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Operative Techniques in
Orthopaedics

Bi-Unicompartmental, Robot-Assisted Knee Arthroplasty

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Robot-assisted surgery has had a significant effect on modern arthroplasty in the United States. Extensive research has hinted at the potential of robotics to improve different aspects of surgery (eg, higher precision and associated favorable clinical outcomes). In addition to technical advances in surgery, there is also progress regarding knee implant design, for example, implants designed to obviate the need for sacrificing cruciate ligaments of the knee during surgery, which is believed to lead to preferable functional outcomes and more natural knee motion. Robotic assistance is considered valuable in this instance, owing to higher levels of accuracy and more accurate implant alignment. In this article, we summarize advantages and issues associated with robot-assisted surgery. We briefly discuss less-invasive, ligament-retaining surgery and alternatives to traditional total knee arthroplasty. We present preliminary data regarding patient-reported outcomes from total knee arthroplasty and a less-invasive alternative treatment. We also present the specific surgical technique used in our clinic (bi-unicompartmental knee arthroplasty), which combines the advantages of modern tissue-sparing multicompartmental knee arthroplasty and robot-assisted bone preparation.
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Robotic Assistance in Orthopaedic Surgery

Robots could be described as programmable entities that execute physical tasks and actions or series thereof more or less autonomously. Robotic technologies are present in multiple areas of life in modern civilization, whether in production, service, or the medical field. In medicine, robot-assisted interventions have become a cornerstone of modern surgery,[1,2] for example, in minimally invasive operations.[3] This development has been observed in orthopaedic surgery as well.[4-8] For robotic assistance in surgical procedures, 2 major concepts and related philosophies have emerged. One approach includes meticulous preoperative planning or templating and subsequent autonomous execution of the preprogrammed surgical treatment. A more common approach, specifically in orthopaedic surgery, includes an equally specific presurgery planning and templating phase, whereas during the actual surgery, the surgeon moves the robotic arm and may (depending on the robotic system used) receive guided feedback (haptic or tactile systems and visual or auditory) during bone preparation.[8]

Robotic systems, such as the TCAT robotic tool as part of the TSolution One Surgical System (THINK Surgical Inc, Fremont, CA), formerly known as ROBODOC, or the tactile-guided RIO Robotic Arm (MAKO Surgical Corp, Fort Lauderdale, FL) (Fig. 1) have been used extensively in orthopaedic surgery such as total knee arthroplasty (TKA) and partial knee replacement treatments such as unicompartmental knee arthroplasty (UKA) treatments.[9-19] In the initial planning phase of the surgery, these systems depend on computed tomography (CT) scans of the knee that are used to generate a 3-dimensional (3D) model of the operative joint. In combination with intraoperative registration of bony landmarks via a digitizing device, and evaluation of flexion-extension gaps, the robotic device is "fed" accurate data about the precise, required bone preparation. During the bone resection process, preoperative and intraoperative information is then used to establish spatial limitations for the system. Once the surgeon approaches those defined limits during bone

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Figure 1 Two currently approved robotic systems: (A) MAKO RIO Robotic Arm Interactive Orthopaedic System (MAKO Surgical Corp, Ft. Lauderdale, FL) for MAKOplasty and (B) TSolution One Surgical System (THINK Surgical Inc, Fremont, CA) including TPLAN 3D planning workstation and TCAT computer-assisted tool. Source: THINK Surgical Inc, MAKO Surgical Corp. (Color version of figure is available online.)

preparation, an auditory signal as well as visual or haptic feedback is provided to alert the operator.

From a surgeon's perspective, 2 major advantages associated with this approach are (1) the ability to precisely execute the surgical plan and to minimize the loss of bone matter due to inaccuracies of bone preparation and (2) possession of authority over the robotic arm, so there is full operator control at each stage.

A disadvantage of robotics in arthroplasty is the initial cost for both the robotic device and the software that is customized to specific surgeries. In addition to the purchasing costs, there is a requirement for maintenance of the technology, which makes it difficult to afford for a number of clinics. Overall, the cost-benefit trade-off may be an important factor for many facilities; in clinics that have surgical staff that is well experienced regarding the surgery and has a good track record regarding manual TKA, financial considerations may be a decisive factor against robotic devices.

Several studies have reported high surgical precision with robotic assistance,[20,21] and others have evaluated the value of robotics in TKA. There is no consensus yet, as results are mixed, with reported favorable accuracy,[22,23] better alignment,[10,24,25] and less postoperative bleeding,[9,26] but also longer surgery duration and complexity[9,27] and higher complication rates at early stages.[28] More research is needed to evaluate the long-term benefits.

Robotics and Unicompartmental Arthroplasty

Severity of osteoarthritis usually prescribes adequate treatment options, which can be nonsurgical (eg, viscosupplementation, bracing, and medication) if symptoms are not too severe. If these treatments are not effective and pain management becomes challenging, surgery may become an option.[29] Owing to a number of different contributing factors (eg, lifestyle changes associated with modern western civilization), the number of knee arthroplasties has increased significantly in the United States[30,31] and there still are risks and unresolved issues related to the intervention.[31-33] One of the most significant issues is patient dissatisfaction after knee arthroplasty.[34-38]

A lingering question related to arthroplasty is what can be done to improve results for patient satisfaction, function, and longevity, while keeping the financial burden on the health care system manageable.

It is well known that UKA is a viable alternative to TKA in specific cases where one of the compartments is significantly affected, with outcomes that are equal or better in comparison with TKA.[39-43] Owing to the nature of the treatment, more natural tissue is retained, including cruciate ligaments and bone matter. This provides a solution leading to better function specifically for younger, more active individuals and makes potential future revision or conversion to TKA easier.

A number of research studies related to robot-assisted knee arthroplasty have focused on UKA, where high accuracy becomes crucial for longevity of the treatment. Analysis of postsurgery X-rays showed that UKA using robotic assistance was successful in providing high accuracy.[44,45] Accurate alignment of implant components and proper execution are strong predictors of durability and surgery success in UKA.[46] Higher precision owing to the use of robotics has been shown to lead to better reproducibility and improved patient outcomes.[16]

UKA failures are rare in general, but it is believed that technical errors that are a main cause of such failures may be prevented effectively with robot-assisted surgery.[47] Radiographic analysis of component alignment after robotic-arm UKA was the focus of a clinical study investigating errors of bone preparation.[48] The authors showed that robotic surgery was superior when compared with conventional manual