the initial few cases involving robotic assistance but quickly decrease soon thereafter, to approximately 1 hour, as the surgical team becomes more proficient with the setup, preparation, and nuances of the surgical procedure.

Rationale for Robotics in Unicompartmental Knee Arthroplasty

The results of UKA are affected by a variety of factors, including underlying diagnosis, patient selection, prosthesis design, polyethylene quality, and implant alignment and fixation. If a patient is appropriately selected and a soundly designed implant with good polyethylene is used, then accuracy of implantation is likely the most important factor in implant performance and durability.

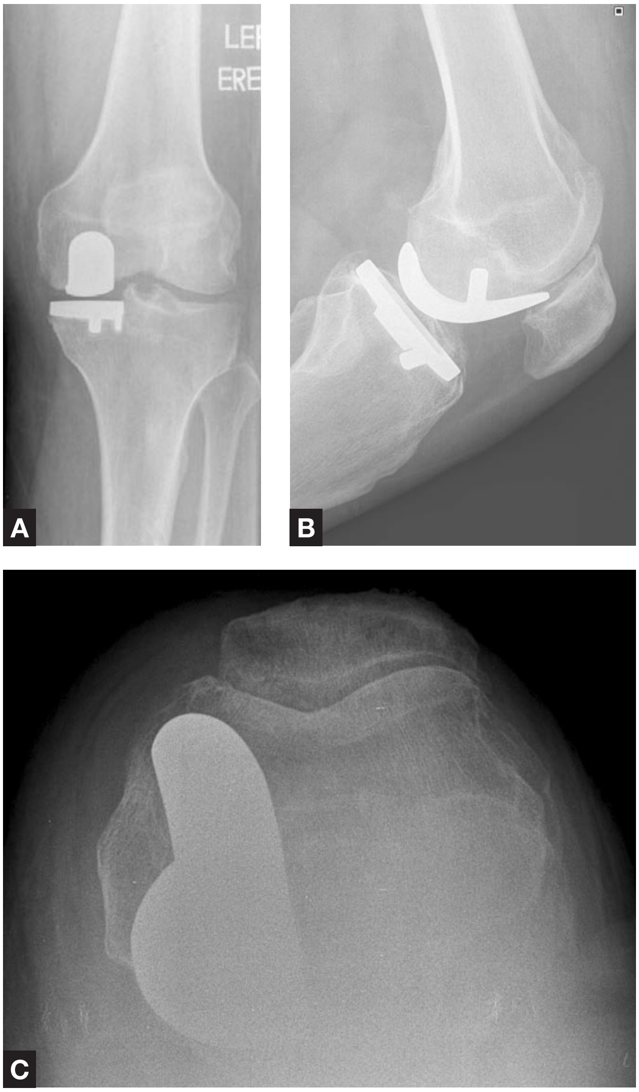

Figure 3. Standing anteroposterior (A), lateral (B), and sunrise (C) radiographs show well-aligned unicompartmental knee arthroplasty performed with robotic arm assistance corresponding to preoperative plan.

Although a well-performed UKA has clear potential benefits and reasonable outcomes, the technical challenges and relative inaccuracy associated with performing the procedure using conventional instrumentation and techniques, particularly when a minimally invasive surgery (MIS) approach is used, have been impediments to more widespread endorsement of UKA. The component positioning and limb alignment errors that occur with conventional approaches have been a primary reason for inconsistent results and a major impetus for developing more sophisticated techniques to improve component alignment, which again is a major determinant of mid- and long-term success after UKA. To this end, robotic technology continues to be advanced.

Excessive posterior tibial slope, tibial component malalignment, and mechanical axis varus malalignment predispose the prosthesis to early failure.[22,24,25] Study results have shown that, with use of conventional approaches and instrumentation in UKA, it is difficult to consistently align the tibial component accurately.[6,24,26] In up to 40% to 60% of cases involving conventional methods,[26,27] alignment may be off more than 2° from the preoperative plan (Figure 2). In addition, range of component alignment varies considerably, even among cases managed by skilled knee surgeons.[24] The problem is compounded when MIS approaches are used, as in most contemporary UKAs.[6,7] According to an analysis of the results of 221 consecutive UKAs performed through an MIS approach, the range of tibial component alignment was large (18° varus to 6° valgus; mean, 6°; SD, 4°).[6]

Computer navigation was introduced to UKA to reduce the number of outliers and improve accuracy, but the percentage of outliers (>2° from the planned implant position) may still approach 15%.[26] This highlights the challenges of using conventional tools for bone preparation. Robotic guidance was introduced to capitalize on the improvements obtained with computer navigation and to further refine and enhance the accuracy of bone preparation, even with MIS techniques[27] (Figure 3).

The complexity of revision of a failed UKA to a TKA and the results of that revision are partially dependent on the extent of bone compromise.[28] When more bone resection is performed during UKA, revision becomes more challenging, and the need for bone-defect augmentation increases. Robotic assistance is intended not only to make component position more consistent but also to limit bone resection and reduce the thickness of the tibial polyethylene inserts needed to balance the knee.

Conclusions

Over the next 25 years and beyond, there will be a large and rapid increase in the number of patients who present for treatment of knee arthritis. Many patients will still forgo TKA because of trepidation about pain and lengthy recovery. At least 10% of these patients, and potentially a much larger percentage, may be candidates for less invasive UKA; for this group, robotic arm technology will have increasing relevance. As the novel robotic arm technology described in this supplement enables tissue-sparing surgery, procedures can be performed through an MIS approach with a level of accuracy that has been elusive with conventional instrumentation. The synergistic application of computer imaging and robotic tools will likely be a profound stimulus for the broader adoption of UKA.

Author's Disclosure Statement

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