Commentary

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Despite the Technical Demands and Stringent Tolerances

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Description

Robots have been used in surgery since the late 1980s. Orthopaedic surgery began to incorporate robotic technology in 1992, with the introduction of ROBODOC, for the planning and performance of total hip replacement. The use of robotic systems has subsequently increased, with promising short-term radiological outcomes when compared with traditional orthopaedic procedures. Robotic systems can be classified into two categories: Autonomous and haptic (or surgeon-guided). Passive surgery systems, which represent a third type of technology, have also been adopted recently by orthopaedic surgeons.

Orthopaedic Surgery

While autonomous systems have fallen out of favour, tactile systems with technological improvements have become widely used. Specifically, the use of tactile and passive robotic systems in unicompartmental knee replacement (UKR) has addressed some of the historical mechanisms of failure of non-robotic UKR. These systems assist with increasing the accuracy of the alignment of the components and produce more consistent ligament balance. Short-term improvements in clinical and radiological outcomes have increased the popularity of robot-assisted UKR. Robot-assisted orthopaedic surgery has the potential for improving surgical outcomes. We discuss the different types of robotic systems available for use in orthopaedics and consider the indication, contraindications and limitations of these technologies. The Robotic Arm Interactive Orthopaedics System (RIO) (MAKO Surgical Corp., Fort Lauderdale, Florida) is an example of a commercially available, tactile robotic system that requires active participation of the surgeon to complete a unicompartmental knee replacement (UKR). It uses pre-operative CT scans to create a three-dimensional (3D) computerised model of the patient's knee.

Robotic Arm

The surgeon uses this model pre-operatively to plan the sizing and placement of the components. Intra-operatively, the surgeon will reference the bony surfaces of the femur and tibia, allowing the pre-operative model to be 'merged' with the actual anatomy of the knee. After taking the knee through a range of movement, the flexion-extension gaps can be assessed and the operative plan finalised in terms of component placement, creating an exact cutting zone for the robot. The system's algorithm relies heavily on the pre-operative planning or templating process. During the resection of bone, the surgeon views the 3D model of the knee on a monitor while manipulating the burr. The robotic arm provides auditory as well as haptic feedback, limiting the force-controlled tip of the rotating burr to resect bone only within the confines of the pre-defined cutting zone. An additional safety feature automatically stops the burr if the surgeon goes outside the pre-determined zone. This feature also engages if the computer determines that the surgeon is resecting more bone than necessary. These robotic features monitor the operation and provide the intra-operative data necessary for the preservation of bone stock and accurate placement of the components, both of which are thought to improve the outcome after UKR.5-10 The RIO system allows the surgeon to execute the pre-operative plan with great precision. However, if this plan is flawed, the system cannot compensate for it. In 2010, Roche, Augustin and Conditt4 reviewed 43 cases of RIO assisted UKR and showed that 344 radiological measurements were made with only three abnormal radiological findings.4 They concluded that UKR using this system showed promising initial results.4 The RIO robot-controlled arm allows the surgeon to operate through a much smaller incision, which has been associated with a shorter recovery and rehabilitation time.5-8 Typically, robot-assisted UKR is performed as an outpatient procedure; however certain patients may require a 24-hour hospital stay. Despite the technical demands and stringent tolerances required for UKR, the RIO system has quite a short learning curve, particularly for less experienced surgeons. The system has safety features that monitor the procedure to ensure that the pre-operative plan is executed. In 2009, Coon12 reported on the learning curve, showing that the operation initially took between 80 and 120 minutes, decreasing to about 40 minutes after 20 cases. Recently, a hybrid semi-autonomous robotic system has gained popularity as an innovative use of applied technology in orthopaedic surgery. These novel systems consist of small, bone-mounted robots that are hailed as being more efficient and cost-effective than the larger robotic systems currently in use. The mini bone-attached robotic system (MBARS) robot, which was developed at Carnegie Mellon University, Pittsburgh, Pennsylvania, mounts onto the femur and completes the bone resection cuts during TKR.18 A similar robotic TKR system (Praxiteles; Praxim Ltd, Grenoble, France), is being developed in France. Similar to many new technologies in the surgical sciences, further development and testing are needed before assessing the efficacy of these small, bone-mounted technologies.