

Is computer-navigated and robot-assisted total hip replacement superior to the conventional freehand technique? A review of the last decade

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ABSTRACT

Background: Total hip arthroplasty (THA) is a highly successful procedure, yet postoperative dislocation remains a significant cause of early revision surgery. Accurate acetabular component positioning is critical to minimize instability, particularly in patients with altered spinopelvic mechanics. Computer-navigated and robot-assisted technologies have been introduced to improve surgical precision; however, whether increased radiographic accuracy translates into superior clinical outcomes remains unclear.

Methods: A literature review of PubMed and Embase was conducted in January 2026, including English-language studies published between 2016 and 2026 comparing computer-navigated or robot-assisted THA with conventional freehand THA. Clinical trials, prospective and retrospective cohort studies, and case-control studies were included.

Results: Computer-assisted techniques consistently demonstrate improved acetabular component positioning accuracy. However, most comparative studies show no significant reduction in dislocation or overall revision rates. Large database analyses report minimal differences in short- to mid-term clinical outcomes. Operative time is frequently increased with computer-assisted procedures. Long-term survivorship data remain limited.

Conclusions: Although computer-navigated and robot-assisted THA improve radiographic precision, current evidence does not demonstrate consistent superiority in clinical outcomes or revision rates compared with the conventional technique. High-quality long-term studies and cost-effectiveness analyses are needed.

KEYWORDS

THA, computer-navigated, robotics-assisted, total hip replacement, total hip arthroplasty.

Introduction

Total hip arthroplasty (THA) is widely regarded as one of the most successful surgical procedures in modern orthopedics, providing substantial pain relief and improved quality of life for patients with end-stage hip pathology [1]. However, despite excellent overall outcomes, postoperative dislocation remains a clinically relevant complication and one of the leading causes of early revision surgery following primary THA [2].

To reduce dislocation risk and further improve outcomes, accurate cup placement is essential, but the conventional Lewinnek safe zones, previously thought to decrease dislocation risk, have not been shown to serve as a universal guide [3–5]. Malpositioning of the acetabular cup has been associated with increased rates of dislocation, impingement, accelerated wear, and revision surgery [6–8]. In recent years, improved understanding of the hip–spine relationship has made the concept of “safe” cup positioning more complex. Patients with prior spinal fusion, spinal deformity, or reduced spinopelvic mobility may be at increased risk of instability even when acetabular components are placed within conventional safe zones. In such patients, individualized cup positioning within a narrow range of inclination and anteversion may be required, targets that may be difficult to consistently achieve with the traditional freehand

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technique. To address these limitations, computer-assisted technologies have been introduced into THA. These include image-based robotic systems, CT-based navigation, fluoroscopic navigation, and imageless intraoperative navigation [9]. The benefits include increased accuracy in component placement [10], higher reproducibility of results, and reduced risk of dislocation, all factors potentially leading to improved clinical outcomes. The drawbacks are increased operative times, higher costs [11], the need for additional surgical training, and an unfavorable cost-benefit ratio [12].

Large-scale, high-level evidence on whether improved radiographic accuracy translates into superior clinical outcomes remains limited.

The aim of this review is to examine dislocation rates, revision rates, implant survivorship, and clinical outcomes in patients undergoing primary THA, comparing computer-navigated and robot-assisted THA with the conventional freehand approach.

Methods

This research took the form of a literature review. In January 2026, we searched the PubMed and Embase databases for clinical trials, prospective and retrospective studies, observational studies, and case control studies on primary THA comparing computer-navigated, robot-assisted, and conventional freehand approaches. We included English-language articles published between 2016 and 2026. Reviews, non-hip studies, and studies without an available full text were excluded from the analysis.

Results

A total of 39 articles were included. Although they described different techniques, outcome measures, and methodologies, several common concepts emerged.

Overall, the literature seems to indicate that computer-navigated and robotic-assisted surgery provide clear improvements in acetabular component positioning and radiographic accuracy compared with the freehand technique ^[13-14] (Table I).

Table I Brief comparison between the traditional freehand technique and computer-navigated or robot-assisted THA.

TRADITIONAL THA	COMPUTER-NAVIGATED OR ROBOT-ASSISTED THA
standard training required	additional training required
no additional costs	increased costs
standard operative time	increased operative time
no improvement in component placement accuracy	increased component placement accuracy

In particular, CT-based mixed-reality navigation is shown to be accurate in terms of postoperative acetabular component positioning relative to the preoperative plan ^[15-16]. Imageless navigation systems provide accurate and reliable intraoperative feedback, even though accuracy and precision are inferior compared with CT-based navigation systems ^[17]. Radiographic superiority of computer-assisted techniques appears consistent, but these studies rarely correlated positioning accuracy with long-term clinical outcomes. It is important to note that numerous authors underline the usefulness of computer-navigated or robot-assisted techniques in the ongoing training of young surgeons ^[18], as the ability to consistently achieve accurate cup placement is imperative for the acquisition of advanced surgical skills. Computer-navigated and robot-assisted THA are particularly useful in patients with abnormal anatomy, in revision surgery, and in patients with abnormal spinopelvic parameters, since conventional surgical landmarks may be altered or missing in these cases ^[19].

While acetabular cup placement is widely discussed in the literature, femoral stem positioning appears to be a far less popular topic of discussion and study, with only one of the analyzed articles reporting the use of femoral component navigation. When femoral stem positioning is discussed, intraoperative

navigation or assistance is shown to lead to favorable results, particularly in terms of dislocation rates ^[15]. There could be many reasons for this trend. One hypothesis is that the use of trial stems during surgery and the ability to minutely adjust stem characteristics with modular components has limited the need for femoral component navigation.

Surgical time and perioperative factors are a topic of discussion in many of the studies we analyzed. Overall, the studies report increased operative times with computer-navigated or robot-assisted techniques ^[13]. It is important to note that this may be due not to the technology-assisted technique itself, but to the characteristics of patients and cases treated in centers where advanced surgical techniques are more commonly used ^[14].

Some authors report no increase ^[14], or even reductions, in operative time, associated with improved clinical outcomes ^[20], specifically when using robot-assisted THA ^[21].

Clinical outcome differences between the techniques in question are far less clear. There seems to be no clear overall consensus in the literature either in terms of PROMs or dislocation and need for revision.

Some studies declare a clear superiority of computer-navigated and robotic-assisted THA over the traditional technique, citing for example lower rates of complications and readmissions following THA ^[20,22], as well as lower loosening ^[23] and dislocation rates ^[15,24].

Others instead report no significant difference between the standard technique and technology-assisted THA ^[13,25], while one even seems to suggest a slightly higher revision rate in navigated THA ^[12].

It is important to note that much of the literature focuses on the surgical aspects of freehand vs computer-guided or robot-assisted THA, without considering clinical outcomes ^[14].

Discussion

This review demonstrates that computer-navigated and robot-assisted THA reliably improve acetabular component positioning accuracy compared with the conventional freehand technique. Radiographic precision is consistently enhanced across multiple technologies and study designs.

However, current evidence does not consistently demonstrate superior short- or mid-term clinical outcomes, lower dislocation rates, or reduced revision rates with computer-assisted techniques. Large database analyses often show minimal or no clinically meaningful differences, and in some cases slightly higher revision rates have been reported.

Several factors may explain this discrepancy. First, instability is multifactorial and influenced by patient-specific variables such as spinopelvic mobility, soft-tissue balance, surgical approach, and implant design. Improved cup positioning alone may not fully mitigate these risks. Second, many studies have relatively short follow-up periods, limiting assessment of implant survivorship.

Future research should emphasize long-term outcomes, cost-effectiveness analyses, and patient-centered functional metrics such as return to activity, high-demand mobility, and

quality-of-life measures. Subgroup analyses focusing on high-risk populations—such as patients with prior spinal fusion—may help identify cohorts that derive the greatest benefit from navigated or robotic technologies.

Economic considerations remain critical. Increased operative time, capital investment, and training requirements must be justified by measurable clinical benefit. At present, it remains uncertain whether improved radiographic precision offsets these costs.

Conclusions

Current evidence suggests that computer-navigated and robot-assisted THA improve component positioning accuracy compared with the conventional freehand technique. However, this radiographic precision has not consistently translated into superior short- to mid-term clinical outcomes, reduced dislocation rates, or lower revision rates.

Long-term survivorship data and robust cost-effectiveness analyses remain insufficient to definitively establish superiority over the conventional technique. Further high-quality, long-term comparative studies are required before computer-assisted THA can be considered unequivocally superior to traditional approaches.

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