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The Emerging Role of Robotics in Revision Hip and Knee Arthroplasty: A Scoping Review

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1. Abstract

1.1. Background

Total hip arthroplasty (THA) and total knee arthroplasty (TKA) are among the most commonly performed surgical procedures, with utilization continuing to rise. As primary arthroplasty volumes increase, rates of revision procedures are also growing. Revision arthroplasty presents unique technical challenges, including bone loss, distorted anatomy, and compromised soft tissue envelopes. Robotic-assisted technology has demonstrated improved accuracy in primary arthroplasty; however, its role in revision procedures remains less clearly defined.

1.2. Purpose

To evaluate the current evidence on robotic-assisted revision THA and TKA, with a focus on surgical accuracy, clinical outcomes, safety, and limitations of current technology.

1.3. Study Design

Scoping Review

1.4. Methods

A scoping review was conducted in accordance with PRISMA-ScR guidelines. A comprehensive search of PubMed and the Cochrane Library was performed for studies published between January 2010 and December 2025. Eligible studies included adult patients undergoing robotic-assisted revision THA or TKA and reporting clinical or technical outcomes. Study selection, data extraction, and synthesis were performed independently by two reviewers. Outcomes of interest included component alignment, functional outcomes, complications, operative time, and implant survivorship.

1.5. Results

A total of 22 studies met inclusion criteria. Robotic-assisted techniques generally demonstrated improved component positioning accuracy, alignment, and reproducibility compared with conventional methods. However, improvements in functional outcomes were inconsistent across studies. Operative time was generally increased with robotic assistance, while blood loss and length of stay showed no consistent differences. Complication rates were low and comparable between robotic-assisted and conventional techniques. Early survivorship outcomes were favourable across both groups, with no clear differences in revision or reoperation rates identified within available follow-up periods.

1.6. Conclusion

Robotic-assisted revision arthroplasty offers improved surgical precision and consistency without increasing complication rates. However, these technical advantages have not consistently translated into better functional outcomes or long-term clinical benefits compared with conventional techniques. Much of the current literature is limited by variability in study design, small sample sizes, and short follow-up periods. Additional high-quality, longitudinal studies are needed to better understand the clinical value of these technologies.

2. Introduction

Total joint arthroplasty represents one of the most effective and widely performed interventions for end-stage degenerative joint disease, with projected annual volumes exceeding 650,000 total hip arthroplasties (THA) and 1.26 million total knee arthroplasties (TKA) in the United States by 2030 [1]. Rates of these procedures have continued to rise despite significant economic changes in the United States over the last 10 years [2,3]. THA is a procedure that involves replacing a degenerated, arthritic, or otherwise dysfunctional hip joint with an artificial ball-and-socket type joint. Indications for the procedure include pain, diminished function, radiologic changes, and failed conservative therapy [4]. Indications for TKA are similar, involving pain, functional limitation, radiographic degeneration, and failure of conservative management [4]. The knee joint is particularly susceptible to degenerative changes due to its weight-bearing function, complex biomechanics, and limited amount of cartilage.

Despite the success of primary arthroplasty, revision procedures are increasing at an even greater rate, reflecting both the expanding volume of primary surgeries and the growing longevity of the patient population [4,5]. Of the cases reviewed, the most common reason for revision was postoperative joint instability, which accounted for 22.5% of revision cases. This may be associated with continued degeneration of natural soft tissue that was not replaced in the original surgery. This is distinct from mechanical loosening, the second most common cause of revision, which involves failure of the implanted components. Postoperative infection is the next leading cause of revision arthroplasties [6].

Revision joint arthroplasty surgeries present unique technical challenges, including bone loss, distorted anatomy, and compromised soft tissue envelopes, all of which complicate implant fixation and restoration of joint biomechanics [7,8]. The most important of these complications is patient bone loss [7]. Inherently, there is less natural soft tissue present in patients who have already had a primary joint replacement surgery, and maximizing soft tissue preservation is associated with significant improvement in mobility and decreases in recurrent pain symptoms [8]. Lower amounts of soft tissue maintained during arthroplasty procedures was associated with higher risks of second and third revision surgeries [9]. Advanced reconstructive strategies, such as bone grafting, have been utilized and shown to improve post operation recovery and decreased needs for third revision surgeries. Soft tissue donations from other patients, however, comes with its own risks including transplant rejection and an increased risk of infection [8]. Other unique risks of revision surgeries include distorted anatomy from the implant, increasing fracture risk, and soft tissue imbalance from acute or chronic implant rejection.

The increasing use of robotics in surgery has interesting implications in THA, TKA, and revisional joint procedures. Robotic-assisted (RA) surgeries have shown more accurate implant placement, which could help to mitigate a lot of the adverse reactions to the procedures and decrease risk of revisional surgery. Some drawbacks to robotic-assisted (RA) surgery have been found, including a seven procedure learning curve for surgeons and increased physician anxiety while using new tools [10]. Due to the relatively new advent of robotic use in arthroplasty procedures, further research is needed to show how this affects risk of requiring revision surgery [11]. However, the application of robotic systems in revision arthroplasty remains poorly defined, as the majority of existing literature focuses on primary THA and TKA. Exploratory analyses showed that the most important factors for patients receiving a revision arthroplasty included returning to normalcy, faith in surgical team, decreasing frequency of hospital visits, and decreasing travel time for hospital visits, but did not mention method of procedure [12]. Therefore, this scoping review aims to evaluate the current evidence surrounding robotic-assisted (RA) revision THA and TKA, with a focus on surgical accuracy, clinical outcomes, and limitations of current technology.

2.1. Methods

This scoping review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) framework. A protocol outlining the review objectives, eligibility criteria, and planned search and data-charting procedures was developed prior to study initiation and followed throughout the review process.

2.2. Eligibility Criteria

Eligibility criteria were defined using the Population–Concept–Context (PCC) framework. Studies were eligible for inclusion if they were published between January 2010 and December 2025, provided original clinical data, evaluated robotic-assisted revision total hip arthroplasty (THA) or revision total knee arthroplasty (TKA), and included adult patients aged 18 years or older. Eligible study designs encompassed randomized controlled trials, prospective or retrospective cohort studies, case series with original clinical data, and pilot or feasibility studies. To be included, studies were required to report at least one clinically relevant outcome related to revision arthroplasty, such as component alignment, functional outcomes, complications, operative time, or implant survivorship.

2.3. Search Strategy

A comprehensive literature search was conducted across two major biomedical databases: PubMed and the Cochrane Library. Searches covered the period from January 1, 2010, through December 31, 2025. Search strategies incorporated controlled vocabulary and free-text terms related to robotic surgery, revision arthroplasty, revision THA, and revision TKA. Boolean operators were used to combine concepts, and search strings were adapted for each database. No automation tools or machine-learning classifiers were used. The search identified 25 records from PubMed and 42 records from the Cochrane Library, for a total of 67 records. After removal of 9 duplicates, 43 unique records proceeded to title and abstract screening.

2.4. Study Selection

Study selection occurred in two stages. First, two reviewers independently screened titles and abstracts using predefined eligibility criteria. Records deemed potentially relevant underwent full-text review, also conducted independently by two reviewers. Discrepancies at either stage were resolved through discussion.

Of the 43 records screened, 20 were excluded because they reported no results, were pending or in-progress trials, or did not meet eligibility criteria. One additional record was excluded due to inaccessible full text. A total of 22 studies met inclusion criteria and were included in the final review. The study selection process is summarized in the PRISMA-ScR flow diagram (Figure 1).

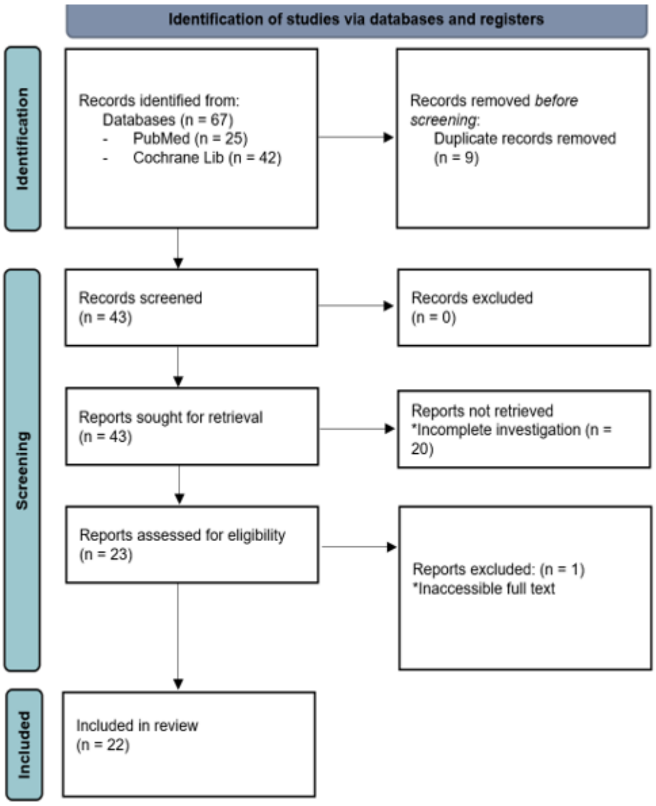


Figure 1: PRISMA-ScR flow diagram illustrating the identification, screening, and inclusion of studies from database searches. A total of 67 records were identified (25 from PubMed and 42 from the Cochrane Library), with nine duplicates removed prior to screening. 43 records underwent title and abstract screening, all of which proceeded to full-text retrieval. 20 reports could not be retrieved due to incomplete investigations, leaving 23 full texts assessed for eligibility. One report was excluded due to inaccessible full text, resulting in 22 studies meeting all criteria and being included in the final review.

2.5. Data Charting

A standardized data-charting form was developed and piloted to ensure consistency across reviewers. Two reviewers independently extracted data from all included studies, resolving disagreements through consensus. Extracted variables included study characteristics (author, year, country, design), surgical context (revision THA vs revision TKA), robotic platform, registration method, imaging modality, bone-loss classification, implant type, and details of the revision procedure. Clinical outcomes included component alignment accuracy, functional scores, complications, operative time, survivorship, and comparisons with conventional revision techniques.

2.6. Synthesis of Results

Consistent with scoping review methodology, no formal risk-of-bias assessment or meta-analysis was performed. Extracted outcomes were synthesized descriptively and organized by surgical procedure (revision THA vs revision TKA), robotic platform, technical application, and clinical outcome domain. Heterogeneity in robotic systems, revision indications, bone-loss patterns, and outcome reporting precluded quantitative pooling. Findings were therefore summarized narratively to map the current state of evidence and identify gaps relevant to future research.

Revision Total Hip Arthroplasty (rTHA)

2.7. Preoperative CT Planning

RA revision total hip arthroplasty (rTHA) begins with preoperative CT imaging of the pelvis and femur that is used to generate a three-dimensional (3D) reconstruction of the patient’s hip anatomy. The models are essentially templates that help guide the surgeon to strategically plan acetabular cup inclination, anteversion, femoral stem size, amount of leg lengthening or shortening needed, and restoration of the hip center of rotation. CT-based planning enables patient-specific implant selection and positioning tailored to individual anatomy and biomechanics [13-17].

2.8. Restoration of Hip Biomechanics and Alignment Optimization

During a RA rTHA, the robotic system translates the preoperative plan into intraoperative execution, allowing for precise restoration of hip biomechanics. The robotic arm provides real-time feedback and haptic boundaries to guide acetabular reaming and cup placement within predefined inclination and anteversion angles [13-16]. Additionally, RA rTHA aims to conserve bone by limiting unnecessary removal of subchondral bone and avoiding excessive over-reaming of the acetabulum. Additionally, robotic systems facilitate placement within established radiographic targets, such as the Lewinnek and Callanan safe zones, which are associated with reduced risk of dislocation. In conventional THA, it was reported that 62% of cups were in the modified safe zone in comparison to RA THA that yielded 92% [14]. Similarly, RA THA group in study [17] had a higher proportion of patients in the cup placement safe zones as well. Robotically assisted cups have been shown to more consistently fall within these safe zones compared to conventionally placed cups, reflecting improved accuracy and reproducibility [13-17]. This increased precision may contribute to reduced rates of dislocation and impingement while improving prosthetic hip stability and implant longevity [13-15].

2.9. Technical Challenges

No intraoperative complications related to robotic systems, such as iatrogenic damage to bone or surrounding soft tissue, were reported, suggesting that robotic guidance can be safely integrated into surgical workflows [13,15]. While challenges such as distorted anatomy may complicate preoperative planning, CT-based software and intraoperative mapping techniques help mitigate these issues by enabling patient-specific modeling and controlled bone resection. However, these challenges are not entirely eliminated and may still impact accuracy in complex cases. There was no statistical difference in revision cases between RA THA and conventional THA [13,15,17]. However, the study did not further evaluate whether revision procedures are more technically challenging with RA THA, highlighting an area for future investigation. Several limitations were identified across the included studies. Study [16] was affected by loss to follow-up and a high proportion of patient attrition over time. In study [16,17], all procedures were done by a single-surgeon study, which may limit generalizability to broader surgical populations and can therefore vary the intraoperative findings.

3. Revision Total Knee Arthroplasty (rTKA)

3.1. Alignment and Balancing

RA revision total knee arthroplasty (rTKA) systems are used to optimize mechanical and kinematic alignment through improved preoperative planning, intraoperative guidance, and live feedback that improve the precision of implant positioning and restoration of limb alignment during surgery. These systems integrate imaging-based or imageless mapping to generate specific models for patients. This allows surgeons to specify implant size, orientation, and positioning to the patient's individual anatomy. For example, CT-based robotic systems create 3D reconstructions that guide bone resections and implant placement to optimize mechanical alignment along with knee kinematics [18]. Furthermore, robotic assistance has shown to improve the accuracy of component alignment and reduce variability compared to conventional techniques. This is the primary rationale for its development and increased implementation [19].

Robotic techniques help provide dynamic tracking of limb position and continuous feedback on alignment parameters. This enables much more precise execution of the operative plan and outcomes. Systems such as ROSA assist with accurate jig positioning and translation of the planned alignment into the final implant construct, resulting in fewer outliers from the desired mechanical axis and improved overall limb alignment [20]. Similarly, RA techniques continuously demonstrate improved prosthetic alignment compared to traditional and even computer assisted approaches. This supports their role in optimizing coronal and sagittal alignment during TKA [1].

Beyond alignment, robotic systems play a vital role in flexion extension gap balancing, which is essential for joint stability and functional outcomes postoperatively. Conventional TKA relies on subjective intraoperative assessment, that varies from surgeon to surgeon, of ligament tension. In contrast, robotic systems provide quantitative, live measurements of soft tissue balance throughout the range of motion. This feedback is vital for a surgeon to improve operative execution. Imageless systems such as NAVIO and CORI enable intraoperative mapping of the articular surface, measurement of the mechanical axis, along with assessment of soft tissue tension under varus/valgus stress. This enables surgeons to evaluate gap symmetry dynamically [21]. These systems guide adjustments to implant positioning and bone resections based on live gap data provided by the systems. This improves the accuracy of flexion and extension balancing, a critical component of surgical procedures.

Additionally, robotic techniques incorporate ligament balancing methods that evaluate and adjust gap tension prior to and during bone resection. This live feedback and data enables surgeons to improve decision making before and during operation. Additionally, this allows surgeons to optimize component positioning to achieve balanced gaps in both flexion and extension before final implantation. Literature suggests that improved gap balancing and soft tissue management with robotic systems can potentially enhance surgical precision and reduce postoperative alignment deviations, which is a potential complication [18]. Improper flexion extension gap balance is known to contribute to altered knee biomechanics and prosthetic failure, this capability represents a significant advantage of RA techniques.

3.2. Joint Line Restoration

Restoration of the native joint line is a critical parameter in TKA. It can directly influence knee biomechanics, ligament tension, and overall functional outcomes for the patient. Impacting the joint line can offset soft tissue balance, impair flexion extension mechanics, and overall contribute to abnormal loading patterns that may accelerate prosthetic wear or compromise implant durability. These are consequences that must be considered. In addition to overall mechanical alignment, precise component positioning along with preservation of joint line height and orientation is vital for achieving optimal postoperative knee functional outcomes [18].

The impact of joint line restoration is further emphasized in modern alignment approaches. Functional and kinematic strategies specifically aim to replicate the patient's original knee anatomy, including restoration of the joint line, in order to optimize soft tissue balance and improve outcomes [22]. In contrast to traditional mechanical alignment, which prioritizes a neutral limb axis, these approaches highlight the need to maintain native joint line orientation and may reduce the need for soft tissue releases. This would better preserve physiological knee kinematics [22]. Accurate joint line restoration is closely associated with achieving balanced flexion extension gaps and more natural joint mechanics.

RA has been introduced to improve the precision of these parameters through enhanced planning and execution of bone resections. Robotic systems utilize preoperative imaging and 3D modeling to determine ideal implant positioning. This allows for more accurate restoration of anatomical landmarks such as the joint line and posterior condylar offset (19). This high level of precision helps reduce variability associated with manual techniques and improves the reproducibility of component placement. This ultimately improves outcomes.

Robotic platforms provide live feedback and allow surgeons to make vital adjustments to implant positioning before and during bone resection. This capability enables fine tuning and refinement of femoral and tibial cuts to maintain joint line height and orientation while also optimizing alignment and soft tissue balance. Additionally, RA systems facilitate “pre-resection planning”. This is achieved with virtual component positioning and gap assessment that are performed prior to irreversible bone cuts. This enables surgeons to adjust the operative plan to better preserve the native joint line and achieve balance [22]. Some extended randomized data demonstrate similar final joint line measurements between RA and conventional techniques. However, robotic systems are consistently designed to enhance the accuracy and consistency of component positioning and alignment [19]. This suggests that the advantage lies in reducing outliers and improving surgical consistency rather than producing large differences in average radiographic parameters.

3.3. Bone Defect Management

Robotic planning in bone defect management centres on defining implant position in three dimensions before bone preparation begins and then executing that plan with greater precision during operation. For example, stem related reconstruction using robotic systems preoperatively and CT-based planning helps to select femoral implant size and position in 3D. Then the robotic platform prepares the femur according to that generated plan. This approach is intended to improve the fit and orientation of the stem and reduce the variability associated with manual canal preparation [23].

More complex reconstructions can utilize robotic planning that allows the position to be adjusted to the patient’s anatomy rather than forcing every case into a single target. For example, acetabular reconstruction uses CT-based 3D templating to plan component positioning. The surgeon could then modify abduction and anteversion goals to avoid conflicts with bone anatomy such as implant prominence. Optical navigation then registered the intraoperative anatomy to the preoperative plan, and the robotic arm guided reaming and cup placement while helping recreate the desired centre of rotation. This is particularly relevant and crucial in difficult anatomy, where robotic assistance was used in patients with more challenging anatomy and a higher incidence of preoperative deformity [16].

The same preoperative principles are important when stems are required. Robotic execution on the femoral side has been associated with more neutral stem alignment, a higher canal fill ratio, lower subsidence, and less leg length discrepancy. This indicates that preoperative planning combined with robotic preparation may improve reconstruction of the femoral side when accurate stem fixation and restoration of mechanics are critical for the goals [24].

A highlight and strength of robotic planning is that it supports patient specific targets. Tailoring the operation for each unique patient. Rather than relying only on conventional safe zones, robotic systems can be used to pursue anatomic goals that account for bone anatomy, pelvic tilt, spinal mechanics, functional demands, and femoral version. Greater precision helps the surgeon reproduce those individualized targets more reliably, which is valuable when reconstruction is technically demanding [16].

Robotic planning therefore offers the greatest advantage in cases requiring stems or complex reconstruction by improving preoperative planning, enabling implant position to be modified to abnormal anatomy on a case by case basis. This enables the translation of the plan accurately during surgery.

4. Results

4.1. Study Characteristics

Of the 22 included studies, five were comparative studies [2,14,16,25,26], one was a secondary analysis of a randomized controlled trial (RCT) [27], and the remaining studies included a mix of case series and randomized trials [13,18,19-21,23,28,29]. Sample sizes across these studies ranged from 77 to 1,406 participants at baseline and from 77 to 1,348 at the final follow up. Similarly, duration till follow up also had a large range, spanning from three months to 15 years. Most studies however had a follow-up duration between one to three years with only a few long-term studies [2,13,18-21,26-29]. Within these 22 studies, multiple robotic platforms were also used, such as MAKO RIO, ROBODOC, ROSA, NAVIO, CORI, and MAKO [25,26].

4.2. Alignment and Component Positioning Outcomes

When comparing robotic and conventional revision techniques with respect to component positioning, accuracy, joint line restoration, and alignment precision, consistent trends were observed. Across studies that reported these metrics, robotic assistance demonstrated improvements in all three metrics [2,13,14,16,18-21, 23,25-29]. Robotic platforms incorporate patient-specific preoperative CT imaging, which reduces margin of error during component placement and contributes to improved positioning accuracy and restoration of joint anatomy. Although not all studies directly reported joint line restoration, several noted that robotic platforms more closely replicated native joint biomechanics [2,13,20,23,25,27-29]. These improvements were also associated with greater consistency, tighter clustering of measurements, and fewer outliers [2,13,14,16,18-21,25,27-29]. Collectively, these findings highlight the anticipated advantages of robotic assistance regarding accuracy and reproducibility during procedures.

4.3. Operative and Perioperative Outcomes

In contrast, evaluation of metrics such as operative time, blood loss, and length of stay revealed less consistent advantages of robotic assistance. Although not all studies reported all three outcomes, those that did demonstrated that robotics did not always yield favourable results. For example, several studies noted that robotic procedures often increased operative time [19-21]. In some cases, robotic platforms increased operative time by more than 40 minutes in comparison to conventional methods [21]. Similarly, findings regarding blood loss during operation were mixed [19-21]. There was no clear trend across the included studies that indicated either increased or decreased efficiency due to robotic assistance. Lastly, robotics and conventional methods were both shown to have similar effects on the length of stay [20,21,27]. Together, these findings did not demonstrate a significant advantage in using robotic platforms during procedures.

4.4. Survivorship and Revision Outcomes

Finally, early survivorship and re-revision rates were also analyzed. Across all 22 studies, early survivorship and re-revision rates revealed favourable outcomes for both RA and conventional techniques. All studies reported early survivorship rates of at least 95%, with several noting higher rates among RA procedures [2,13,18,19,21, 23,25-27,29]. Although some patients required revision surgery, these procedures were usually due to issues such as aseptic loosening [2,16,18,19,29] or head/liner exchanges [13,16] rather than complications due to malposition or malt racking. Furthermore, regardless of whether robotic assistance or conventional techniques were used, none of the studies reported re-revision procedures during their follow-up periods.

4.5. Functional Outcomes

Functional outcomes vary by procedure type. In THA, a prospective cohort study with three-year follow-up found no significant differences in Oxford Hip Score (42 vs 41, p=0.914) or Forgotten Joint Score (89 vs 86, p=0.065) between robotic and conventional groups [25]. However, a pair-matched controlled study at two-year follow-up reported significantly higher Harris Hip Scores (p<0.001) and FJS-12 scores (p=0.003) favouring robotic assistance, with 2.4 times higher odds of achieving meaningful FJS-12 thresholds (17). A 14-year FDA trial follow-up demonstrated significant improvements in HSQ pain (83.75 vs 72.65, p=0.019) and total WOMAC scores (8.44 vs 11.32, p=0.034) favouring robotics, although differences fell below MCID thresholds [13]. A 10-year randomized trial found no differences in JOA scores between robotic milling and hand rasping [23].

In UKA, a randomized trial with two-year follow-up showed no overall OKS or AKSS differences between groups. However, analysis of active patients (preoperative UCLA >5) revealed much better outcomes with robotic assistance. Median OKS 46 vs 41 (p=0.009) and median AKSS 193.5 vs 174.0, exceeding MCIDs [29]. Early recovery data showed robotic patients had 55.4% lower pain scores through eight weeks (p=0.040) [27].

In TKA, a three-arm pilot trial with three-year follow-up found that despite superior alignment and 100% robotic survivorship, robotic TKA demonstrated significantly lower KSS knee scores (91±3) compared to conventional groups (93±3, p=0.011) [18]. A separate randomized trial reported comparable OKS and EQ-5D-5L improvements between groups at one year [20].

4.6. Complication Rates and Safety Outcomes

Complication rates were low across all studies. Intraoperative complications were rare: THA studies reported 0% in robotic groups versus 1.5% in manual posterior hips [16], UKA trials reported none in either group [27,29], TKA trials reported none, but robotic TKA had longer surgical times (75.8 vs 56.3 minutes, p<0.001) and a small amount of increased blood loss (1.2 vs 0.9 mmol/L, p=0.029) [20].

Postoperative complications showed no significant differences. THA dislocation rates ranged 0-2% across groups; minor complications were comparable (8.2% robotic vs 7.1% manual) [13,16,17,25]. UKA reported no postoperative infections requiring subsequent operations [29]. TKA reported one conventional patient (1.6%) with deep infection requiring two-stage treatment at 3 years [18].

Reoperation and revision rates trended up for robotics without statistical significance. THA pair-matched study: 1.1% robotic revision vs 3.5% manual (p=0.621) (17). UKA: 100% robotic survivorship vs 96.3% manual at 2 years (29). TKA: 3-year survivorship 100% robotic vs 97% CAS vs 96% conventional [18].

4.7. Comparative Analysis

Robotic assistance consistently improved radiographic accuracy across all applications. In THA, RA posterior THA achieved 97% within target zone versus 76% manual posterior (RR reduction 87%, p<0.01) and 84% fluoroscopic anterior [16]. A pair-matched study found 98.8% robotic within Lewinnek safe zone versus 78.8% manual (OR 22.6, p<0.001), with significantly lower leg-length discrepancy (3.0±2.6mm vs 4.0±2.7mm, p=0.013) (17). Functional superiority was reported in two studies [13,17), but not replicated in others [23,25].

In UKA, robotic assistance achieved significantly more accurate component implantation in all three planes [27,29]. Functional benefits were confined to active patients (UCLA >5), with robotic surgery and preoperative activity identified as key predictors of excellent AKSS outcomes, while manual surgery and depression predicted worse outcomes [27].

In TKA, robotic assistance achieved mechanical axis deviation <1° in 72% versus 30% conventional, with deviation >3° in 0% robotic versus 15% conventional [18]. Another trial found malalignment in 18% robotic versus 38% conventional (p=0.047). Despite these significant alignment advantages, functional improvements were not observed at one to three years. Predictors of outcome included preoperative OKS and implant design; robotic assistance showed a non-significant positive trend (b=2.78, p=0.13) [20].

5. Discussion

5.1. Synthesis of Findings

Three consistent trends emerge: (1) robotic assistance reliably improves radiographic accuracy across THA, UKA, and TKA; (2) safety profiles are comparable with no increased complications; (3) translation of improved alignment to functional outcomes is inconsistent, appearing most evident in active UKA patients and long-term THA follow-up. The evidence includes multiple randomized controlled trials and prospective cohorts with follow-up ranging from one to 14 years. Long-term FDA trial data represents a notable strength for THA. Subgroup analyses in UKA studies provide insight into patient-specific moderators of treatment effect. THA studies conflict on functional superiority; TKA studies consistently show improved alignment without corresponding functional benefit, raising questions about alignment as the primary driver of outcomes. Variability in surgical approaches, implant designs, and robotic platforms prevent pooled analysis. Most of the studies exclude complex cases, which limits the generalizability. Variability in robotic platforms (active vs semi-active, CT-based vs imageless) prevents standardization. Industry sponsorship brings up potential funding bias. MCID thresholds for group comparisons at long-term follow-up are not standardized, complicating interpretation of statistically significant but clinically modest differences.

5.2. Technical Challenges and Registration Limitations

Arthroplasty systems assisted by navigation and robotics are highly dependent on accurate intraoperative registration to ensure the surgical plan accurately corresponds to patient anatomy. The process is complex and involves correlating preoperative imaging information with intraoperative anatomical or fiducial landmarks. Because revision arthroplasty typically involves prior implants, bone loss, and/or altered anatomy, this registration process becomes increasingly difficult due to the distortion or obscuring of landmarks that are typically required.

Many RA surgeries, including THA, rely on preoperative computed tomography (CT) imaging to generate the 3D anatomical models for these registration purposes and surgery planning. An example of this can be seen with a robotic systems operation of femoral canal preparation where preoperative planning and CT information is used to execute the robotic milling of the proximal femur [23]. Accuracy and execution requires very precise alignment between the preoperative plan and CT model as well as what patient anatomy is seen intraoperatively [23]. Prior surgeries and/or deformities make the identification of reliable reference points much more difficult and can potentially affect the accuracy of the registration process [23]. Historically, some robotic platforms used for hip arthroplasty required the placement of these fiduciary markers in the femur prior to surgery to better align the procedure for intraoperative registration [13]. These fiduciary markers are essentially used to align the robotic system with the preoperative CT imaging and surgical plan with spatial positions that correspond directly to the patient's intraoperative anatomy [13]. This approach can enhance the precision of the robotic system in procedures with patients having intact anatomy. Revision settings may present additional challenges if bone defects, implants, or altered femoral geometry is present, all of which may interfere with marker placement or identification.

Intraoperative registration may also rely on temporary navigation pins that can secure optical tracking arrays to the patient skeleton. These pins are typically placed within the femoral or tibial diaphysis for knee procedures or the iliac crest for hip surgeries. These fixation points enable intraoperative mapping of anatomical landmarks. While introducing additional surgical steps and prolonging surgery, these temporary navigation points are essential components of many computer/robot assisted systems and may introduce additional complication risk [16]. In a retrospective cohort study of 839 patients and 3,136 pin sites, five complications were found. The complications included pin site infection, neuropraxia, and suture abscess, all of which were managed without further operations (16). The corresponding rate of complication per pin site was recorded as 0.16% and 0.60% per patient [16]. Furthermore, revision arthroplasties face complications due to compromised bone quality or previously installed hardware, affecting the safe placement of navigation pins and possibly affecting the tracking system used by the computer or robot tools used in the operations [16].

Altered anatomical landmarks may cause even further registration challenges, as malposition of prosthetic components in knee arthroplasty is possible when landmarks are altered pathologically [18]. Variations in bone morphology can cause inaccurate identification of reference points required for robotic procedures and computer assisted guidance [18]. Although these findings were reported in primary procedures, this issue can still present in secondary procedures and beyond.

Robotic systems prepare bone with minimal deviation from the registered surgical plan. Therefore, accuracy of implant placement depends heavily on clarity and accuracy of the imaging assisted registration process. This indicates that errors in registration and preparation phases directly affects the accuracy of the robotic systems execution which may compromise implant positioning accuracy [23].

5.3. Learning Curve and Operative Efficacy

Introducing robotic and navigation assisted tools in arthroplasty also introduces a learning phase where surgeons must adapt to new workflows, preoperative planning requirements, and intraoperative registration processes. Additional steps increase procedure complexity and changes conventional techniques which may influence surgical efficiency early on. One study describes the use of tracking pins and landmark registration that is required for navigation assisted arthroplasty, showcasing the additional technical steps that are necessary for system use [16]. Despite these added steps, the study consisting of 839 hip and knee arthroplasty procedures demonstrated complication rates no higher than 0.60% per patient, suggesting that early adoption of navigation and robotic assistance systems do not significantly increase adverse events [16].

One of the common reported indicators for this learning curve is increased operation time during early implementation. A randomized controlled trial compared robot assisted and manual TKA reported that the assisted procedures are associated with increased operative times of approximately 38–44 minutes compared to manual techniques early in adoption [21]. The time differences were attributed to the additional steps such as the anatomical mapping and system registration that must take place pre-operatively and the pre- and intra-operative surgical planning required by the robotic platforms [21].

Although operative efficiency has been reported to decrease initially, several studies suggest that robotic guidance may improve technical accuracy which can even be seen in the early stages of adoption. RA THA demonstrated higher rates of acetabular cup placement within established safe zones compared with conventional techniques, with 100% of robotic cases falling within the Lewinnek safe zone versus 80% of manual cases [14]. Improved prosthetic alignment was also consistently reported in robotic and computer assisted total knee arthroplasties, despite the increased procedure complexity seen with these systems [14].

Studies that assessed long-term outcomes indicate that even with the improvement of technical parameters in RA operations, the overall clinical benefit as related to conventional techniques is still uncertain [23]. A randomized clinical trial with a minimum 10-year follow-up found no significant difference in clinical outcome scores or revision rate between the RA and conventional femoral preparation techniques in THA [23]. These data indicate that although surgical precision may be enhanced via robotic and navigation assisted surgeries the long-term clinical outcomes must continue to be assessed to determine which method is superior.

There are many studies that evaluate robotic arthroplasty conducted by skilled surgeons within controlled research settings. One such example reported that robotic procedures that were performed by surgeons who had received prior robotic training experience may be able to reduce the apparent learning curve [21]. The consensus is that robotic arthroplasty adoption may initially increase operation times due to system set up, preparation, and registration requirements, but the rates for complications remain low and implant positioning accuracy may improve early on in adoption of these systems [14,16,18,21,23].

5.4. Radiation Exposure and Imaging Considerations

Imaging is already heavily relied on for preoperative planning, but robotic and navigation software require 3D anatomical models, most widely used and most cost effective for this method being CT imaging. This approach does enable precise implant templating and intraoperative guidance, but it introduces concerns regarding additional radiation exposure compared to traditional arthroplasty techniques that would traditionally rely on standard radiographs and anatomical landmarks visualized during operation.

One such robotic system, ROBODOC, utilizes CT scans of the hip and knee to construct a 3D model for preoperative planning. Surgeons use ROBODOC and CT to digitally position implants and guide robotic milling of the femoral canal during surgery [13]. This method of CT-based workflow allows for accurate and safe reconstruction of patient anatomy such as the femoral head position, leg length, and offset, but it requires additional imaging beyond that is used in conventional arthroplasty [13].

Another example study indicates that RA THA also uses CT imaging to form a computer aided design model of the joint [14]. The model is then used to plan implant placement prior to surgery and is then matched with intraoperative anatomical landmarks to guide robot execution (14). In this method, accuracy of acetabular cup positioning compared to conventional techniques was much improved, but this method requires extensive CT imaging as part of the robotic workflow [14].

Because conventional arthroplasty generally relies on standard radiographs, less CT imaging, and more use of intraoperative landmark visualization by the surgeon, conventional arthroplasty generally results in less patient exposure to radiation. However, new none-CT based techniques are being developed. X-ray, MRI, and infrared imaging methods are becoming more popular to limit radiation exposure. CT imaging remains as a gold standard for precise 3D bone modelling [13,14].

5.5. Limitations of Current Evidence

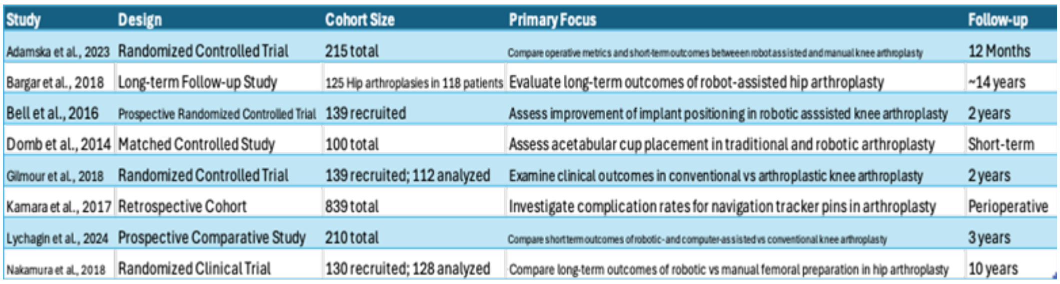
Many of the studies evaluating robot assisted arthroplasty are limited by relatively small sample sizes and short follow-up durations, which in turn restricts the ability to draw definitive conclusions in relation to long-term outcomes and implant survivorship. Randomized controlled trials that have been included frequently involve modest patient cohorts and short-term evaluation. One prospective randomized controlled trial that compared robot assisted and conventional uncompartmentalized knee arthroplasty involved only 139 patients with accurate postoperative accuracy only available in 120 patients [28]. Follow-up took place at only three months and primarily assess positioning accuracy via CT, limiting the ability to conclude long-term outcomes or implant durability [28]. Another randomized controlled trial in RA TKA reported primarily perioperative data like operation time and early postoperative outcomes and only limited long-term follow-up [21]. A third study evaluated robot assisted techniques in 139 patients in which a mix of conventional methods and robot assisted techniques and follow-up took place only two years following operation [29]. In this study, follow-up data analyzed 119 patients [29]. Although several studies provided longer-term follow-up data, these studies were still limited as well. In one study, follow-up took place 14 years postoperatively and demonstrated durable implant fixation and clinical outcomes [13]. This study was limited to observational data and was based on a specific patient cohort treated with an early robotic system, limiting the ability to generalize robot assisted arthroplasty outcomes across other assistance platforms [13]. Similarly, another study from 2018 reported results from a randomized clinical trial with a minimum of 10-year follow-up [23]. It compared conventional and robotic femoral preparations in THA [23]. Even with the extended follow-up time, the study population was limited to 65 robot assisted operations and no significant difference in long-term outcomes was distinguishable between the experimental cohort and the control cohort used conventional methods [23].

Table 2 summarizes these studies and indicates the sample sizes as well as the focuses of each study. Common limitation with the current literature on robotic arthroplasty, as many studies rely on small cohorts or short-term follow-up based on technical accuracy rather than long-term implant survival or functional outcomes. Robotic medicine is still relatively new, and more studies are sure to take place as the methods evolve, however larger multicenter trials with extended follow-up periods are necessary to more completely evaluate long-term clinical benefits [13,21,23,29].

Table 1: Detailed search strategies used across major biomedical databases for the identification of studies evaluating robotic-assisted revision total hip and knee arthroplasty. The table outlines the full Boolean search string applied in PubMed including MeSH terms, title/abstract keywords, exclusion filters, language limits, and date restrictions as well as the corresponding Cochrane Library strategy using free-text terms and Boolean operators. These structured queries were designed to capture original clinical studies published between 2010 and 2025 involving robotic-assisted revision THA or TKA while excluding non-English, cadaveric, non-original, and primary-only arthroplasty research.

Database	**Search String**
PubMed	(((("arthroplasty, replacement, hip"[MeSH Terms] OR "arthroplasty, replacement, knee"[MeSH Terms] OR "hip arthroplasty"[Title/Abstract] OR "knee arthroplasty"[Title/Abstract] OR "THA"[Title/Abstract] OR "TKA"[Title/Abstract] OR "total hip"[Title/Abstract] OR "total knee"[Title/Abstract]) AND ("revision"[Title/Abstract] OR "revision surgery"[Title/Abstract] OR "revision arthroplasty"[Title/Abstract]) AND ("robotic"[Title/Abstract] OR "robot-assisted"[Title/Abstract] OR "robot-assisted"[Title/Abstract] OR "ROSA"[Title/Abstract] OR "MAKO"[Title/Abstract] OR "robotic arm"[Title/Abstract])) NOT ("cadaver"[Title/Abstract] OR "cadaveric"[Title/Abstract] OR "review"[Publication Type] OR "editorial"[Publication Type] OR "comment"[Publication Type])) AND 2010/01/01:2025/12/31[Date - Publication] AND "english"[Language]) AND ((clinicaltrial[Filter] OR randomizedcontrolledtrial[Filter]) AND (fft[Filter]) AND (humans[Filter]) AND (english[Filter]) AND (2015:2025[pdat]))
Cochrane Library	(hip arthroplasty OR knee arthroplasty OR THA OR TKA OR "total hip" OR "total knee") AND (revision OR "revision arthroplasty" OR "revision surgery") AND (robotic OR "robot-assisted" OR "robot assisted" OR ROSA OR MAKO OR "robotic arm") NOT (cadaver OR cadaveric OR review)

Table 2: Characteristics of Included Studies.



Study	Design	Cohort Size	Primary Focus	Follow-up
Adamska et al., 2023	Randomized Controlled Trial	215 total	Compare operative metrics and short-term outcomes betweeen robot assisted and manual knee arthroplasty	12 Months
Bargar et al., 2018	Long-term Follow-up Study	125 Hip arthroplasies in 118 patients	Evaluate long-term outcomes of robot-assisted hip arthroplasty	~14 years
Bell et al., 2016	Prospective Randomized Controlled Trial	139 recruited	Assess improvement of implant positioning in robotic asssisted knee arthroplasty	2 years
Domb et al., 2014	Matched Controlled Study	100 total	Assess acetabular cup placement in traditional and robotic arthroplasty	Short-term
Gilmour et al., 2018	Randomized Controlled Trial	139 recruited; 112 analyzed	Examine clinical outcomes in conventional vs arthroplastic knee arthroplasty	2 years
Kamara et al., 2017	Retrospective Cohort	839 total	Investigate complication rates for navigation tracker pins in arthroplasty	Perioperative
Lychagin et al., 2024	Prospective Comparative Study	210 total	Compare short term outcomes of robotic- and computer-assisted vs conventional knee arthroplasty	3 years
Nakamura et al., 2018	Randomized Clinical Trial	130 recruited; 128 analyzed	Compare long-term outcomes of robotic vs manual femoral preparation in hip arthroplasty	10 years

6. Cost and Implementation

6.1. Financial Burden Associated with Acquiring Robotic Systems

Unfortunately, in the healthcare world today, cost of treatment is an ever-rising obstacle. The continuous rise in cost of resources, materials, equipment, training, and staffing has become more prevalent now more than ever. Due to this dilemma, patient care has and continues to be impacted in detrimental ways. The first-line treatments that may be the most efficient and produce the greatest outcomes for patients may not be available due to the financial burden of the resources needed. In a random controlled trial studying the cost of robotic arthroplasty for hip replacements, it was shown that the robotic systems imposed a substantial financial burden in the acquisition, implementation, usage, and upkeep. It should be noted that these costs can be offset through volume usage. However, this is particularly difficult in more rural areas or publicly funded systems such as the NHS used in the United Kingdom [30].

The five-year investigation examined the cost effectiveness of robotic arm-assisted systems in the United Kingdom [31]. The study exemplified the significant financial burden of the use of robotics in surgery compared to manual surgical procedures. The study showed that the robotic arm-assisted uncompartmentalized knee arthroplasty (rUKA) had a much higher cost per procedure at around £1,070 per patient. Whereas the manual noncompartmental knee arthroplasty (mUKA) was approximately £913 per patient. The increased amount per patient with rUKA compared to mUKA was due to the extra costs of using the robot along with CT scanning, all in addition to the intraoperative materials used [31].

One study examined the cost as well as the patient outcomes with rUKA through a ten-year cost utility study (27). This investigation showed that there is a significant upfront financial burden with acquiring the robotic systems. Further, the upkeep with system usage and maintenance, replenishment of disposable instrumentation, and use of imaging with CT is a substantial ongoing financial burden to institutions [27].

6.2. The Impact of Robotics on Operative Workflow and Efficiency

The implementation of robotics in orthopedic surgery has shown multiple and considerable benefits overall. In one study, the accuracy and long-term efficiency of acetabulum positioning in THA was evaluated [16]. The assessment recorded acetabulum placement with an optimal "target zone" of an inclination of 30o - 50o and an anteversion of 10o - 30o, as well as relative and absolute risks. It was shown that the use of robotic assistance in a THA showed significant and immediate improvement in the workflow and efficiency of acetabulum placement. RA THA showed a target zone achievement of 97% compared to the manual THA of 84%. Further, RA THA had a relative risk reduction of 87%, and an absolute risk reduction of 21% compared to manual THA [16].

RA TKA also showed very promising results. In one study, RA TKA showed superior prosthetic placement and alignment, as well as an increase in total survivorship rates of the total knee replacement when compared to the manual TKA [18]. Another evaluation of RA TKA showed that using robotic assistance in the TKA led to significant improvement in implant position and radiological alignment compared to the conventional manual TKA (20). While these studies have proven that the overall workflow and efficiency is significantly increased in the use of RA surgical procedures, the overall functional outcomes of prosthetics remained relatively the same between RA procedures and the conventional manual procedures [19].

6.3. The Influence of Institutional Surgical Volume on Cost-Effectiveness and Adoption

While the onset of capital investment in robotic systems have proven to cause quite a financial burden to institutions initially, these systems have shown to fulfil their worth in paying back the financial debt. However, this is also both volume and longevity contingent. In one study, rUKA showed a notable decrease in revision rates, infection, and increased implant longevity. With rUKA leading in patient care and being more utilized, this offsets a substantial portion of not only the initial capital investment, but also the upkeep associated with these systems [27].

Furthermore, rUKA offsets other outside costs associated with mUKA [30]. This was exemplified by a total overall cost reduction of $7,179 with overall shorter lengths of hospital stay, as well as less analgesia needed during the RA procedures [30]. With these factors in mind, the financial burden of acquiring robotic systems can quite considerably be offset due to the overall benefits of the systems. However, this is often due to the location, size, and institutional surgical volume of the hospital. The higher the surgical volume of the hospital, the more effective and efficient these systems can be used and decrease overall debt accumulation.

7. Limitations and Future Directions

7.1. Lack of High-Quality Randomized Evidence

The role of emerging techniques in robotics has been a topic of discussion in terms of how well robotics can help surgeons provide optimal treatment for patients undergoing hip and knee procedures. Knee arthroplasty is a safe and effective procedure associated with improved quality of life and reduced pain. RA revision hip and knee arthroplasty is being adopted more widely, but high-level comparative evidence supporting its clinical benefit remains limited.

There have been follow-up studies in knee arthroplasty demonstrating improved alignment and quality of life at two years; however, long-term studies confirming these findings remain limited [29]. While numerous studies have shown that RA techniques can improve alignment and bone remodeling, no long-term randomized trials have demonstrated improved patient outcomes or durability [19].

Although these techniques are increasingly used in clinical practice, long-term comparative data evaluating outcomes across patient populations remain limited. Most available studies focus on short-term follow-up. Long-term clinical and imaging outcomes, especially at around 10 years, are not well established, highlighting a key gap in the literature [21].

7.2. Limited Long-Term Survivorship Data

While new and emerging techniques in RA techniques for hip and knee revision arthroplasty have been limited to short term data comparison studies, the field of science is yet to grow in revision techniques. Survivorship of patients who have received revision hip and knee arthroplasty during a long-term follow up, has not been seen in extended data findings. There is a strong literature gap in the lack of long-term survivorship data in hip and knee revision arthroplasty where patients have demonstrated a better quality of life and improvement of treatments through everyday means. The studies that are available now have been primarily about the long-term follow ups for survivorship of patients who have had primary procedures done for the hip and knee, not for revision surgeries. The need to have long-term follow ups for survivorship data for revision surgeries should be sought after since it indicates the durability of the surgery as well as indicating the complexity of the surgery as well [23]. In primary hip arthroplasty, there is a first time surgery for the hip replacement with an artificial implant. Patients have presented with better clinical outcomes such as low infection rate and reduction in pain and better alignment for a first time surgery during their long-term follow up for a primary hip arthroplasty [13]. Though there is limited data for many follow ups and outcomes for patient survivorship, there is a need for long-term comparative studies which show increased clinical outcomes through new technological advancements for revision techniques in hip and knee arthroplasty [13].

7.3. Need for Standardized Outcome Reporting

A large volume of patient outcome data has been reported across the literature. However, data from primary arthroplasty are far more extensive and consistent compared to revision procedures, where high-level comparative studies remain limited. Standardized outcome metrics including pain scores, functional assessments, complication rates, and revision techniques, are needed to improve consistency across studies. More consistent data collection would allow for better comparison between studies and improve the ability of surgeons and researchers to refine surgical protocols.

Although some studies highlight improvements in imaging accuracy, others incorporate both technical and functional outcomes. For example, a randomized controlled trial in uncompartmentalized knee arthroplasty demonstrated that robotic assistance improved implant positioning and patient-reported outcomes at two years [29]. Similarly, a randomized controlled trial in RA TKA evaluated both femoral rotational alignment and clinical outcomes, integrating technical and functional measures [21]. Despite these findings, variability in outcome reporting continues to limit direct comparison across studies.

7.4. Integration of Artificial Intelligence (AI) and Advanced Planning Technologies

Advances in revision hip and knee arthroplasty continue to focus on improving surgical precision and patient outcomes. Emerging technologies, including artificial intelligence (AI) and 3D planning systems, may further improve RA techniques. Integration of AI-driven planning with robotic execution has the potential to improve surgical decision-making, optimize implant positioning, and support more personalized treatment strategies. A recent randomized controlled trial demonstrated that a novel RA hip system improved imaging outcomes and reduced complications [24].

This suggests that combining robotics with AI planning and 3D integration could help doctors make better decisions and provide more personalized treatments for patients. Large ongoing studies are examining how effective and cost-efficient RA hip replacement is, showing that robotics is playing an increasingly impactful role in a clinical setting [30]. As these systems become more widely used, there is a strong potential to combine these integrated plans which cater best to a patient's needs as the world of Al is developing.

8. Conclusion

Rates of revision of previous THA and TKA procedures are rising even faster than rates of new joint replacement surgeries. Revision joint arthroplasty surgeries come with risks that are unique compared to primary joint replacement surgeries. Some risks are bone loss, distorted anatomy from the implant, increasing fracture risk, and soft tissue imbalance from acute or chronic implant rejection. In this scoping review, robotic assistance demonstrated improvements in component positioning, accuracy, joint line restoration, and alignment precision, largely due to the ability of robotic platforms to incorporate patient-specific preoperative CT imaging, reduce margin-of-error during component placement, and allow for greater consistency, tighter clustering of measurements, and fewer outliers. Collectively, these findings point to the advantages of robotic assistance in enhancing accuracy and reproducibility during procedures.

At the same time, evaluation of metrics such as operative time, blood loss, and length of stay revealed less consistent advantages of robotic assistance. Robotic procedures were shown to have increased operative time, and there was no clear trend when it came to increased or decreased efficiency with robotic assistance. There were low complication rates and no significant differences in postoperative complications. However, early survivorship and re-revision rates showed good outcomes for both RA and conventional techniques. Although some studies reported improved functional outcomes, THA studies conflict on whether there is superiority when it comes to functionality. TKA studies consistently show improved alignment without corresponding functional benefit.

In the end, revision hip and knee arthroplasty with robot assistant looks to be beneficial, but there is a need for more comprehensive literature. Most of the studies do not include complex cases, and there is a large variability in robotic platforms which ultimately prevents standardization. Additionally, studies are done on small populations and there is no long-term follow-up. There is also a literature gap in long-term survivorship data in hip and knee revision arthroplasty, and further research is needed to show how robotics could assist in revision surgeries themselves since most of the literature is limited to primary THA and TKA procedures. It would be more beneficial in the future if studies are performed with larger multicentre trials and longer follow-up durations. This will allow for evaluation of long-term clinical benefits and a clearer definition on the role robotics play in revision hip and knee arthroplasty.

References

1. Sloan M, Premkumar A, Sheth NP. Projected Volume of Primary Total Joint Arthroplasty in the U.S., 2014 to 2030. J Bone Joint Surg Am. 2018; 100(17): 1455-1460.
2. Kurtz SM, Ong KL, Lau E, Bozic KJ. Impact of the economic downturn on total joint replacement demand in the United States: updated projections to 2021. J Bone Joint Surg Am. 2014; 96(8): 624-30.
3. Bhattacharyya T, Saravanan G, Yoon S, Paul S. The Missing Revision Burden: Total Hip and Knee Replacement Revision Rates in the United States, 1996 to 2020. JB JS Open Access. 2025; 10(4): e25.00192.
4. Gademan MG, Hofstede SN, Vliet Vlieland TP, Nelissen RG, Marang-van de Mheen PJ. Indication criteria for total hip or knee arthroplasty in osteoarthritis: a state-of-the-science overview. BMC Musculoskelet Disord. 2016; 17(1): 463.
5. Paprosky WG, Perona PG, Lawrence JM. Acetabular defect classification and surgical reconstruction in revision arthroplasty. A 6-year follow-up evaluation. J Arthroplasty. 1994; 9(1): 33-44.
6. Bozic KJ, Kurtz SM, Lau E, Ong K, Vail TP, Berry DJ. The epidemiology of revision total hip arthroplasty in the United States. J Bone Joint Surg Am. 2009; 91(1): 128-33.
7. Dennis DA, Berry DJ, Engh G, Fehring T, MacDonald SJ, Rosenberg AG, Scuderi G. Revision total knee arthroplasty. J Am Acad Orthop Surg. 2008; 16(8): 442-54.
8. Ali E, Howard LC, Neufeld ME, Masri BA. Treatment of femoral bone loss in revision total hip arthroplasty: a clinical practice review. Ann Jt. 2024; 9: 4.
9. Ong KL, Lau E, Suggs J, Kurtz SM, Manley MT. Risk of subsequent revision after primary and revision total joint arthroplasty. Clin Orthop Relat Res. 2010; 468(11): 3070-6.
10. Kayani B, Konan S, Huq SS, Tahmassebi J, Haddad FS. Robotic-arm assisted total knee arthroplasty has a learning curve of seven cases for integration into the surgical workflow but no learning curve effect for accuracy of implant positioning. Knee Surg Sports Traumatol Arthrosc. 2019; 27(4): 1132-1141.
11. Gill RHS, Haddad FS. Unicompartmental knee arthroplasty: an exemplar of surgical and engineering collaboration. Bone Jt Open. 2024; 5(12): 1120-1122.
12. Matthews AH, Redman H, Evans JP, Lamb SE, Briggs T, Price A. What factors are important to patients when considering a revision total knee replacement in a network model of care? An exploratory qualitative analysis. BMC Musculoskelet Disord. 2025; 27(1): 17.
13. Bargar WL, Parise CA, Hankins A, Marlen NA, Campanelli V, Netravali NA. Fourteen-year follow-up of randomized clinical trials of active robotic-assisted total hip arthroplasty. J Arthroplasty. 2018; 33(3): 810-4.
14. Domb BG, El Bitar YF, Sadik AY, Stake CE, Botser IB. Comparison of robotic-assisted and conventional acetabular cup placement in THA: matched-pair controlled study. Clin Orthop Relat Res. 2014; 472(1): 329-36.
15. Hepinstall M, Zucker H, Matzko C, Meftah M, Mont MA. Adoption of robotic arm-assisted THA yields reliable clinical and radiographic outcomes at ≥2 years. Surg Technol Int. 2021; 38: 440-5.
16. Kamara E, Robinson J, Bas MA, Rodriguez JA, Hepinstall MS. Robotic vs fluoroscopic guidance in THA: acetabular positioning during learning curve. J Arthroplasty. 2017; 32(1): 125-30.
17. Perets I, Walsh JP, Mu BH, Mansor Y, Rosinsky PJ, Maldonado DR. Short-term clinical outcomes of robotic-arm assisted THA: pair-matched controlled study. Orthopedics. 2021; 44(2): E236-42.
18. Lychagin AV, Gritsyuk AA, Elizarov MP. Short-Term Outcomes of Total Knee Arthroplasty Using a Conventional, Computer-Assisted, and Robotic Technique: A Pilot Clinical Trial. J Clin Med. 2024; 13(11): 3125.
19. Kim YH, Yoon SH, Park JW. Does Robotic-assisted TKA Result in Better Outcome Scores or Long-Term Survivorship Than Conventional TKA? A Randomized, Controlled Trial. Clin Orthop Relat Res. 2020; 478(2): 266-275.
20. Möller A, Kasabji F, Fischer M. Improved surgical accuracy in total knee arthroplasty using the ROSA® knee system: A randomised-controlled unblinded trial. Knee Surg Sports Traumatol Arthrosc. Published online December. 2025.
21. Adamska O, Modzelewski K, Szymczak J. Robotic-Assisted Total Knee Arthroplasty Utilizing NAVIO, CORI Imageless Systems and Manual TKA Accurately Restore Femoral Rotational Alignment and Yield Satisfactory Clinical Outcomes: A Randomized Controlled Trial. Medicina (Kaunas). 2023; 59(2): 236.
22. Young SW, Tay ML, Kawaguchi K. The John N. Insall Award: Functional Versus Mechanical Alignment in Total Knee Arthroplasty: A Randomized Controlled Trial. J Arthroplasty. 2025; 40(7S1): S20-S30.e2.
23. Nakamura N, Sugano N, Sakai T, Nakahara I. Does Robotic Milling for Stem Implantation in Cementless THA Result in Improved Outcomes Scores or Survivorship Compared with Hand Rasping? Results of a Randomized Trial at 10 Years. Clin Orthop Relat Res. 2018; 476(11): 2169-2173.
24. Huang Z, Zhang Z, Wang W, Wang G, Lu X, Zhang H. Improved radiographic outcomes and decreased complications rate on the femoral side can be achieved by a novel designed whole-process robotic assisted hip system for total hip arthroplasty: a prospective randomized controlled trial. J Robot Surg. 2024; 18(1): 79.
25. Fontalis A, Raj RD, Kim WJ, Gabr A, Glod F, Foissey C, Kayani B. Functional implant positioning in total hip arthroplasty and the role of robotic-arm assistance. International orthopaedics. 2022.
26. Batailler C, Putzeys P, Lacaze F, Vincelot-Chainard C, Fontalis A, Servien E, Lustig S. Patellofemoral Arthroplasty is an efficient strategy for isolated patellofemoral osteoarthritis with or without robotic-assisted system. Journal of personalized medicine. 2023.
27. Blyth MJG, Anthony I, Rowe P, Banger MS, MacLean A, Jones B. Robotic arm-assisted versus conventional unicompartmental knee arthroplasty: Exploratory secondary analysis of a randmoised controlled trial. National Center for Biotechnology Information. November. 2017.
28. Bell SW, Anthony I, Jones B, MacLean A, Rowe P, Blyth M. Improved accuracy of component positioning with robotic-assisted Unicompartmental Knee Arthroplasty: Data from a prospective, randomized controlled study. The Journal of bone and joint surgery. American volume. 2016.

29. Gilmour A, MacLean AD, Rowe PJ, Banger MS, Donnelly I. Robotic-Arm-Assisted vs Conventional Unicompartmental Knee Arthroplasty. The 2-Year Clinical Outcomes of a Randomized Controlled Trial. National Center for Biotechnology Information. February. 2018.
30. Griffin J, Davis ET, Parsons H. UK robotic arthroplasty clinical and cost effectiveness randomised controlled trial for hips (RACER-Hip): a study protocol. BMJ Open. 2023; 13(10): e079328.
31. Clement ND, Fraser E, Gilmour A. Cost-utility analysis of robotic arm-assisted medial compartment knee arthroplasty. Bone Jt Open. 2023; 4(11): 889-898.