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Operative Techniques in
Orthopaedics

Robotic Lateral and Medial Unicompartmental Knee Arthroplasty

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Unicompartmental knee arthroplasty (UKA) for end-stage degenerative disease of the knee limited to one compartment is a viable alternative to total knee arthroplasty (TKA). UKA necessitates less bone resection and tissue disruption, reduces blood loss, and preserves cruciate ligaments. UKA can be performed in either of the 3 knee compartments with medial compartment the most common. Lateral compartment UKA is a technically difficult surgery, but robotic systems can mitigate the difficulty for surgeons. Recently, robot-assisted systems have become available for UKA that have been shown to improve accuracy of component placement and allow for intraoperative real-time dynamic ligament balancing. A 3-dimensional model of the patient's anatomy is created from a preoperative computed tomography scan of the patient's knee, which is mapped to anatomical landmarks registered intraoperatively. Components are then placed for an operative resection plan. The robot-assisted system provides haptic feedback to the surgeon during bone resection, including an alert, should the high-speed burr leave the preplanned resection area. Postoperative measures have shown superior accuracy of component accuracy with robotic systems compared with conventional UKA surgical techniques. Currently, short-term and midterm clinical outcomes of robot-assisted UKA are available that appear similar to those of conventional UKA.
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Introduction

Joint arthroplasty is the current gold standard for treating patients with end-stage degenerative joint disease (DJD) of the knee. With improvements in surgical technique, component design, and instrumentation, unicompartmental knee arthroplasty (UKA) has seen a resurgence in the treatment for patient with DJD limited to the medial, lateral, or patellofemoral compartment with a reported annual growth in the use of UKA of 32.5%.[1] The goal of UKA is to restore the normal height of the affected compartment through a gap-filling technique. The benefits of UKAs include a decrease of the overall risk of complications from 11.0%-4.3%, decreased tissue disruption, reduced blood loss, reduced surgical costs, less bone resection, smaller incisions, and preservation of the cruciate ligaments in addition to adjacent viable compartments.[2-4] In comparison with total knee arthroplasty (TKA), patients with UKA experience improved gait, greater range of motion (ROM), and a faster postoperative recovery.[4-7] In a comparison of patients undergoing bilateral knee arthroplasties with UKA in one knee and a TKA in the other knee, patients were generally more satisfied with their UKA.[8]

Degenerative disease of the medial compartment of the knee is more common than that of the lateral compartment. UKA procedures of the lateral compartment represent only 10% of all UKA performed and only 1% of all knee arthroplasties.[9] Lateral UKA is performed approximately 10 times less often than medial UKA,[4,10] potentially contributing to the inconsistence in lateral UKA survivorship, with reported failure rates attributed to surgeon inexperience with the technical difficulties of lateral UKA.[4,11,12] Lateral

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compartment UKA is technically more challenging compared with medial UKA owing to differences in anatomy and biomechanics of the lateral compartment during the ROM. The lateral tibial plateau is convex, whereas the medial plateau is concave, and the lateral collateral ligament has greater laxity than the medial collateral ligament.[4] Sagittal tibial slope is greater on the lateral side than medial side. Femoral rollback is more pronounced laterally, leading to different joint kinematics and wear patterns. Anteromedial wear is typically seen in the medial compartment, whereas posterolateral wear is seen in the lateral compartment. In recent years, the introduction of computer navigation and robot-assisted systems has expanded the orthopaedic surgeon's armamentarium and their use continues to be explored for joint replacement. The use of robot-assisted techniques in UKA has been shown to improve accuracy in component positioning, ligament balancing, and postoperative alignment for medial compartment UKA.[1,13] For the technically more challenging lateral UKA in particular, the use of robot-assisted systems may improve survivorship. Although a variety of computer-assisted systems are currently available, this article focuses on the operative technique of a robot-assisted system with haptic guidance for bone resection during UKA. Use of this system has improved the accuracy and precision of bone resection and component placement[1,13]; however, only short-term to midterm results are currently available for medial and lateral UKA.

Passive Systems

Passive systems, also known as navigation, assist the surgeon with the preoperative planning, surgical simulation, and intraoperative guidance (Table 1).[14-16] The passive system performs no direct action on the patient, but uses 3-dimensional (3D) position sensors to track the target bone and surgical tools to provide a visual representation and facilitate surgical planning.[15] The passive systems provide detailed information to the surgeon intraoperatively, including real-time assessment of joint biomechanics, to make recommendations, and monitoring of the accuracy of bone cuts.[17]

Active Systems

Active systems are computer-controlled systems that perform a preoperative surgical plan with surgeon supervision (Table 1). The surgeon will carry out the surgical exposure and then the robot precisely cuts the bone according to the surgical plan.[15] The ROBODOC uses a helical computed tomography (CT)-based preoperative planning system performed using ORTHODOC (Curexo Technology Corp) to create a 3D visualization of the femur and tibia.[17] This allows the surgeon to select and plan the femoral and tibial component sizes using virtual trials and assess the mechanical axes of the hip and knee.[18] Furthermore, there are multiple systems that are currently under investigation that are small bone-mounted devices. The first of these is the mini bone-attached robotic system, which mounts onto the femur and prepares the bone for implantation during arthroplasty.[19] Similarly, a minimally invasive TKA bone-mounted system called Praxiteles (Praxim Ltd, Grenoble, France) is in development in France.[20] However, the new technology implemented in these small bone-mounted devices will require further testing and development.

Synergistic Systems

Synergistic systems, or haptic systems, combine the skills of the surgeon and the capabilities of the robot to give the surgeon active control over all aspects of the operation (Table 1).[17] Synergistic robotic systems differentiate themselves from computer-assisted surgery programs by their restraint of surgeon movement with the operative tool. In computer-assisted programs, the surgeon can choose to ignore computer feedback and make bone cuts without restriction. Robotic systems physically restrain movement of the surgical tool to respect the preset surgical boundaries.[7] One such system is the "Robotic Arm Interactive System" developed by MAKO Surgical Corporation (Ft. Lauderdale, FL). The system uses a preoperative CT scan of the patient's knee to create a 3D virtual model of the patient's anatomy.[17] The 3D model is used to develop a surgical plan that allows for selection of component size and positioning. Intraoperatively, the 3D surgical plan is overlayed on the patient's anatomy by registering multiple bony landmarks which can be synced to the CT scan. The robot-assisted system uses a high-speed burr for femoral and tibial resection with haptic feedback that alerts the surgeon and provides physical resistance if the burr is moved outside of the predefined resection area.

Resection Accuracy

Multiple authors have investigated navigation systems to demonstrate the comparative advantages seen in accuracy over conventional operative methods of arthroplasty.[21-24] Stulberg

Table 1 Past and Current Computer Systems for Joint Replacement

Device	Company	Year of First Use	Other Applications
Passive			
Navigation System II	Stryker	2006	None
iASSIST	Zimmer	2013	None
Knee 3	BrainLab	2012	None
Active			
ROBODOC	Curexo Technology	1992 (2009 for Knee Arthroplasty)	Total Hip Replacement (THR)
Haptic			
NavioPFS	Blue Belt Technologies	2013	None
RIO	Stryker	2008	UKA, TKA, total hip replacement