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INVITED EDITORIAL

Robotic-assisted total knee replacement: pioneering precision and the future of joint reconstruction

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Total knee replacement (TKR) is one of the most common orthopedic procedures, with demand increasing due to longer life expectancy and higher patient activity levels.[1] Achieving successful outcomes requires precise implant positioning and ligament balancing, particularly in younger, more active patients.[1] However, traditional TKR methods often rely on manual techniques, which can introduce variability and limit consistency.[1,2]

Robotic-assisted technology tackles surgical challenges by enhancing accuracy, minimizing variability, and customizing surgical planning, such that the robotic-assisted system provides an efficient solution for precise bone resection, alignment, and implant positioning.[2] As this technology becomes more widely accepted, it has the potential to redefine surgical standards and improve patient outcomes.[2,3] However, further investigation is needed to address questions about its cost-effectiveness and long-term benefits.

Robotic-arm-assisted TKR utilizes bone registration to ensure accurate intraoperative spatial orientation of the limb, with fixed arrays precisely tracking the femoral and tibial bone resection areas throughout the procedure.[2,3] Stereotactic boundaries limit bone resection to the defined haptic windows, minimizing manual errors and reducing the risk of iatrogenic soft tissue injury that can occur with the handheld sawblade used in traditional TKR, which will ultimately increase the accuracy rate.[3] Accuracy rate can be measured using radiographs, mechanical alignment, or posterior condylar offset ratio (PCOR). A similar study indicated that robotic-arm-assisted total knee replacement (TKR) achieves superior accuracy and precision in bone resections and implant positioning compared to traditional techniques.[4]

The result of a systematic review and meta-analysis by Ren et al.[5] with seven studies concluded that patients who undergo robotic-assisted TKR show lower deviation values of β, γ, and δ angles and the rate of mechanical outliers is lower in the robotic-assisted group; therefore, robotic-assisted TKR enhances implant accuracy and also reduces alignment errors in sagittal and coronal planes.

A systematic review conducted by Onggo et al.[6] included 18 studies showing a clinically significant difference in the Hospital for Special Surgery Knee score between robotic and conventional TKR, with the robotic-assisted group having a better score. Fary et al.[7] observed that the active range of motion (ROM) was significantly greater in patients who underwent robotic-assisted TKR than in those treated with the conventional method. At one-month follow-up, the improvement in ROM was 5.1°, and in three months, it was 2.9° greater in the robotic-assisted group than in the conventional group. A precise bone cut may be performed in the robotic-assisted

group, which may decrease the soft tissue injury and inflammatory markers.[3] The above-cited systematic review and a meta-analysis conducted by Ren et al.[5] found no significant difference in knee ROM in patients who underwent robotic-assisted and conventional methods in six months and two years of follow-up.

One of the primary barriers to the widespread adoption of robotic-assisted TKR is cost. The high upfront investment in robotic systems and the associated per-case costs may limit the widespread availability and accessibility, particularly in resource-constrained settings. Future advancements in technology and increased competition among manufacturers could contribute to cost reductions, potentially expanding the accessibility of robotic systems in clinical practice.

Robotic-assisted TKR represents a significant leap forward in orthopedic surgery, offering enhanced precision, improved patient outcomes, and the potential to redefine surgical standards. Systems such as the VELYS provide surgeons with tools to achieve unparalleled accuracy in implant positioning and ligament balancing. While challenges such as cost and training remain, ongoing advancements in technology and research are likely to address these barriers, paving the way for broader adoption. As the field evolves, robotic-assisted TKR has the potential to set a new benchmark for excellence in knee replacement surgery. The future of orthopedic surgery lies in harnessing the potential of robotics, ensuring that every procedure is performed with the highest level of precision and care.

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