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ROBOTIC-ASSISTED HIP ARTHROPLASTY COMPARED TO THE CONVENTIONAL TECHNIQUE, A CURRENT SYSTEMATIC REVIEW

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Abstract: This systematic review set out to compare the outcomes of robot-assisted total hip arthroplasty with conventional surgical techniques, focusing on clinical, radiographic and functional results. With advances in robotic systems, it is essential to evaluate the possible benefits over traditional methods in order to improve patient care. A systematic search was carried out in the PubMed database, covering studies published between 2018 and 2024 that compared robot-assisted and conventional total arthroplasties. The keywords used included "robot", "robotic", "arthroplasty" and "hip". Randomized clinical trials, prospective and retrospective cohort studies, and comparative observational studies with postoperative outcomes were included. Studies that did not provide direct comparisons, presented significant preoperative comorbidities or did not include robust follow-up were excluded. Ninety-seven studies were initially identified, with six meeting the criteria for full analysis. The results showed that robot-assisted surgeries offered greater precision in implant alignment, with a tendency towards better functional outcomes and a lower risk of complications. However, surgical time was slightly longer. Despite these advantages, the long-term clinical results show little difference compared to conventional techniques, suggesting that more studies are needed to define the superiority of robotic systems.
Keywords: Hip arthroplasty; Robotic surgery; Conventional arthroplasty; Orthopedics, Hip

INTRODUCTION

Total hip arthroplasty (THA) is a procedure with a very high post-operative satisfaction rate for patients undergoing this treatment, and is widely used technically and scientifically to treat various pathologies affecting the hip joint. In recent years, there have been major global technological advances, and this has been no different in medicine, and more recently in orthopaedics, especially with the introduction of robotically assisted procedures, in the case covered by this article, Robotically Assisted Total Hip Arthroplasty (RoATQ).

Through this systematic review, we sought to cover and detail the latest on the subject, including the functional and radiographic results of the procedure compared to the conventional open technique.

THEORETICAL FRAMEWORK OR LITERATURE REVIEW

Total hip arthroplasty (THA) is one of the most widespread and effective surgeries for the treatment of degenerative diseases, such as advanced osteoarthritis of this joint[SINGH, 2011, KUNZE et al, 2022]. These surgical interventions are relatively safe procedures that mainly aim to relieve pain, restore joint function and improve patients' quality of life by replacing damaged joints with prosthetic components, called tribological pairs, made up of acetabular and femoral parts. Traditionally, these surgeries are performed using conventional methods, in which the surgeon does all the planning and manual execution of the procedure. However, in recent years, robotically assisted surgery has emerged as an innovative technology that promises greater precision in the positioning of prostheses [CHEN et al, 2018].

Epidemiologically, the number of hip replacements has increased globally due to the aging of the population and the growing search for improved mobility and, consequently,

quality of life [PATEL et al, 2023]. In 2019, at least 262,369 THA surgeries were performed in the United States, counting only Medicare patients, and it is projected that by 2030, the number of total hip replacements will reach 433,372 procedures [SHICHMAN et al, 2023]. In this context, robotic surgery, which was initially used in areas such as urology and gynecology, is now gaining ground in orthopedics, with the potential to further improve the results of these interventions.

The literature already points to some potential advantages of robotic surgery in arthroplasty. Studies suggest that precision in the alignment of prosthetic components, which is crucial for the long-term success of the surgery, is superior when robotic technology is used [KOW et al, 2024]. On the other hand, there are challenges and barriers that still need to be overcome, including the high initial costs of implementing this technology, the learning curve associated with the use of robotic systems, the availability of resources and the increase in surgical time until the surgeon gains the necessary experience with these systems. The incorporation of new technologies in orthopaedics can be challenging or disrupt the routine of surgeons already experienced in joint replacement procedures. These innovations do not always result in significant improvements in operations that have already been proven and perfected over time [KUNZE et al, 2022].

Although the potential benefits of robotic surgery are promising, the comparison with conventional methods still generates debate in the scientific community. Some studies argue that the clinical improvements seen with robotic surgery do not justify the additional costs in all cases [KUNZE et al, 2022]. Therefore, the choice between robotic and conventional methods remains a central issue. Although robotic technology offers advances in terms of precision and potentially better outcomes, there is still a gap in knowledge about which patients benefit most from this type of intervention and in which circumstances the conventional method may still be preferred.

Given these considerations, this study seeks to answer the following question: does robotic surgery really provide superior results in terms of clinical, functional and radiographic outcomes when compared to conventional methods in hip arthroplasty? The overall aim of this study is to carry out a systematic review to compare the two methods, synthesizing the current evidence and offering a critical analysis of the benefits and limitations of each approach.

METHODOLOGY

RESEARCH STRATEGY

A systematic search was conducted in **PubMed** databases to identify studies published between 2018 and 2024 that compared robotic surgery with conventional methods in hip arthroplasty. The keywords used included "robot", "robotic", "arthroplasty" and "hip". Specific search criteria were defined to ensure the inclusion of studies relevant to the comparison between robotic and traditional methods.

INCLUSION AND EXCLUSION CRITERIA

The inclusion criteria for this systematic review were: (1) studies that directly compared robot-assisted total hip arthroplasty surgeries with conventional techniques; (2) studies that reported post-operative clinical, radiographic or functional outcomes; (3) randomized clinical trials, prospective and retrospective cohort studies, and observational comparative studies; (4) publications in English or Portuguese.

Studies were excluded if: (1) did not report direct comparisons between the two methods; (2) involved patients with significant comorbidities that could directly influence surgical outcomes; (3) were narrative reviews, meta-analyses or case studies; (4) did not present adequate clinical follow-up or robust postoperative measurements.

SELECTION PROCESS

Initially, 97 studies were identified through the databases. After an initial screening of titles and abstracts, 12 articles were selected for full-text analysis and included in this review, 6 of which made direct comparisons between the techniques. Two independent reviewers assessed the eligibility of the studies based on the pre-defined inclusion and exclusion criteria.

QUALITY ASSESSMENT AND DATA EXTRACTION

The included studies were assessed for methodological quality using the **Newcastle-Ottawa Scale** for cohort studies and the **Cochrane Risk of Bias Tool** for randomized clinical trials. The main variables extracted from the studies included the type of surgery (hip arthroplasty), the use of a robotic system, surgical time, alignment accuracy, clinical outcomes (pain, function, recovery time), and postoperative complications.

DATA SYNTHESIS

The extracted data was organized into comparative tables showing the characteristics of the studies, the research design (randomized, cohort, retrospective, etc.), the sample size, the type of intervention performed, and the authors' conclusions about robot-assisted surgery compared to conventional methods. A qualitative synthesis of the results was carried out due to the heterogeneity of the outcomes and methodologies used in the studies.

RESULTS

The systematic search identified a total of 97 studies, of which 6 were selected for final analysis after applying the inclusion and exclusion criteria. The articles included were grouped in a table: Table 1.

ANALYSIS AND DISCUSSION OF RESULTS

The results of this systematic review highlight the advantages and challenges associated with the use of robotic systems in hip arthroplasty procedures. Several studies included in this analysis show that robot-assisted surgery can offer greater precision in implant positioning, which is crucial for improving clinical outcomes and implant durability [TIAN et al, 2023] (FIGURES 01 AND 02).

GUO et al. (2022) reported that robot-assisted surgery in total hip arthroplasties (THA) improved the accuracy of acetabular dome positioning, reducing the need for surgical revisions. (FIGURE 03)

Although increased precision is a significant advantage, the impact of robotic surgery on operative time and post-operative recovery varies between studies. XU et al. (2024) observed that the use of the LANCET system in THA resulted in greater surgical efficiency, reducing operative time compared to the conventional method. On the other hand, ZHUANG TF. et al. (2023) found that, although robotics provided greater precision, there was no significant difference in functional results compared to conventional THA, whether functional or acute or late end results, such as dislocations and wear, suggesting that the advantage in these terms may not be universal, in addition to the delta of surgical time being highly variable, whether due to intrinsic patient issues or surgeon expertise.

Authors	Year	Methodological Design	No. of Patients	Intervention	Main results
Xu et al. [7]	2024	Prospective randomized, multicentre, parallel-controlled clinical trial	116	LANCET Robotics vs Conventional	The LANCET robotic system has increased surgical efficiency, reducing operative time in total hip arthroplasty, without compromising safety or clinical results.
Guo et al. [8]	2022	Retrospective study	93	Robotics vs Conventional	Robotic-assisted total hip arthroplasty provided more precise positioning of the acetabular cup, with less variation from the predefined target angle, compared to conventional surgery. In addition, patients in the robotic group had a lower rate of angular deviations and a more uniform distribution of implant positions.
Tian R. et al. [9]	2024	Multicenter, prospective, randomized study	104	Robotics vs Conventional	There was no significant difference in postoperative HHS scores, variations in HHS, femoral deviation and lower limb length between the two groups. The seven-axis robot-assisted THA system is safe and effective, providing better positioning of the acetabular cup compared to conventional THA. The improvements observed in HHS scores, limb length and femoral deviation in the robot-assisted group were similar to those in the conventional group.
Zhang X. et al. [10]	2024	Multicenter randomized trial	73	Robotics vs Conventional	The RAS-THA group showed less variability in the planning of the vertical center of rotation (VCOR), better alignment of the femoral stem and a reduction in leg length discrepancy compared to the CO-THA group. There were no significant differences in the Lewinnek safe zone and the femoral canal filling rate. RAS-THA proved to be effective in improving VCOR and reducing variability in leg discrepancy, regardless of surgical approach, gender or overweight.
Zhuang TF. et al [11]	2023	Preliminary study	62	Closed robotic system VS Open robotic system	The authors concluded that robot-assisted, in both open and closed systems, has similar surgical outcomes and safety rates, with comparable learning curves and accurate positioning of the acetabular component. The differences in the rate of positioning within the safe zone were not significant, making the robotic method relatively a useful option for achieving the planned positioning of the acetabular cup.
Tian R. et al [12]	2023	Retrospective Study	160	Robotics vs Conventional	Robot-assisted total hip arthroplasty (Ro-ATQ) with a seven-axis system showed superior results in the proficiency phase compared to the conventional technique. In the proficient phase, robotic surgery showed greater precision in positioning the acetabular cup and superior control of leg length, with 90.5% of acetabular implants positioned in the "Lewinnek safe zone", in contrast to 77.5% in the conventional group.

Table 1: Studies on Total Hip Arthroplasty

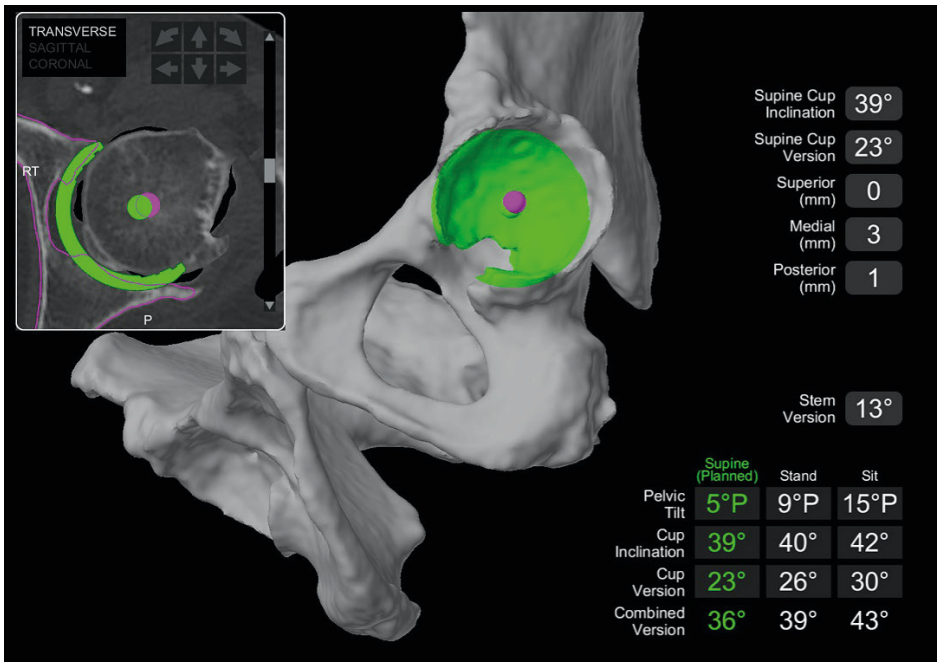

FIGURE 01 - Robotically assisted acetabular planning

Source: STRYKER ORTHOPAEDICS

Note: Planning of acetabular size, including inclination, version and center of rotation, in a tomographic study of the robotically assisted procedure.

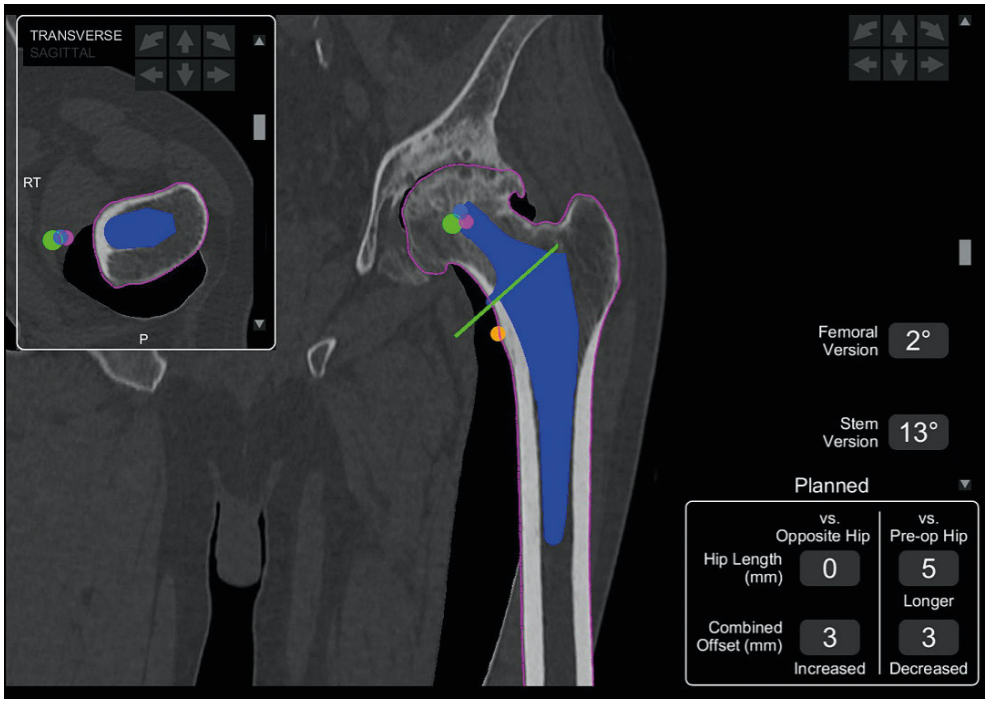

FIGURE 02 - Robotically assisted femoral planning

Source: STRYKER ORTHOPAEDICS

Note: Planning the size of the femoral stem, based on the patient's anatomy, in a tomographic study of the robotically assisted procedure, being able to select cemented or uncemented stems.

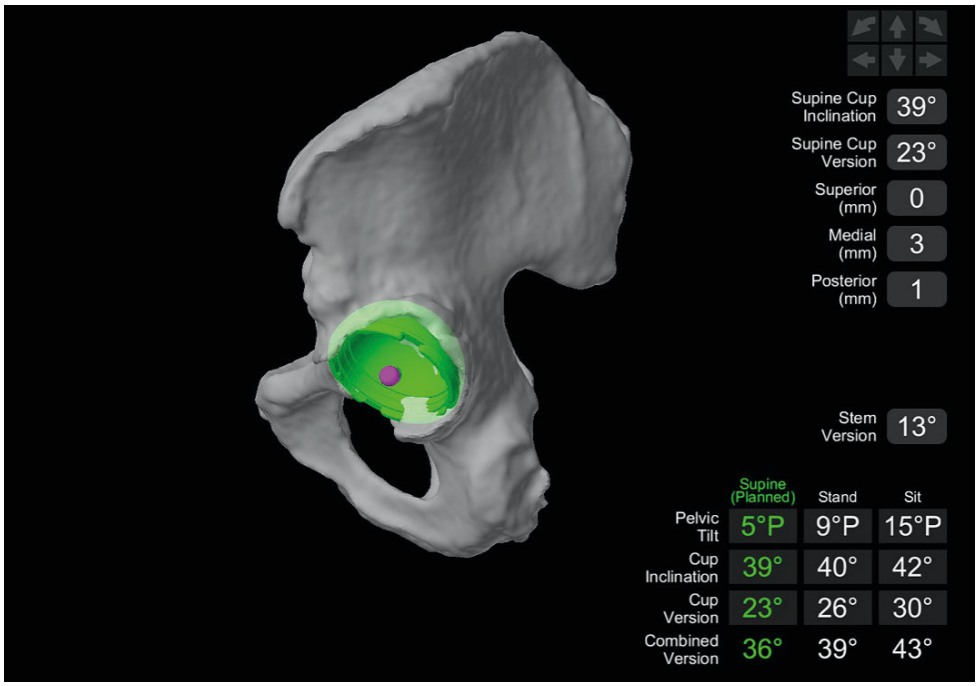

FIGURE 03 - Acetabular positioning

Source: STRYKER ORTHOPAEDICS

Note: Positioning of the acetabular component based on the patient's pelvic position (sitting, standing, prone)

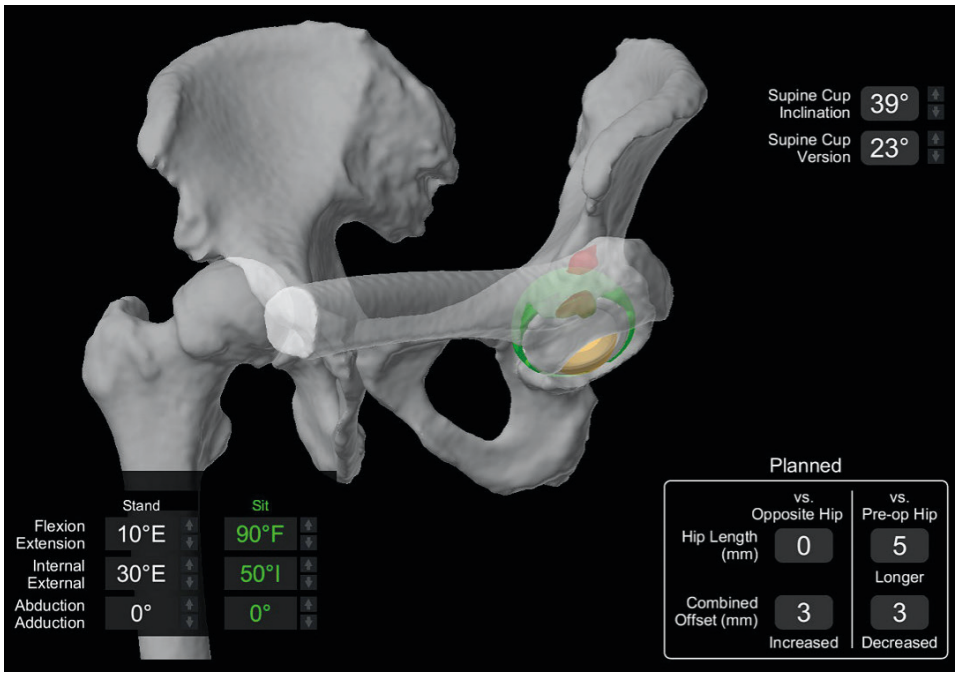

FIGURE 04 - Acetabular positioning

Source: STRYKER ORTHOPAEDICS

Note: Evaluation of the "impingement" of the components in different positions of the limb, pre- and intra-operatively, showing in red the regions where they occur, making it easier to assess situations of possible dislocation.

The safety and efficacy of robot-assisted surgery have also been widely evaluated. XU et al. (2024) confirmed that robotic surgery was safe and effective, offering a three-dimensional intraoperative view that allows direct visualization of component positioning and impingement of tribological pairs (FIGURE 04) without posing additional risks to patients. However, the absence of significant differences in short-term functional outcomes, as observed by ZHUANG TF. et al. (2023), suggests that although robotics offers advantages in technical aspects, these benefits do not always translate into substantial improvements in clinical results. Therefore, the adoption of robotic technology in arthroplasty should be carefully evaluated, considering the costs, the learning curve and the expected benefits.

In short, the variability in clinical results and the need for a significant learning curve for surgeons indicate that although robotic technology represents an important advance, it should be implemented with caution and in contexts where the benefits outweigh the challenges. The real impact of robotics on clinical practice still requires further long-term studies and a comprehensive analysis of costs and results to ensure that patients benefit fully from this emerging technology.

FINAL CONSIDERATIONS

This systematic review concludes that robot-assisted surgery, compared to conventional methods, offers significant benefits in terms of surgical precision, especially in the alignment of implants in hip arthroplasties, leading to more precise objective and radiographic results, especially in the angular tangent and dysmetry of the limb, in addition to the final positioning of the tribological pairs, which can be humanly modified, whether on purpose or not, thus justifying the employability of this surgical method, which also causes a certain leveling among surgeons who use it in relation to the results obtained.

Although these technological advances can improve surgical efficiency and potentially reduce post-operative complications, the short-term clinical results do not demonstrate a substantial difference, whether functional, mechanical or objective, analyzed radiographically in relation to conventional methods conducted by experienced surgeons, since the patient's final perception of improvement is very similar, whether using the robotically assisted technique or the conventional open technique. In addition, the effective implementation of robotic technology requires a considerable learning curve for surgeons, which can initially lead to an increase in operative time, limiting its initial benefits in this regard, as well as additional operating costs that can be substantially higher than the conventional technique, and the indication for each case should be carefully evaluated. Therefore, the adoption of robotic systems should be weighed up, taking into account the costs involved, the possible increase in surgical time and the specific needs of patients, to ensure that the benefits outweigh the challenges in clinical practice, and its study, especially in the long term, lacks sufficient objective data for a definitive assessment of its superiority.

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