Impact Surgery

Editorial

e-ISSN: 3033-4470

We Need to Talk About the Robot in the Room: Orthopaedics

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Cite as: Mohammed, Z., Khatri, C., Searle, H., Metcalfe, A., & Davis, E. We Need to Talk About the Robot in the Room: Orthopaedics. *Impact Surgery*, 2(7), 233-235. https://doi.org/10.62463/surgery.279

Orthopaedics has grappled with robotics for three decades. One of its first major ventures, ROBODOC (Curexo Technology Corp, South Korea, 1992), was an 'active' robotic system designed to autonomously execute bone cuts required for arthroplasty. Concerns over safety, workflow, and a lack of intraoperative flexibility limited its widespread adoption. It was superseded by TSolution One (THINK Surgical, USA) in 2014, adding improved CT-based planning, enhanced registration, and safeguards against soft-tissue injury. It remains the only autonomous robotic system available today[1]. Yet, whether robotics in orthopaedics ultimately offers improvements in clinical or cost effectiveness remains uncertain. Adoption has often outpaced evidence, and only now are large-scale RCTs, such as the RACER trials, underway to assess the value of robotics in arthroplasty[2,3].

In contrast to 'active' systems, many contemporary orthopaedic robotic platforms are 'semi-active', requiring direct input from the surgeon throughout the procedure. Workflow requires either detailed preoperative CT/radiograph imaging or intraoperative imageless surface mapping to construct a 3D anatomical model, guiding planning and anatomical registration. Intraoperatively, navigation systems and infrared trackers align this model with the patient's anatomy, allowing the surgeon to undertake resection and placement work guided by predefined boundaries. The approach to tissue interaction varies between devices, with some systems requiring direct cutting by a robotic arm-mounted tool, the implementation of patient-specific guides or the utilisation of compact handheld smart tools[4,5].

Mazor Robotics (Israel) has attempted to mitigate the risk of iatrogenic nerve injury during pedicle screw placement during spinal surgery. Early studies have suggested up to 98% accuracy in robotic-assisted pedicle screw placement; however, database studies have linked it to increased readmission and reoperation[6]. These adverse signals may reflect confounding factors such as early adoption in lower-volume centres or preferential use in anatomically complex or revision cases. Currently, level 1 evidence is awaited to determine whether these associations reflect true risk or artefact.

Arthroplasty has also become a natural focus for robotic innovation, reflecting both the frequency of these procedures and the complexity of outcomes. Hip and knee replacements are among the most frequently performed operations worldwide, but up to one in five patients remain dissatisfied with the result[7]. Although this is likely multifactorial, robotic systems aim to address some of its most tangible elements by aiming to improve alignment, component sizing, and positioning, all of which are recognised contributors to function and implant longevity[3].

The most widely adopted robotic arthroplasty platform in the UK, MAKO (Stryker, USA), is a robotic-arm-based system that requires preoperative CT imaging for planning. Early data suggest that intraoperative soft-tissue protection mechanisms are associated with reduced inflammation, less pain, and shorter hospital stays[7,8]. Conversely, the second most popular platform, CORI (Smith & Nephew, UK), is a handheld ‘smart-tool’ system that foregoes pre-operative imaging in favour of intra-operative surface mapping to register anatomy[5]. With both models, the surgeon remains in direct control of a burr-like handpiece, with haptic feedback and real-time navigation supporting accuracy. Other systems entering UK practice, including ROSA (Zimmer Biomet, USA), VELYS (DePuy Synthes, USA), SkyWalker (MicroPort, China), and Apollo (Corin, UK), highlight the spectrum of approaches available[9].

Robotics also offers a practical method of enacting new theoretical concepts of alignment for knee replacements. ‘Kinematic alignment’ seeks to restore the joint to its pre-arthritic state by restoring the patient’s native anatomy rather than enforcing a fixed ‘mechanical axis’. The broader question of what constitutes the optimal alignment remains controversial; however, robotic systems offer a level of planning and executional precision that was previously unattainable with conventional instrumentation[10]. Some argue that the key to answering this question lies in the integration of AI and machine learning in analysing large datasets to identify personalised, patient-specific kinematics[11].

Several key challenges remain for robotic orthopaedic surgery. Semi-active systems require additional resources for preoperative imaging and planning. Intra-operatively, robotics requires increased consumables and can increase both intra-operative and case turnover time[2]. A learning curve, estimated to range between 12 and 35 cases, must be overcome to achieve competence[12]. In addition, capital costs for purchase and maintenance can exceed £1,000,000 per robot, limiting access to resource-restricted or financially pressured healthcare systems[2]. Given the significant time and pressure on institutions, the question remains whether incremental improvements in alignment and precision are sufficient to justify such a significant outlay. For robotics to be cost-effective, they will likely need to demonstrate sustained functional improvements for patients while also lowering revision rates, healthcare utilisation, and productivity loss. Consequently, the BOA/RCSEng/RCSEd have highlighted safeguards for safe adoption of robotics. Given that evidence varies across robotic platforms, institutions are advised to evaluate each device on its own data rather than extrapolating from others. Along with this, appropriate governance, structured training, and prospective audit measures are needed to ensure new technologies are introduced with robust supporting evidence and safeguards[13].

The Robotic Arthroplasty Clinical and Cost-Effectiveness Randomised trials (RACER-Knee and RACER-Hip) are landmark multicentre double-blind RCTs designed to address these questions[2,3]. RACER trials will randomise over 700 patients to robotic-assisted versus conventional arthroplasty, with the Forgotten Joint Score at 12 months as the primary clinical endpoint alongside cost-effectiveness analyses. This will help address the key policy question of whether robotic systems can offer meaningful benefits for patients and value for healthcare systems. Whilst these trials offer a promising evaluation of the MAKO robot within hip and knee arthroplasty, further trials for other systems and innovations will require concurrent evaluation, in keeping with the IDEAL framework[14]. Innovation in orthopaedic robotics is moving at pace, and we must support this with high-quality clinical research, whether to determine the best targets for the future, or to robustly evaluate current technologies, to give our patients of the future the best possible outcomes.

Funding: No specific funding was received for this article.

Conflicts of interest: None declared.

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