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Robotic Guidance Does Not Improve Component Position or Short-Term Outcome in Medial Unicompartmental Knee Arthroplasty

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ABSTRACT

We performed a retrospective review in a matched group of patients on the use of robotic-assisted UKA implantation versus UKA performed using standard operative techniques to assess differences between procedures. While both techniques resulted in reproducible and excellent outcomes with low complication rates, the results demonstrate little to no clinical or radiographic difference in outcomes between cohorts. Average operative time differed significantly with, and average of 20 minutes greater in, the robotic-assisted UKA group ($P = 0.010$). Our minimal clinical and radiographic differences lend to the argument that it is difficult to justify the routine use of expensive robotic techniques for standard medial UKA surgery, especially in a well-trained, high-volume surgeon. Further surgical, clinical and economical study of this technology is necessary.

Medial unicompartmental knee arthroplasty (UKA) for isolated medial knee arthritis is a highly successful and efficacious procedure [1–10]. However, multiple published reports demonstrate that this procedure is technically more challenging than total knee arthroplasty (TKA) and that surgical technical errors result in high early failure rates [11–16]. In a national, multicenter review of failed UKA cases, Epinette et al [11] observed that technical mistakes were the greatest contributor to UKA failure. Hamilton et al [12] reported that following their acceptance of UKA, it was necessary to reduce their use of "minimally invasive" exposures for UKA, as these limited exposures led to increased technical errors, complications, and inferior outcomes. Other authors have documented that a combination of patient selection, component design, and component placement is interrelated with the subsequent success of UKA [13–16].

Recent changes in component design, surgical instrumentation, and surgical techniques have led to improved UKA radiographic and clinical outcomes of UKA [1,3,5,17]. The changes in surgical instruments that have taken place include systems that allow more accurate flexion–extension gap balancing and more accurate bone preparation. However, despite these improvements in manual instruments, some surgeons have also recently adopted use of robotic-assisted navigation systems with the goal of even further improving accuracy of implant placement [18–21]. While most experts agree that improvements in component positioning and procedure reproducibility should enhance clinical outcomes and survivorship, the literature has not clearly demonstrated that these new, costly robotic systems can consistently and definitively outperform manual implantation techniques [21–27]. Most reports of robotic-assisted UKA describe slightly improved component position and suggest better early outcomes with fewer outliers [22,25,26]. However, these reports are universally short term and fail to show definitive improvements in clinical outcome [23].

Again, such robotic navigation technology is extremely costly and requires acquisition of additional preoperative three-dimensional cross-sectional imaging such as computed tomography (CT) scan with significant expense and radiation exposure to the patient. Our current health care environment is focused heavily on cost containment—therefore, expenses such as robotics for UKA surgery must be justified as regards improved both clinical efficacy and cost-effectiveness.

Therefore, as a result of conflicting current literature regarding the efficacy of robotic-assisted UKA, we designed a research study to address three specific questions that compare the use of robotic-assisted UKA versus manually implanted. First, we examined whether robotic UKA resulted in significant increases operating room time and/or patient length of stay (LOS) compared with manual UKA. Second, we determined whether there are any significant radiographic differences in the component placement and reproducibility of the UKA procedure between the two techniques. Finally, our last question was to determine whether there are any demonstrable improvements short-term clinical differences or patient performance as a result of robotic-assisted UKA.

Materials and Methods

Following institutional review board (IRB) approval, we initiated a retrospective and consecutive review of 30 robotic-arm assisted medial

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compartment UKA cases versus 32 manual medial compartment UKA cases. Patients were assigned to each group based on patient preference. Patients who presented to the practice of the primary surgeon (SKK), who were candidates for medial UKA and who specifically requested a robotically performed procedure subsequently underwent a robotically assisted UKA. Patients who did not specifically request a robotic procedure underwent a manual UKA. In order to reduce any bias that may have resulted from patients specifically requesting a robotic procedure, data collection was done in a completely blinded fashion both with regard to radiographic and clinical parameters. Patient confidentiality and anonymity was maintained and all reviewers were blinded to any patient specific identifiers. Cases for this study were performed between June 2009 and July 2011 and selected in chronologic, consecutive sequence to eliminate bias of selection prior to review. An important consideration for this analysis is that all the robotic cases included in this review were performed after the senior author had completed approximately 75 robotically assisted medial UKA. This was done to ensure that minimal "learning curve" issues would exist when analyzing the robotic cohort. All patients in the study had minimum follow-up of 24 months postoperatively.

An identical surgical technique was used by the senior author for both the manual and robotic-assisted UKA procedures; all cases were performed by the senior author, a fellowship-trained, joint arthroplasty surgeon with significant previous experience in manual UKA techniques.

Identical and consistent selection criteria were utilized for all patients, such that patients with medial osteoarthritis, an intact anterior cruciate ligament, with an anteromedial tibial arthritis wear pattern and a correctible deformity confirmed by varus/valgus stress radiography were included in the study. The degree of patellofemoral disease was not used as a selection parameter for any patients in the study.

The surgical technique in cases utilized a median parapatellar approach that was performed after induction of spinal or general endotracheal anesthesia. A tourniquet at a pressure of 275 mm Hg was used. General anesthesia was introduced only in cases where the attending anesthesiologist was unable to successfully introduce the spinal anesthetic into the patient's spinal column. In both the robotic and manual cases, the surgical technique included the medial exposure, followed by careful visual inspection of the lateral and patellofemoral compartments for evidence of arthritis. Care was taken to avoid release of the superficial and deep medial collateral ligament. Meticulous osteophyte removal was performed medial tibia and femur adjacent to the MCL. Careful osteophyte removal was also performed in the intercondylar notch. All components in both study groups were fixed with Palacos antibiotic-impregnated cement and included dual-peg femoral and tibial components. Prior to closure, all patients received a 60-cc intraarticular injection of 0.25% Marcaine with 1/2000 epinephrine combined, followed by an identical wound closure technique in all patients.

Manual UKA Procedure

In the manual UKA cohort, all cases were performed using a fully extramedullary referencing technique which, for coronal alignment, utilizes three anatomic landmarks—the tibial crest, the center of the ankle, and the tibial eminence. Utilizing digital radiography, the tibial slope resection reference was determined from the radiographic measurement of anatomic slope, and through additional visual exposure of the medial aspect of the tibia during placement of the tibial alignment guide. Reference for the tibial resection depth was identified by the greatest depth of tibial plateau wear (defect), with a subsequent target resection of 1 to 2 mm below this point. Following tibial resection, the extension gap was checked with a minimal target of 8 mm, and the flexion gap was assessed for posterior femoral resection of 6.5 mm with 1 to 1 degrees of varus undercorrection and 1 to 2 mm of laxity with the knee at 20-degree extension. Following distal femoral resection, the posterior femoral condyle was rechecked for a goal of 2 to 3 mm of laxity with the knee at 90 degrees. The femoral component size was selected, posterior condylar and chamfer resections were performed, trial components were inserted and a recheck of flexion/extension gap balance was performed. The final components were then implanted and closure performed. A high-flexion, metal-backed tibial component design was used in all cases (Zimmer High-Flex UKA, Zimmer, Inc., Warsaw, IN). The femoral and tibial components are designed with a dual peg to enhance component fixation stability.

Robotic-Assisted UKA Procedure

For the robotic UKA procedure, all patients underwent a preoperative CT scan from the hip, through the knee and ankle. This CT scan was then downloaded into the robotic-assisted software platform for preoperative implant planning. Following an exposure technique that was identical to that used for the manual UKA cohort, a haptic robotic arm and computer guidance system was used (RIO™ Robotic Arm Interactive Orthopedic System, Mako Surgical Corporation, Fort Lauderdale, FL) that required computer registration of the real tibial and femoral joint line bone surfaces and tibial and femoral mechanical axes. Intraoperatively, tibial and femoral tracker devices for robotic registration were placed in the tibial and femoral diaphyses. For mechanical axis determination, the robotic system utilizes the center of the ankle as determined by the midpoint between the extreme medial and lateral points of the medial and lateral malleoli respectively, and all landmarks are registered and stored for reference. The center of the hip is determined by taking the hip through a large, circular range of motion for approximately 10–15 cycles.

Following bone registration, all osteophytes were removed followed by application of valgus stress to knee at 20-degree intervals from full extension to 120 degrees of flexion. The data acquired were used to generate a ligament balancing curve that was then used to virtually manipulate position of femoral and tibial components within the robotic software platform to achieve balanced flexion and extension gaps. Once the "virtual" gap balance has been achieved, the haptic robotic arm is used to first burr the distal and posterior femoral surfaces followed by burring of the tibial plateau. All trial components are then inserted, and both gap balance and mechanical axis undercorrection are assessed using robotic software. Any adjustments in gap balance or implant alignment were performed by using repeated burring if necessary. Implantation of final UKA components was performed with a dual-pegged femoral and dual-pegged, metal-backed, tibial component, designed and manufactured by the robotic device corporation (Restoris UniCompartmental Knee System, Mako Surgical Corporation, Fort Lauderdale, FL).

Medical Record/Radiographic Review

Full hospital and clinic medical record review of demographic, preoperative, intraoperative and postoperative measures was performed. Radiographic analysis of preoperative and postoperative images evaluating sagittal and coronal alignment, and component positioning were performed by two fellowship-trained orthopedic surgeons with significant experience in UKA surgery and in radiographic analysis using the FDA-approved OsiriX imaging system (Pixmeo; Geneva, Switzerland). Full-length coronal images through the hip, knee, and ankle were used for all radiographic analysis both preoperatively and postoperatively. The included figures and legend demonstrate the measurement protocol (Fig. 1A–B).

Statistical Methods

Independent-samples *t*-tests were used to compare the two groups on all continuous variables. Chi-square (χ^2) tests were used for categorical variables. Variables used to assess accuracy were