Review

Technology-Assisted Direct Anterior Total Hip Arthroplasty: A Narrative Review of Clinical Evidence, Challenges, and the DAMiS Traction Bed

Ann. Ital. Chir., 2026 97, 3: 449–459
https://doi.org/10.62713/aic.4443

Xuan Yuan[1], Jianshui Mao[1]

[1]Department of Orthopedics, The Fourth Affiliated Hospital of Zhejiang University School of Medicine, 322000 Yiwu, Zhejiang, China

Total hip arthroplasty (THA) is a crucial intervention for managing degenerative hip diseases, with the anterior approach offering potential advantages of reduced postoperative pain and earlier postoperative recovery. Despite significant advantages, the system has several limitations, such as limited surgical exposure and the risk of soft tissue damage, which ultimately affect clinical outcomes. Various technology-assisted strategies have been introduced to address these challenges in anterior THA, aiming to enhance intraoperative stability, surgical precision, and early rehabilitation, among which the Dynamic Adjustable Modular Integrated System (DAMiS) traction bed is a commonly used traction-assisted approach. Recent studies have reported that traction-assisted techniques may be associated with improvements in selected perioperative outcomes, such as complication rates, implant positioning, and early postoperative recovery, although these findings are primarily derived from retrospective studies with heterogeneous designs. Nonetheless, most available studies are limited by single-center, retrospective designs, small sample sizes, and short follow-up durations, and few provide direct comparisons with conventional techniques. This review provides a narrative overview of technology-assisted direct anterior total hip arthroplasty, outlining the clinical applications, benefits, and limitations of various assistive strategies and discussing future directions for their clinical integration. Further high-quality multicenter trials and long-term evaluations are required to validate the clinical utility of technology-assisted approaches and to guide their appropriate adoption in anterior THA.

Keywords: anterior total hip arthroplasty; Dynamic Adjustable Modular Integrated System; traction bed; surgical precision; complication prevention; enhanced recovery

Introduction

Total hip arthroplasty (THA) is a well-established and highly effective option for managing degenerative hip diseases, such as osteoarthritis and avascular necrosis, increasingly prevalent conditions worldwide [1,2]. These conditions are usually associated with severe pain, impaired mobility, and diminished quality of life, making THA a crucial intervention to restore function and relieve pain [3,4]. With the ongoing increase in hip degenerative diseases, the demand for reliable and successful hip replacement surgeries continues to grow.

Among the surgical interventions for THA, the anterior approach has emerged as a preferred option for both surgeons and patients [5]. Unlike the conventional posterior or lateral approaches, the anterior method reaches the hip joint through an intermuscular and interneurons plane, thereby minimizing injury to surrounding soft tissues, including muscles and tendons [6]. This minimally invasive technique is often associated with less postoperative pain, earlier mobilization, and a shorter overall recovery time [7]. As a result, many patients resume normal activities faster and experience better early functional outcomes. However, despite several advantages associated with the anterior approach [8], it also poses certain challenges.

One of the key challenges of the anterior approach is limited surgical exposure, which can hinder clear visualization of the hip joint's anatomy and adjacent structures, including muscles, tendons, and nerves [9]. Inadequate exposure can reduce the accuracy of implant positioning, increasing the risk of component malalignment, nerve damage, prosthesis instability, and subsequent complications such as dislocation or early loosening [10,11]. These risks are further amplified by the steep learning curve of the anterior approach, leading to greater variability in outcomes across different surgical settings.

To address these limitations, several technology-assisted strategies have been introduced to improve surgical exposure and intraoperative control during anterior THA. Particularly, traction-assisted systems aim to facilitate controlled limb positioning and greater operative stability. The Dynamic Adjustable Modular Integrated System (DAMiS) traction bed is one such traction-based platform developed to support intraoperative stability and adjustable lower-limb positioning [12]. By improving exposure without exces-

Submitted: 12 November 2025 Revised: 25 December 2025 Accepted: 31 December 2025 Published: 10 March 2026
Correspondence to: Jianshui Mao, Department of Orthopedics, The Fourth Affiliated Hospital of Zhejiang University School of Medicine, 322000 Yiwu, Zhejiang, China (e-mail: 8017003@zju.edu.cn).
Editor: Hui Lu

sive soft tissue retraction, traction-assisted systems, such as DAMiS, may help optimize implant alignment and reduce procedure-related trauma [13]. However, current study has not consistently demonstrated greater operative stability, early postoperative comfort, or better recovery outcomes compared with conventional techniques [14].

With the increasing use of anterior THA and the emerging role of DAMiS-based technology, a comprehensive evaluation of its clinical utility is warranted. Meanwhile, advances in technological integration, standardized training models, and patient-specific surgical planning are increasingly affecting how anterior THA continues to develop. Therefore, this narrative review provides an overview of technology-assisted direct anterior total hip arthroplasty by summarizing current techniques and ongoing challenges, and by outlining how assistive strategies, including traction-based systems such as the DAMiS traction bed, have been applied to improve surgical precision, reduce complications, and enhance postoperative recovery.

Methodology

This review used a narrative, non–systematic design. A comprehensive literature search was conducted in PubMed, Web of Science, and Embase for studies published between 1 January 2010, and 31 March 2025. We performed both single-term and combined keyword searches. Single keywords included "direct anterior approach", "anterior total hip arthroplasty", "traction table", and "Dynamic Adjustable Modular Integrated System". Key combined searches included ("direct anterior approach" AND "traction table"), ("direct anterior approach" AND "Dynamic Adjustable Modular Integrated System"), ("anterior total hip arthroplasty" AND "traction table"), and ("anterior total hip arthroplasty" AND "Dynamic Adjustable Modular Integrated System"). The initial search retrieved 117 records. To better capture manuscripts focused on surgical exposure, additional combinations incorporating "exposure system" were also applied. Titles and abstracts were first screened for relevance to anterior THA and traction-assisted techniques, followed by full-text evaluation against predefined inclusion and exclusion criteria. Finally, 56 studies were included in the narrative synthesis.

Both clinical and radiographic evidence was included, such as randomized trials, cohort studies, comparative analyses, and relevant systematic reviews. Findings were interpreted with focus on the hierarchy of evidence, prioritizing systematic reviews and meta-analyses for broader conclusions, while using individual clinical studies to inform technique- and device-specific discussion. Non-English articles, case reports, biomechanical simulations lacking clinical outcomes, and studies not specifically focused on anterior THA or traction-based systems were excluded. Reference lists of key articles were also reviewed to identify additional eligible studies. Because the included studies varied widely in design, sample size, and reported outcomes, no quantitative pooling or meta-analysis was performed. Instead, findings were presented descriptively to outline current evidence, evaluate heterogeneity, and highlight gaps that require further investigation.

Current Techniques and Challenges

Although the anterior approach for THA has become increasingly popular, several technical and clinical challenges continue to limit its widespread adoption and can affect surgical outcomes.

Limited Surgical Exposure and Precision

One of the most critical challenges is achieving adequate surgical exposure due to the hip joint's complex anatomy [15]. The surgeons must navigate around major muscles, tendons, and neurovascular structures, which elevates technical difficulty and increases the risk of intraoperative complications [16]. When exposure is inadequate, precise positioning of prosthetic components becomes more difficult, despite being crucial to optimal outcomes and long-term stability of the hip joint [17]. Surgical precision in THA is essential to prevent malalignment, which can disrupt joint biomechanics, increase wear, and increase the risk of early failure [18]. As the anterior approach offers a more restricted surgical field, achieving reliable component positioning can be particularly challenging for less experienced surgeons [19].

Soft Tissue Protection and Postoperative Complications

Another critical concern is soft tissue protection. Excessive retraction of muscles and neurovascular structures during the anterior approach can cause intraoperative injury, leading to persistent pain, weakness, or sensory deficits after surgery [20,21]. Despite being minimally invasive, the anterior approach still carries risks such as infection, implant dislocation, and prosthesis loosening, each of which can compromise function and may necessitate revision procedures [22,23]. Furthermore, greater intraoperative tissue damage can delay recovery, prolong rehabilitation, and slow the return to routine activities [24].

Learning Curve and Variability in Outcomes

Compared with the posterior or lateral approaches, the anterior approach requires a distinct set of skills and a comprehensive understanding of specific anatomical landmarks [25]. Surgeons must carefully balance adequate exposure with the preservation of soft tissue, a balance that can be difficult to achieve without significant experience. Consequently, the associated learning curve may lead to greater variability in outcomes, particularly in centers where the anterior approach is not routinely performed [26].

Need for Innovative Solutions

Despite these challenges, advancements in surgical techniques and the introduction of new technologies, including

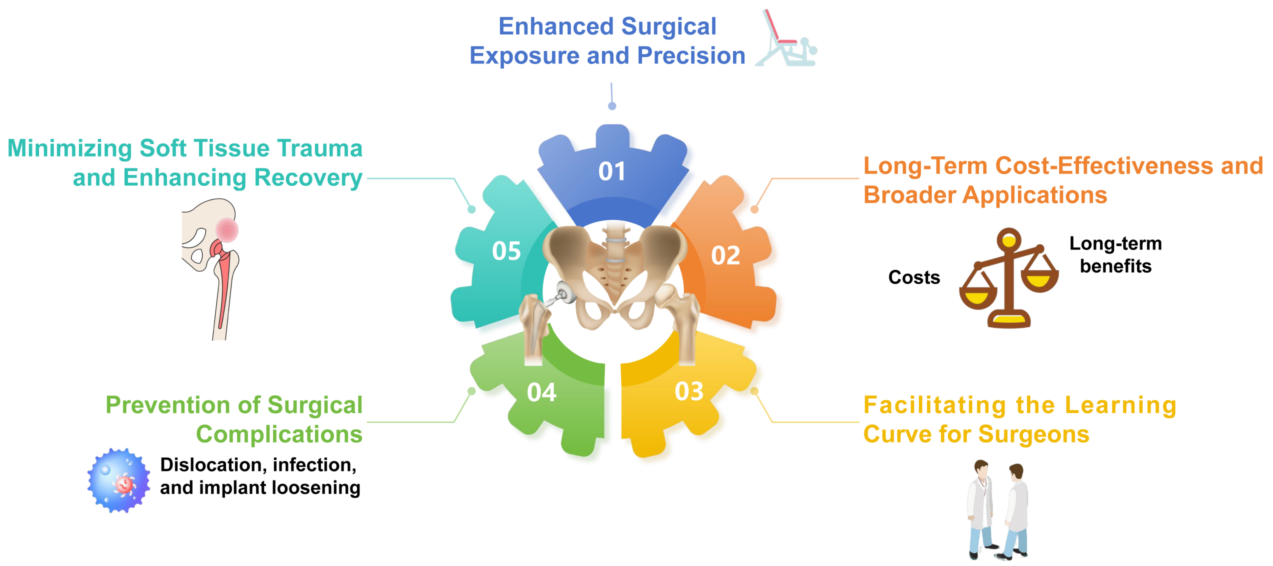

Fig. 1. Key functional domains of the Dynamic Adjustable Modular Integrated System (DAMiS) traction bed in anterior total hip arthroplasty (THA). The figure outlines five functional domains in which the DAMiS traction bed supports direct anterior THA: improvement of surgical exposure, enhancement of procedural precision, preservation of soft-tissue protection, alleviation of procedure-related complications, and support for surgical training and broader clinical adoption. The figure was created using Microsoft PowerPoint (version 365, Microsoft Corporation, Redmond, WA, USA).

the DAMiS traction bed, may help mitigate key limitations of anterior THA. DAMiS is designed to provide controlled lower-limb positioning during the procedure; however, current evidence remains inconsistent regarding improvements in surgical visualization and the accuracy of implant positioning [14]. By improving exposure and reducing reliance on aggressive soft-tissue retraction, DAMiS may offer a practical means to address some technical challenges inherent to the anterior approach.

Application of DAMiS Traction Bed Technology in Anterior THA

The DAMiS traction bed has been introduced as an adjunct design to address some limitations of the anterior approach to THA (Fig. 1). Fig. 2 shows the clinically relevant areas of DAMIS-assisted anterior total hip arthroplasty, outlining the key functional pathways through which the use of the DAMIS traction system may affect clinical outcomes and patient satisfaction.

Enhanced Surgical Exposure and Precision

The DAMiS system, through its modular and adjustable traction mechanism, may assist surgeons in achieving more controlled hip joint positioning and in addressing challenges related to limited exposure in the anterior approach [27,28]. In traditional methods, visualization can be limited by the complex anatomy and surrounding structures. By enabling more controlled limb positioning, DAMiS may support more consistent implant alignment in certain clinical contexts [29,30]. Some studies link its use with fewer alignment-related complications, although the magnitude and consistency of this effect vary across studies and clinical settings [31,32]. The additional intraoperative stability provided by DAMiS may also help surgeons work within anatomical constraints, although outcomes appear affected by surgeon experience and institutional factors [33,34].

Minimizing Soft Tissue Trauma and Enhancing Recovery

One of the key features of the DAMiS system is its potential to reduce soft tissue injury. The anterior approach traverses a narrow intermuscular plane, where forceful or excessive retraction can damage muscles and adjacent neural structures [35,36]. By enabling more controlled positioning of the limb and hip joint, DAMiS may reduce unnecessary tissue tension, which could in turn alleviate postoperative discomfort and the likelihood of soft-tissue–related symptoms [37]. Hence, minimizing soft-tissue trauma may support earlier mobilization and more rapid rehabilitation, potentially reducing the risk of postoperative complications such as deep vein thrombosis (DVT) [38,39].

Contribution to Complication Prevention

Complications such as dislocation, infection, and implant loosening remain crucial concerns in THA. DAMiS may support more stable component positioning, although reported effects on positioning accuracy remain inconsistent across studies [40,41]. Continuous, controlled traction may also help streamline intraoperative steps and potentially contribute to shortening operative time, which could reduce the duration of tissue exposure to contaminants, but evi-

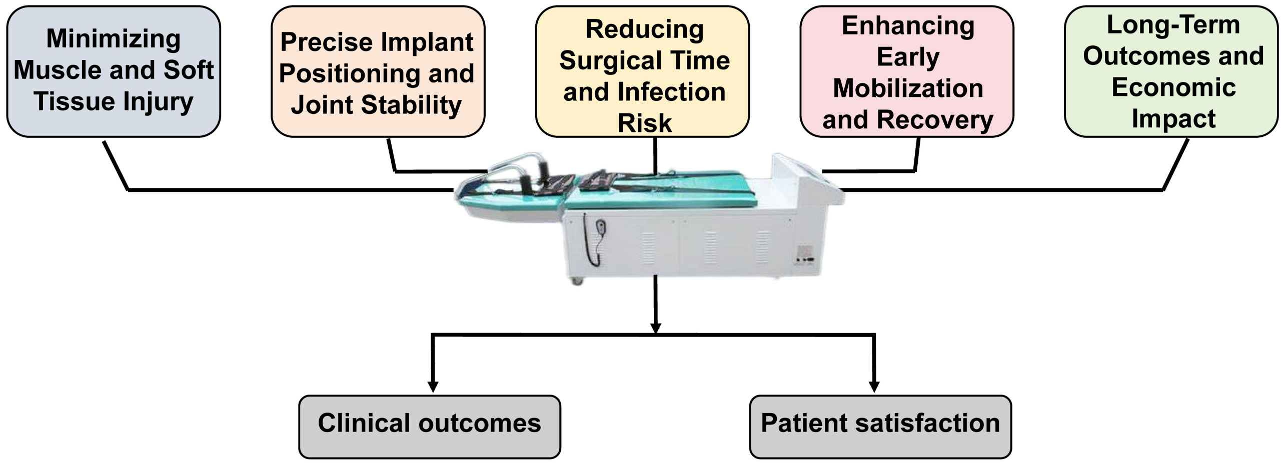

Fig. 2. Clinically relevant domains of DAMiS-assisted anterior total hip arthroplasty. The figure was created using Microsoft PowerPoint (version 365, Microsoft Corporation, Redmond, WA, USA).

dence linking DAMiS use to lower infection risk remains inconsistent. By preserving the integrity of soft tissues, DAMiS may help maintain local biological barriers that protect against infection, which could theoretically enhance perioperative safety [12].

Facilitating the Surgical Learning Curve

The anterior approach to THA relies on accurate recognition of approach-specific anatomical landmarks, and traction-table systems such as DAMiS may provide a more standardized operative setup that could be beneficial during early adoption of the technique [42]. By offering stable limb positioning and potentially enhancing visualization, such systems may reduce certain sources of technical variability in selected settings. A more standardized intraoperative environment may help support surgeons as they adapt to the procedural workflow of the anterior approach; however, current evidence regarding any direct effect on the surgical curve remains limited and inconsistent. While improved intraoperative control may reduce the technical difficulty perceived in some cases, its impact on performance consistency and downstream clinical outcomes has not been clearly established.

Mechanisms of Complication Prevention and Accelerated Recovery in Anterior THA

The DAMiS traction bed technology has been proposed as a structured adjunct to support complication prevention and postoperative recovery processes in anterior THA. These mechanisms are primarily linked to improved soft tissue protection, more controlled implant positioning, surgical efficiency, and facilitation of early mobilization, factors that collectively influence both short- and long-term clinical outcomes.

Minimizing Muscle and Soft Tissue Injury

Soft tissue injury remains a key concern in anterior THA, despite the approach is often considered minimally invasive. Although it typically avoids major muscle detachment, retraction in a narrow surgical field can still cause trauma to muscles, tendons, and adjacent nerves due to retraction and manipulation [43,44]. By providing stable, controlled traction, DAMiS may reduce reliance on aggressive retraction and thereby limit iatrogenic soft tissue damage. Less tissue trauma is generally associated with reduced postoperative discomfort and inflammation, which may support a smoother early recovery [45]. Preserving periarticular tissues may also reduce the likelihood of hematoma formation and nerve-related complications, potentially benefiting postoperative recovery.

Precise Implant Positioning and Joint Stability

Accurate implant positioning is essential to the long-term success of THA, as suboptimal alignment can increase the risk of dislocation, accelerate wear, and contribute to implant failure [46]. By stabilizing the operative field and enabling controlled limb manipulation, DAMiS may facilitate key surgical steps and support more consistent implant alignment in certain settings [27]. Improved alignment may enhance joint stability and reduce abnormal biomechanical stress, factors commonly associated with revision risk, particularly in anterior THA where limited exposure can compromise visualization.

Surgical Efficiency and Reduction of Infection Risk

The intraoperative stability provided by DAMiS can improve procedural efficiency by enabling more controlled maneuvers and potentially alleviating operative time. Reduced operative duration may decrease tissue exposure to potential contaminants and thereby contribute to a lower risk of postoperative infection [28]. Additionally, shorter procedures may also reduce the physical and cognitive burden on the surgical team, which may support overall performance and procedural consistency [47]. These potential advantages may be particularly relevant for elderly patients or those with compromised immune systems, who are more vulnerable to complications and delayed recovery [48].

Early Mobilization and Functional Recovery

Early mobilization is critical to minimizing complications such as DVT and for promoting functional recovery. By limiting intraoperative tissue trauma, DAMiS may be associated with less postoperative pain and inflammation, potentially enabling patients to begin physical therapy earlier [49]. Early weight-bearing and rehabilitation can help restore muscle strength and functional mobility, enabling a faster return to independence and reducing the need for prolonged hospitalization [50].

Long-Term Outcomes and Economic Impact

The durability of THA outcomes depends on surgical accuracy and effective prevention of complications. DAMiS may contribute to favorable outcomes by supporting controlled limb manipulation and potentially improving component alignment, although these advantages have not been demonstrated consistently. Such an effect reduces factors associated with revision risk, but long-term advantages remain to be validated in prospective studies.

While DAMiS has a higher initial cost, its potential long-term economic benefits have not been consistently quantified [51]. In general, reduced complications, shorter hospital stays, and fewer revision rates could lower overall healthcare costs. Additionally, improved functional outcomes and patient satisfaction may reduce the long-term burden on healthcare systems and workers, supporting more sustainable healthcare delivery [52].

Overall, DAMiS traction bed technology provides a structured method intended to enhance exposure and limb control during anterior THA, but its effects on complication rates and recovery are inconsistent across study [12]. By supporting soft tissue preservation, controlled limb positioning, efficient surgical workflow, and earlier mobilization, DAMiS may offer potential benefits in selected perioperative domains. However, its overall impact on clinical outcomes, patient satisfaction, and cost-effectiveness remains variable and requires further validation through high-quality comparative studies.

Summary of Existing Research on DAMiS Traction Bed Technology in Anterior THA

Current studies on DAMiS traction bed technology have explored its potential associations with surgical precision, complication rates, postoperative recovery, and economic considerations in anterior THA.

Implant Alignment and Joint Stability

Accurate implant alignment is crucial to the success of THA. DAMiS technology stabilizes the surgical field. However, its reported effects on component positioning and dislocation risk vary across studies. Recent analyses indicate that traction-table systems used in anterior THA can influence surgical exposure and limb control; however, evidence regarding consistent improvement in component positioning or complication rates remains inconsistent [14]. Although clear reductions in dislocation rates or measurable gains in alignment accuracy have not been consistently demonstrated, traction-assisted systems may still contribute to intraoperative stability. Any potential effects on prosthesis wear patterns or long-term implant survival remain undefined and require further validation in robust prospective investigations.

Complication Prevention and Infection Control

DAMiS may help stabilize and streamline intraoperative workflow, which has been considered a crucial factor that could minimize complications. Recent studies indicate that traction-table systems such as DAMiS, when used during anterior THA, may contribute to lower overall complication rates compared with conventional approaches. Improved intraoperative stability and potentially shorter surgical times may be associated with reduced soft-tissue trauma and, in theory, contribute to lower infection risk and improved perioperative safety [53,54].

Surgical Efficiency and Resource Optimization

Recent studies have found shorter operative times with the use of DAMiS, supporting significant gains in surgical accuracy, although a consistent reduction in perioperative risk has not been uniformly observed. In a selected study, traction-table–assisted anterior THA using DAMiS has been associated with lower intraoperative blood loss, earlier functional recovery, and shorter hospital stays [12]. Furthermore, computer-assisted and robotic systems have been reported to enhance intraoperative stability and precision, contributing to a shorter learning curve and a more standardized surgical workflow [55]. Collectively, these results suggest that well-structured assistive technologies may improve operative efficiency, reduce surgeon fatigue, and support earlier postoperative recovery in specific clinical contexts.

Recovery and Functional Outcomes

Using a DAMiS traction-table–assisted anterior approach may minimize soft-tissue injury and promote earlier postoperative mobilization. A study has reported that patients undergoing DAMiS-assisted anterior THA may ambulate earlier, have shorter hospital stays, and report lower postoperative pain than those treated with conventional posterior approaches, although these findings can be influenced by study design and patient selection [56]. Earlier mobilization, potentially driven by reduced postoperative pain, may also decrease the risk of complications such as DVT and help accelerate rehabilitation [57].

Long-Term Outcomes and Economic Value

Current evidence indicates that DAMiS-assisted anterior approaches may provide long-term benefits by reducing tissue trauma and supporting faster recovery. These potential advantages may influence long-term outcomes, but such effects have not been consistent across studies. From an economic perspective, THA is generally regarded as cost-effective, whereas cost-effectiveness evidence specific to DAMiS-assisted approaches remains limited [58]. Because procedures linked to fewer complications and faster recovery tend to be more cost-effective, DAMiS-assisted techniques may have the potential to offer long-term clinical and cost-related value, although current evidence is still limited. To provide a structured overview of current evidence on technology-assisted direct anterior THA, Table 1 (Ref. [12,59–63]) summarizes representative quantitative findings from studies evaluating different categories of assistive approaches aimed at enhancing surgical exposure, workflow, or procedural accuracy. Given the substantial heterogeneity in outcome measures and follow-up durations across included studies, the results presented in Table 1 should be interpreted cautiously and are not intended for direct comparison. Although these modalities differ substantially in mechanism and clinical role, the reported outcomes are organized into shared thematic domains, including implant alignment, complication profiles, surgical efficiency, early recovery, and long-term function. The listed studies are presented to illustrate how diverse technology-assisted approaches have been applied to address similar clinical objectives in anterior THA, thereby providing contextual insight into the broader landscape of surgical optimization.

Limitations and Challenges

Despite its potential benefits in anterior THA, the DAMiS traction bed technology has several limitations and challenges that may affect its broader adoption and long-term clinical application.

Cost and Accessibility

The initial cost required for DAMiS is substantially higher than that of conventional surgical tables, which may limit availability, particularly in smaller healthcare hospitals and resource-limited settings. Consequently, equitable access will be an important concern as adoption expands.

Though DAMiS technology requires a greater initial cost, its long-term economic value has not yet been established and should be validated through high-quality cost-effectiveness studies with long-term follow-up. In principle, a decrease in complications, shorter hospital stays, and fewer revision surgeries may contribute to considerable healthcare cost savings, but these potential benefits remain inadequately quantified [58]. Enhanced recovery trajectories and reduced postoperative complications may also increase patient satisfaction and reduce readmission rates, thereby easing economic burden on healthcare systems [64]. Beyond immediate outcomes, DAMiS sets a precedent for future innovations in orthopedic surgery [65]. Its modular, adjustable design reflects the growing trend toward individualized and adaptive surgical equipment. This approach aligns with the broader goal of personalized medicine, ensuring that surgical technologies are tailored to meet the needs of both patients and surgeons [66].

Lack of Large-Scale, Long-Term Evidence

Current studies are limited by small sample size and shorter follow-up duration, with evidence primarily derived from single-center or retrospective designs. The lack of multicenter randomized controlled trials (RCTs) and long-term follow-up data restricts robust assessment of how traction systems influence implant survival, complication rates, and overall cost-effectiveness.

Moreover, existing evidence on traction-table–assisted anterior THA remains heterogeneous, and reported advantages are not consistent across clinical settings. Wernly *et al*. [42] found no significant differences in implant positioning, complications, or functional outcomes between direct anterior approach (DAA) performed with and without a traction table, and reported more accurate leg-length restoration in the non-traction group. Lenze *et al*. [28] similarly demonstrated that traction-table use shortened operative time, but did not improve key biomechanical parameters such as offset restoration. Nakamura *et al*. [54] reported that while perioperative efficiency improved after the initial learning curve, mid-term outcomes and implant survival at 2–5 years remained unchanged, suggesting that the learning curve may primarily affect operative efficiency rather than long-term clinical performance.

Collectively, these observations reveal substantial variability across studies and suggest that the benefits of traction systems, such as DAMiS, may be context-dependent rather than consistently superior. This variability underscores the need for rigorous multicenter trials with standardized outcomes and longer follow-up.

Learning Curve Considerations

While DAMiS may help reduce technical challenges, the anterior approach itself continues to present a steep learning curve. Surgeons must develop a comprehensive understanding of the relevant anatomy and gain significant procedural experience, and the use of assistive technology alone does not replace the need for comprehensive training.

Comparison With Other Emerging Technologies

There is limited research directly comparing DAMiS with other alternative innovations, such as robotic-assisted or navigation-guided surgery. In the absence of such compar-

Table 1. Summary of reported clinical and radiographic outcomes associated with technology-assisted direct anterior THA.

Study technique	Direction of benefit (standardized)	Key quantitative outcomes	Reference
DAMiS traction table-assisted anterior THA	Better early recovery and fewer complications	Less blood loss (p = 0.018); shorter incision (p = 0.001); faster first ambulation (p = 0.016); shorter hospital stays (p = 0.001); lower postoperative VAS (p = 0.001); higher early HHS ($p < 0.05$); lower complication rate (p = 0.011)	[12]
Robotic-assisted DAA THA	Better component positioning and COR restoration	Cups within safe zone: 98% vs 68% (p = 0.0002); improved ΔHCOR (p = 0.03) and ΔVCOR (p = 0.04); fewer COR outliers (10% vs 28%, p = 0.03); similar 1-year HHS	[59]
Robotic-assisted DAA THA	More accurate leg-length restoration	Mean LLD: 4.05 mm vs 6.0 mm (p = 0.001); adjusted mean difference –1.84 mm (p = 0.003); moderate–severe LLD reduced (44% vs 55%)	[60]
Direct anterior approach with robotic assistance	Better leg-length control and functional outcome	Post-op LLD: 4.03 $\pm$ 3.93 mm vs 5.39 $\pm$ 3.83 mm (p = 0.031); higher 2-year HHS (p = 0.012)	[61]
Robotic-assisted DAA THA	Reduced perioperative narcotic requirement	Lower in-hospital opioids: 42.3 vs 66.4 MME ($p < 0.001$); reduced 6-week opioid use: 103.7 vs 127.8 MME (p = 0.025); similar pain scores	[62]
Robotic-assisted DAA THA	Lower readmission and reoperation risk	90-day readmission: 3.74% vs 9.46% (p = 0.04); 1-year reoperation: 0.93% vs 4.73% (p = 0.04); no significant PROM differences at 1 year	[63]

Note: DAMiS, Dynamic Adjustable Modular Integrated System; THA, total hip arthroplasty; DAA, direct anterior approach; COR, center of rotation; HHS, Harris Hip Score; LLD, leg length discrepancy; VAS, visual analogue scale; MME, morphine milligram equivalents; PROM, patient-reported outcome measure; HCOR, horizontal center of rotation; VCOR, vertical center of rotation.

ative studies, it remains unclear whether DAMiS provides superior outcomes or will instead act as a complementary tool alongside these technologies in future clinical practice.

Future Perspectives

Looking ahead, the development and application of DAMiS traction bed technology in anterior THA are likely to evolve along several key directions.

Technological Integration and Innovation

Future versions of DAMiS may integrate advanced intraoperative systems, including 3D imaging, computer navigation, and robotic platforms, to further improve implant accuracy and reproducibility [67,68]. Additionally, artificial intelligence and machine learning algorithms could enable patient-specific adjustment of traction parameters, aligning DAMiS with the broader shift toward precision and individualized surgery.

Standardized Training and Simulation

Standardized training workflows and simulation-based instruction may help bring more consistency to surgical training, although their effectiveness in this context still warrants further investigation. Simulation-based modules could enhance surgeons' familiarity with technology and practice key steps before surgeries, supporting safer and more efficient skill development. Despite the high initial cost, potential long-term savings may be achieved through fewer complications, shorter hospital stays, and reduced revision rates; however, these potential benefits require further validation through robust cost-effectiveness analyses. In parallel, targeted incentives and supportive funding policies could promote broader adoption where appropriate, with the goal of improving healthcare efficiency and patient outcomes.

Development of Objective and Standardized Outcome Measures

Traditional perioperative indicators and patient-reported outcomes are commonly used in anterior THA, but they may not adequately capture the technology-specific advantages introduced by systems such as DAMiS. Future research should focus on developing and validating objective, standardized outcome measures tailored to technology-assisted procedures. These could include quantitative metrics of surgical precision, parameters of intraoperative stability, assessment of soft-tissue strain, and early functional recovery indices that better reflect technology-mediated improvements. Establishing reproducible and procedure- and device-specific outcome frameworks will enable more rigorous comparison across studies and generate stronger evidence for the clinical value of DAMiS.

Individualized and Precision Medicine

In the future, DAMiS may support more individualized surgical care by incorporating patient-specific anatomical and biomechanical data into intraoperative adjustments [69]. This approach would align with current trends in precision medicine and may help optimize outcomes across diverse patient populations.

Policy, Adoption, and Health System Integration

Economic factors will be crucial for the widespread adoption of DAMiS. Incentive programs, healthcare funding policies, and cost-sharing strategies may be required to help offset the initial investments. To justify its broader integration into clinical practice, long-term value must be demonstrated through evidence of reduced revision rates, shorter hospital stays, and lower overall healthcare utilization.

In summary, DAMiS traction bed technology represents a promising adjunct to anterior THA, with potential to improve surgical precision, reduce complication risks, and support enhanced recovery. However, challenges such as high costs, limited large-scale evidence, and the lack of direct comparisons with other advanced technologies must be addressed. Its future role will depend on integration with complementary technologies, structured training protocols, personalized approaches, and supportive policy frameworks that enable robust assessment and consistent adoption.

Conclusions

Studies report that the DAMiS traction bed can improve surgical exposure, positioning accuracy, and early recovery after anterior THA, although these findings are not consistently observed across all clinical settings. Current evidence also suggests potential gains in surgical efficiency and long-term cost-effectiveness.

However, most published data remain limited by small sample sizes, short follow-up duration, and single -center designs. Well-powered, high-quality, multicenter randomized controlled trials with long-term follow-up are still needed to confirm these findings and elucidate effects on implant survival, complication rates, and patient-centered outcomes. Additional limitations include the system's high cost and limited accessibility, along with the lack of direct comparisons with other advanced technologies, such as robotic or navigation-assisted surgery.

Future efforts should focus on integrating DAMiS with digital imaging, navigation, and robotic platforms, establishing standardized training programs, and exploring its role in personalized arthroplasty planning. With more substantial evidence and supportive health policy measures, traction-assisted systems, such as DAMiS, may become useful adjuncts for anterior THA in selected clinical settings. Their definitive impact on surgical safety, outcome consistency, and healthcare sustainability will depend on future well-structured, high-quality comparative studies.

Availability of Data and Materials

Not applicable.

Author Contributions

XY, conceptualization, formal analysis, data curation, writing—original draft, review and editing. JM, methodology, review and editing, project administration, supervision. Both authors have been involved in revising the manuscript critically for important intellectual content. Both authors gave final approval of the version to be published. Both authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Petis S, Howard JL, Lanting BL, Vasarhelyi EM. Surgical approach in primary total hip arthroplasty: anatomy, technique and clinical outcomes. Canadian Journal of Surgery. Journal Canadien De Chirurgie. 2015; 58: 128–139. https://doi.org/10.1503/cjs.007214.

[2] Pijnenburg L, Felten R, Javier RM. A review of avascular necrosis, of the hip and beyond. La Revue De Medecine Interne. 2020; 41: 27–36. https://doi.org/10.1016/j.revmed.2019.10.332.

[3] Fu M, Zhou H, Li Y, Jin H, Liu X. Global, regional, and national burdens of hip osteoarthritis from 1990 to 2019: estimates from the 2019 Global Burden of Disease Study. Arthritis Research & Therapy. 2022; 24: 8. https://doi.org/10.1186/s13075-021-02705-6.

[4] Jennison T, MacGregor A, Goldberg A. Hip arthroplasty practice across the Organisation for Economic Co-operation and Development (OECD) over the last decade. Annals of the Royal College of Surgeons of England. 2023; 105: 645–652. https://doi.org/10.1308/rcsann.2022.0101.

[5] Nassar JE, Ammar LA, Madi M, Mzeihem M, Hemdanieh M, Nassereddine M. Direct Anterior Approach and Posterior Approach for Total Hip Arthroplasty: A Systematic Umbrella Review of Meta-Analyses of Randomized Controlled Trials. Orthopedic Reviews. 2025; 17: 137665. https://doi.org/10.52965/001c.137665.

[6] Ang JJM, Onggo JR, Stokes CM, Ambikaipalan A. Comparing direct anterior approach versus posterior approach or lateral approach in total hip arthroplasty: a systematic review and meta-analysis. European Journal of Orthopaedic Surgery & Traumatology: Orthopedie Traumatologie. 2023; 33: 2773–2792. https://doi.org/10.1007/s00590-023-03528-8.

[7] Shen J, Ji R, Yao S, Ruan P, Zhu Z, Wang X, *et al*. Direct Anterior Approach Provides Superior Prosthesis Adaptability in the Early Postoperative Period of Total Hip Arthroplasty. Orthopaedic Surgery. 2023; 15: 679–686. https://doi.org/10.1111/os.13640.

[8] Pan X, Clark SC, Simon KN, Oeding JF, Couch CG, Taunton MJ, *et al*. How do Rates of Return to Sports Following Direct Anterior

Approach Total Hip Arthroplasty Compare to Other Approaches? A Systematic Review and Meta-analysis. Orthopedic Reviews. 2024; 16: 124486. https://doi.org/10.52965/001c.124486.

[9] Geraci G, Di Martino A, Stefanini N, Brunello M, Ruta F, Pilla F, *et al*. Should we be concerned when the anterior approach to the hip goes accidentally medial? A retrospective study. Arthroplasty. 2024; 6: 47. https://doi.org/10.1186/s42836-024-00269-9.

[10] Romandini M, Ruales-Carrera E, Sadilina S, Hämmerle CHF, Sanz M. Minimal invasiveness at dental implant placement: A systematic review with meta-analyses on flapless fully guided surgery. Periodontology 2000. 2023; 91: 89–112. https://doi.org/10.1111/prd.12440.

[11] Eftekhar Ashtiani R, Ghasemi Z, Nami M, Mighani F, Namdari M. Accuracy of static digital surgical guides for dental implants based on the guide system: A systematic review. Journal of Stomatology, Oral and Maxillofacial Surgery. 2021; 122: 600–607. https://doi.org/10.1016/j.jormas.2020.10.010.

[12] Lu MS, Zhang YP, Jiao YJ, Wang L, Meng X, Zhang J, *et al*. Clinical Outcomes of DAMIS Traction Table-Assisted Anterior Approach versus Posterolateral Approach on Total Hip Arthroplasty in the Treatment of Femoral Head Necrosis. Annali Italiani Di Chirurgia. 2025; 96: 160–167. https://doi.org/10.62713/aic.3829.

[13] Xiong HZ, Yang LD, Bao G, Peng JC, Liu ZH. Improved surgical exposure and early clinical outcomes using a femoral-release-first technique in direct anterior approach during total hip arthroplasty. Journal of Orthopaedic Surgery and Research. 2023; 18: 878. https://doi.org/10.1186/s13018-023-04334-y.

[14] Ramadanov N, Voss M, Hable R, Prill R, Hakam HT, Salzmann M, *et al*. Indirect comparisons of traction table versus standard table in total hip arthroplasty through direct anterior approach: a systematic review and frequentist network meta-analysis. Journal of Orthopaedic Surgery and Research. 2024; 19: 384. https://doi.org/10.1186/s13018-024-04852-3.

[15] Xu X, Ma J. Applied anatomical study of direct anterior approach total hip arthroplasty: optimizing surgical procedures and shortening learning curve. Archives of Orthopaedic and Trauma Surgery. 2025; 145: 497. https://doi.org/10.1007/s00402-025-06115-0.

[16] Fernández-Palomo LJ, González-Pola R. Direct anterior approach complications for total hip arthroplasty. Acta Ortopedica Mexicana. 2023; 37: 361–367.

[17] Papalia GF, Zampogna B, Albo E, Torre G, Villari E, Papalia R, *et al*. The role of patient surgical positioning on hip arthroplasty component placement and clinical outcomes: a systematic re-view and meta-analysis. Orthopedic Reviews. 2023; 15: 74116. https://doi.org/10.52965/001c.74116.

[18] Innmann MM, Streit MR, Kolb J, Heiland J, Parsch D, Aldinger PR, *et al*. Influence of surgical approach on component positioning in primary total hip arthroplasty. BMC Musculoskeletal Disorders. 2015; 16: 180. https://doi.org/10.1186/s12891-015-0623-1.

[19] Post ZD, Orozco F, Diaz-Ledezma C, Hozack WJ, Ong A. Direct anterior approach for total hip arthroplasty: indications, technique, and results. The Journal of the American Academy of Orthopaedic Surgeons. 2014; 22: 595–603. https://doi.org/10.5435/JAAOS-22-09-595.

[20] Stubbs T, Moon AS, Dahlgren N, Patel HA, Jha AJ, Shah A, *et al*. Anterior acetabular retractors and the femoral neurovascular bundle in anterior total hip arthroplasty: a cadaveric study. European Journal of Orthopaedic Surgery & Traumatology: Orthopedie Traumatologie. 2020; 30: 617–620. https://doi.org/10.1007/s00590-019-02611-3.

[21] Yan JF, Zhao L, Li Q. Clinical comparison between direct anterior approach and posterior lateral approach in total hip arthroplasty and risk factors for lateral femoral cutaneous nerve injury. Frontiers in Surgery. 2025; 12: 1482731. https://doi.org/10.3389/fsurg.2025.1482731.

[22] Charney M, Paxton EW, Stradiotto R, Lee JJ, Hinman AD, Sheth DS, *et al*. A Comparison of Risk of Dislocation and Cause-Specific Revision Between Direct Anterior and Posterior Approach Following Elective Cementless Total Hip Arthroplasty. The Journal of Arthroplasty. 2020; 35: 1651–1657. https://doi.org/10.1016/j.arth.2020.01.033.

[23] Mirghaderi P, Pahlevan-Fallahy MT, Rezaee H, Moharrami A, Ravanbod H, Pourgharib-Shahi MH, *et al*. Dislocation incidence and risk factors following direct anterior primary total hip arthroplasty: a consecutive, single-surgeon cohort. BMC Musculoskeletal Disorders. 2025; 26: 442. https://doi.org/10.1186/s12891-025-08683-z.

[24] Iwakiri K, Ohta Y, Minoda Y, Ueno S, Kobayashi A, Nakamura H. Optimizing total hip arthroplasty: the gripper table mounted system for enhanced soft tissue preservation and postoperative outcomes. Archives of Orthopaedic and Trauma Surgery. 2024; 145: 6. https://doi.org/10.1007/s00402-024-05625-7.

[25] Liu R, Zhao Y, Yu Z, Liu C, Sun Q, Nan X. Comparative efficacy of direct anterior approach versus conventional surgical approaches in total hip arthroplasty: a systematic review and meta-analysis of randomized clinical trials. Journal of Orthopaedic Surgery and Research. 2025; 20: 837. https://doi.org/10.1186/s13018-025-06227-8.

[26] Caudron M, Gerset V, Tronc C, Tonetti J, Boudissa M. Anterior approaches in acetabular fractures: a true learning curve analysis. Acta Orthopaedica Belgica. 2024; 90: 17–25. https://doi.org/10.52628/90.1.10974.

[27] Ishii S, Baba T, Hayashi K, Homma Y, Muto O, Ishijima M. Optimizing implant positioning in total hip arthroplasty via the direct anterior approach: The role and technique of conventional traction table and fluoroscopy. Arthroplasty. 2025; 7: 10. https://doi.org/10.1186/s42836-024-00293-9.

[28] Lenze F, Hinterwimmer F, Fleckenstein L, Lazic I, Dammerer D, VON Eisenhart-Rothe R, *et al*. Minimally Invasive Total Hip Arthroplasty: A Comparison of Restoring Hip Biomechanics With and Without a Traction Table. In Vivo. 2022; 36: 424–429. https://doi.org/10.21873/invivo.12720.

[29] Wang Y, Zheng H, Taylor RH, Samuel Au KW. A Handheld Steerable Surgical Drill With a Novel Miniaturized Articulated Joint Module for Dexterous Confined-Space Bone Work. IEEE Transactions on Bio-Medical Engineering. 2022; 69: 2926–2934. https://doi.org/10.1109/TBME.2022.3157818.

[30] Goldberg TD, Kreuzer S, Randelli F, Macheras GA. Direct anterior approach total hip arthroplasty with an orthopedic traction table. Operative Orthopadie Und Traumatologie. 2021; 33: 331–340. https://doi.org/10.1007/s00064-021-00722-x.

[31] Diconi AF, Roman MD, Cristian AN, Boicean AG, Mohor CI, Ion NCI, *et al*. The Effects of Biomechanical Loading on the Tibial Insert After Primary Total Knee Arthroplasty: A Systematic Review. Journal of Clinical Medicine. 2025; 14: 1043. https://doi.org/10.3390/jcm14041043.

[32] Karasavvidis T, Pagan Moldenhauer CA, Lustig S, Vigdorchik JM, Hirschmann MT. Definitions and consequences of current alignment techniques and phenotypes in total knee arthroplasty (TKA) - there is no winner yet. Journal of Experimental Orthopaedics. 2023; 10: 120. https://doi.org/10.1186/s40634-023-00697-7.

[33] Nairn L, Gyemi L, Gouveia K, Ekhtiari S, Khanna V. The learning curve for the direct anterior total hip arthroplasty: a systematic review. International Orthopaedics. 2021; 45: 1971–1982. https://doi.org/10.1007/s00264-021-04986-7.

[34] Shen K, Feng E, Lin F, Weng Y, Chen J. Learning Curve of Total Hip Arthroplasty in Direct Anterior Approach without Requiring Corrective Osteotomy for Hip Dysplasia. Orthopaedic Surgery. 2022; 14: 840–850. https://doi.org/10.1111/os.13231.

[35] Kayani B, Konan S, Chandramohan R, Haddad FS. The direct superior approach in total hip arthroplasty. British Journal of Hospital Medicine. 2019; 80: 320–324. https://doi.org/10.12968/hmed.2019.80.6.320.

[36] Yang XT, Huang HF, Sun L, Yang Z, Deng CY, Tian XB. Direct Anterior Approach Versus Posterolateral Approach in Total Hip Arthroplasty: A Systematic Review and Meta-analysis of Randomized Controlled Studies. Orthopaedic Surgery. 2020; 12: 1065–1073. https://doi.org/10.1111/os.12669.

[37] Faldini C, Rossomando V, Brunello M, D'Agostino C, Ruta F, Pilla F, *et al*. Anterior Minimally Invasive Approach (AMIS) for Total Hip Arthroplasty: Analysis of the First 1000 Consecutive Patients Operated at a High Volume Center. Journal of Clinical Medicine. 2024; 13: 2617. https://doi.org/10.3390/jcm13092617.

[38] Chua MJ, Hart AJ, Mittal R, Harris IA, Xuan W, Naylor JM. Early mobilisation after total hip or knee arthroplasty: A multicentre prospective observational study. PLoS ONE. 2017; 12: e0179820. https://doi.org/10.1371/journal.pone.0179820.

[39] Kunze KN, McLawhorn AS, Jules-Elysee KM, Alexiades MM, Desai NA, Lin Y, *et al*. Effect of anterior approach compared to posterolateral approach on readiness for discharge and thrombogenic markers in patients undergoing unilateral total hip arthroplasty: a prospective cohort study. Archives of Orthopaedic and Trauma Surgery. 2023; 143: 2217–2226. https://doi.org/10.1007/s00402-022-04484-4.

[40] Shoji T, Inoue T, Kato Y, Fujiwara Y, Sumii J, Shozen H, *et al*. Associations between implant alignment or position and patient-reported outcomes after total hip arthroplasty. Clinical Biomechanics. 2022; 97: 105701. https://doi.org/10.1016/j.clinbiomech.2022.105701.

[41] Randelli F, Fioruzzi A, Barion G, Volpe G, Viganò M. Last generation fluted modular titanium stem in revision hip arthroplasty: a narrative review of mid- and long-term outcomes. Annals of Joint. 2024; 9: 5. https://doi.org/10.21037/aoj-23-35.

[42] Wernly D, Wegrzyn J, Lallemand G, Mahlouly J, Tissot C, Antoniadis A. Total hip arthroplasty through the direct anterior approach with and without the use of a traction table: a matched-control, retrospective, single-surgeon study. Journal of Orthopaedic Surgery and Research. 2021; 16: 45. https://doi.org/10.1186/s13018-020-02184-6.

[43] Svarnas G, Popa V, Patsiou TS, Schwab JM, Tannast M. Postoperative muscle atrophy and fatty degeneration with respect to surgical approaches in total hip arthroplasty. Archives of Orthopaedic and Trauma Surgery. 2025; 145: 177. https://doi.org/10.1007/s00402-025-05793-0.

[44] Liu X, Li Z, Wan P, Zhang W, Tian K. Advances in study of surgical approaches and MRI evaluation of total hip arthroplasty. Chinese Journal of Reparative and Reconstructive Surgery. 2024; 38: 618–625. https://doi.org/10.7507/1002-1892.202402033. (In Chinese)

[45] Di Martino A, Keating C, Butsick MJ, Platano D, Berti L, Hunter LN, *et al*. Enhancing recovery: surgical techniques and rehabilitation strategies after direct anterior hip arthroplasty. Journal of Orthopaedics and Traumatology. 2024; 25: 45. https://doi.org/10.1186/s10195-024-00786-y.

[46] Fontalis A, Raj RD, Kim WJ, Gabr A, Glod F, Foissey C, *et al*. Functional implant positioning in total hip arthroplasty and the role of robotic-arm assistance. International Orthopaedics. 2023; 47: 573–584. https://doi.org/10.1007/s00264-022-05646-0.

[47] Reijmerink IM, van der Laan MJ, Wietasch JKG, Hooft L, Cnossen F. Impact of fatigue in surgeons on performance and patient outcome: systematic review. The British Journal of Surgery. 2024; 111: znad397. https://doi.org/10.1093/bjs/znad397.

[48] Cheng H, Clymer JW, Po-Han Chen B, Sadeghirad B, Ferko NC, Cameron CG, *et al*. Prolonged operative duration is associated with complications: a systematic review and meta-analysis. The Journal of Surgical Research. 2018; 229: 134–144. https://doi.org/10.1016/j.jss.2018.03.022.

[49] Wainwright TW, Gill M, McDonald DA, Middleton RG, Reed M, Sahota O, *et al*. Consensus statement for perioperative care in total hip replacement and total knee replacement surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations. Acta Orthopaedica. 2020; 91: 3–19. https://doi.org/10.1080/17453674.2019.1683790.

[50] Chojnowska J, Lewko J, Chilińska J, Cybulski M, Pogroszewska W, Krajewska-Kułak E, *et al*. The Impact of Early Rehabilitation and the Acceptance of the Disease on the Quality of Life of Patients after Hip Arthroplasty: An Observational Study. Journal of Clinical Medicine. 2024; 13: 2902. https://doi.org/10.3390/jcm13102902.

[51] Geilen JEJW, Hermans SMM, Droeghaag R, Schotanus MGM, van Haaren EH, van Hemert WLW. A systematic review comparing the cost-effectiveness of the direct anterior, posterior, and straight lateral approach in total hip arthroplasty. EFORT Open Reviews. 2023; 8: 443–450. https://doi.org/10.1530/EOR-22-0108.

[52] Jesus TS, Lee D, Stern BZ, Zhang M, Struhar J, Heinemann AW, *et al*. The Value of Interventions Aimed at Improving the Patient Experience: Systematic Review of Economic Impacts and Provider Well-Being Outcomes. Healthcare. 2025; 13: 1622. https://doi.org/10.3390/healthcare13131622.

[53] Miura M, Suzuki T, Wako Y, Hoshi H, Fukawa T, Itadera E. Intraoperative fluoroscopic confirmation of the knee improves the accuracy of stem anteversion in total hip arthroplasty with direct anterior approach using traction table. Archives of Orthopaedic and Trauma Surgery. 2024; 144: 4217–4223. https://doi.org/10.1007/s00402-024-05509-w.

[54] Nakamura J, Hagiwara S, Kawarai Y, Hirasawa R, Akazawa T, Ohtori S. Is There a Learning Curve for the 5-Year Implant Survival Rate of Total Hip Arthroplasty Using the Direct Anterior Approach With a Traction Table? A Prospective Cohort Study. The Journal of Arthroplasty. 2024; 39: 2774–2779. https://doi.org/10.1016/j.arth.2024.04.080.

[55] Sugano N. Computer-assisted orthopaedic surgery and robotic surgery in total hip arthroplasty. Clinics in Orthopedic Surgery. 2013; 5: 1–9. https://doi.org/10.4055/cios.2013.5.1.1.

[56] Martusiewicz A, Delagrammaticas D, Harold RE, Bhatt S, Beal MD, Manning DW. Anterior versus posterior approach total hip arthroplasty: patient-reported and functional outcomes in the early postoperative period. Hip International. 2020; 30: 695–702. https://doi.org/10.1177/1120700019881413.

[57] Zhuang Z, Li Q, Yao Y, Shen Y, Chen D, Jiang Q. Incidence and risk factors of perioperative deep vein thrombosis in patients undergoing primary hip arthroplasty via the direct anterior approach. Journal of Orthopaedic Surgery and Research. 2024; 19: 10. https://doi.org/10.1186/s13018-023-04443-8.

[58] Agarwal N, To K, Khan W. Cost effectiveness analyses of total hip arthroplasty for hip osteoarthritis: A PRISMA systematic review. International Journal of Clinical Practice. 2021; 75: e13806. https://doi.org/10.1111/ijcp.13806.

[59] Foissey C, Batailler C, Coulomb R, Giebaly DE, Coulin B, Lustig S, *et al*. Image-based robotic-assisted total hip arthroplasty through direct anterior approach allows a better orientation of the acetabular cup and a better restitution of the centre of rotation than a conventional procedure. International Orthopaedics. 2023; 47: 691–699. https://doi.org/10.1007/s00264-022-05624-6.

[60] Mustapha MB, Muzaffer A, Parvizi J, Tuncay I. Does Robotic Total Hip Arthroplasty Technology Have Any Benefit in Achieving Equal Limb Length via the Direct Anterior Approach? Cureus. 2025; 17: e92716. https://doi.org/10.7759/cureus.92716.

[61] Ma M, Song P, Zhang S, Kong X, Chai W. Does robot-assisted surgery reduce leg length discrepancy in total hip replacement? Robot-assisted posterior approach versus direct anterior approach and manual posterior approach: a propensity score-matching study. Journal of Orthopaedic Surgery and Research. 2023; 18: 445. https://doi.org/10.1186/s13018-023-03864-9.

[62] Buchan GBJ, Bernhard Z, Hecht CJ, 2nd, Davis GA, Pickering T, Kamath AF. Improved perioperative narcotic usage patterns in patients undergoing robotic-assisted compared to manual total hip arthroplasty. Arthroplasty. 2023; 5: 56. https://doi.org/10.1186/

s42836-023-00211-5.

[63] Rogers N, Rullán PJ, Pasqualini I, Khan ST, Klika AK, Surace PA, *et al*. Lower 90-day inpatient readmission and 1-year reoperation in patients undergoing robotic versus manual total hip arthroplasty through an anterior approach. Technology and Health Care. 2024; 32: 3769–3781. https://doi.org/10.3233/THC-231646.

[64] Lloyd M, Ademi Z, Harris IA, Naylor J, Lewis P, de Steiger R, *et al*. Implementing an enhanced recovery from surgery pathway to reduce hospital length of stay for primary hip or knee arthroplasty: a budget impact analysis. BMC Health Services Research. 2024; 24: 1540. https://doi.org/10.1186/s12913-024-11871-7.

[65] Homma Y, Baba T, Watari T, Hayashi K, Kobayashi H, Matsumoto M, *et al*. Recent advances in the direct anterior approach to total hip arthroplasty: a surgeon's perspective. Expert Review of Medical Devices. 2023; 20: 1079–1086. https://doi.org/10.1080/17434440.2023.2280986.

[66] Luo Y. Toward Fully Automated Personalized Orthopedic Treatments: Innovations and Interdisciplinary Gaps. Bioengineering. 2024; 11: 817. https://doi.org/10.3390/bioengineering11080817.

[67] Mantwill F, Schulz AP, Faber A, Hollstein D, Kammal M, Fay A, *et al*. Robotic systems in total hip arthroplasty–is the time ripe for a new approach? The International Journal of Medical Robotics and Computer Assisted Surgery. 2005; 1: 8–19. https://doi.org/10.1002/rcs.55.

[68] Bullock EKC, Brown MJ, Clark G, Plant JGA, Blakeney WG. Robotics in Total Hip Arthroplasty: Current Concepts. Journal of Clinical Medicine. 2022; 11: 6674. https://doi.org/10.3390/jcm11226674.

[69] Kim K, Kwon S, Kwon J, Hwang J. A review of robotic-assisted total hip arthroplasty. Biomedical Engineering Letters. 2023; 13: 523–535. https://doi.org/10.1007/s13534-023-00312-9.