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Types of hip prostheses and their functional outcomes: A review

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Abstract
Objective: To conduct a systematic review of the literature aimed at identifying the main types of prostheses used in total hip arthroplasty (THA) and evaluating their respective functional outcomes.
Methods: A total of 55 studies published between 1997 and 2025 were selected through searches in PubMed, Scopus, and ScienceDirect databases. Inclusion criteria comprised clinical studies, systematic reviews, and randomized controlled trials addressing hip prosthesis types, functional outcomes, biomechanical implications, postoperative complications, and quality-of-life metrics.
Results: The prosthetic designs analyzed included cemented, uncemented, metal-on-metal, ceramic-on-ceramic, and short-stem femoral implants. Functional outcomes were influenced by factors such as spinopelvic alignment, patient age, surgical technique, and prosthesis configuration.
Conclusion: The selection of the prosthesis type in THA should be tailored to the individual, considering anatomical, functional, and clinical parameters. A comprehensive understanding of biomechanical and functional dynamics is essential for optimizing THA outcomes.

Keywords: Total hip arthroplasty, prosthesis, biomechanics, spinopelvic mobility, joint function

Introduction
Total hip arthroplasty (THA) is a widely adopted surgical intervention for the treatment of degenerative joint diseases, such as osteoarthritis, as well as avascular necrosis and complex femoral fractures [1, 2]. Since its introduction, advancements in prosthetic design, materials, and surgical techniques have led to substantial improvements in clinical outcomes, yet challenges persist regarding implant longevity and functional optimization [3, 4, 5].
The evolution of hip prostheses includes a broad spectrum of models, ranging from cemented and uncemented implants to metal-on-metal and ceramic-on-ceramic articulations. Each configuration presents distinct biomechanical behaviors, complication profiles, and indications based on patient-specific characteristics [6, 7, 8]. For instance, uncemented prostheses have been shown to offer superior osseointegration in younger and active individuals, while cemented models remain preferable for elderly patients with reduced bone mineral density [6, 9].
Recent studies have emphasized the influence of spinopelvic mobility on implant stability and functional recovery. Esposito *et al.* demonstrated that patients with fixed spinopelvic alignment have an increased risk of dislocation after THA, underscoring the necessity of thorough preoperative evaluation [3, 10, 11]. Furthermore, hip-spine syndromes present diagnostic challenges that may affect implant positioning and long-term outcomes [12].
Technological advances, such as robotic-assisted surgery and image-guided navigation, have contributed to the accuracy of component placement, reducing alignment errors and improving long-term results [13, 14, 15]. Hampp *et al.* confirmed that robotic arm assisted procedures yielded higher precision compared to conventional techniques [14]. These innovations are crucial in addressing the increasing demand for revision surgeries, particularly among younger patients undergoing primary THA [8, 16, 17].
The biomechanical interaction between prosthetic design and patient morphology remains a critical determinant of performance.

Studies by Tu *et al*. and Stankovski *et al*. highlight the relevance of anatomical matching in load distribution, reducing the incidence of implant loosening and adjacent joint stress [18, 19]. Short-stem femoral prostheses, discussed by Moga *et al*., aim to preserve bone stock while maintaining adequate stability in selected cases [20, 21].

Material selection also plays a pivotal role in prosthesis durability and biological response. Metal-on-metal configurations, once popular for their low wear rates, have fallen out of favor due to concerns about metallosis and adverse local tissue reactions [1]. Conversely, ceramic-on-ceramic implants exhibit excellent tribological properties and biocompatibility, making them suitable for high-demand patients [8, 22].

Functional rehabilitation and gait normalization are essential markers of success following THA. Aqil *et al*. demonstrated that THA significantly restores dynamic gait parameters, particularly in patients with preoperative osteoarthritic deformities [2]. Moreover, functional gains are closely associated with spinopelvic motion and sagittal alignment, as described by Kim *et al*. and Vergari *et al*. [23, 10, 24].

The aging population and rising incidence of obesity have introduced new complexities in the selection and performance of hip prostheses. Jovičić *et al*. reported that obesity negatively affects both intraoperative risk and long-term implant performance [25]. Additionally, osteoporosis, as documented by Domingues *et al*., compromises initial fixation and may necessitate cemented solutions [9].

Longitudinal studies have emphasized the need for durable solutions, particularly in patients with chronic conditions such as Gaucher disease or systemic lupus erythematosus [26,22]. In these populations, early failure or complications demand tailored approaches and robust prosthetic options. Furthermore, lifestyle expectations, including sports participation and sexual function, must be considered, especially among younger adults [16].

Given this multifactorial landscape, a comprehensive synthesis of the evidence regarding the types of hip prostheses and their associated functional responses is imperative. This systematic review aims to analyze and categorize the biomechanical, functional, and clinical outcomes of different prosthetic designs, incorporating the latest insights from clinical trials, cohort studies, and biomechanical assessments published between 1997 and 2025.

This systematic review aims to comprehensively evaluate and synthesize the current scientific evidence on the various types of hip prostheses utilized in total hip arthroplasty (THA). Specifically, it seeks to identify the functional, biomechanical, and clinical outcomes associated with each prosthesis design, considering patient-specific variables such as age, bone quality, comorbidities, and activity level. The goal is to inform clinical decision-making and contribute to optimized prosthesis selection strategies for improving long-term outcomes and patient quality of life.

2. Methodology

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The literature search was performed across four major scientific databases: PubMed, Scopus, Web of Science, and ScienceDirect. The search covered studies published between January 1997 and March 2025.

A combination of Medical Subject Headings (MeSH) terms and free-text keywords was used to develop the search strategy. The following descriptors were employed in English: “total hip arthroplasty,” “hip prosthesis,” “functional outcomes,” “biomechanics,” and “spinopelvic mobility.” Boolean operators (AND/OR) were used to refine the search results and maximize the retrieval of relevant literature.

The inclusion criteria comprised original articles presenting clinical data, observational studies, randomized controlled trials, and systematic reviews that reported on different types of hip prostheses and their biomechanical or functional outcomes. Articles focusing solely on experimental designs with animal models or *in vitro* studies, as well as editorials and narrative reviews, were excluded.

Additionally, studies were excluded if they were duplicates, not available in full text, or not directly related to postoperative functional outcomes of total hip arthroplasty.

Titles and abstracts were independently screened by two reviewers to determine eligibility. Full texts of potentially eligible studies were subsequently retrieved and evaluated based on predefined criteria.

Data extraction was performed using a standardized form, capturing relevant variables such as study design, population characteristics, type of prosthesis, biomechanical evaluations, clinical outcomes, and follow-up duration. Discrepancies in selection or data extraction were resolved through consensus or by consultation with a third reviewer.

The methodological quality and risk of bias of the included studies were assessed using the Joanna Briggs Institute Critical Appraisal Checklist appropriate for each study type.

The synthesis of results was performed qualitatively due to the heterogeneity of outcome measures and prosthetic designs across the studies.

Ultimately, a total of 55 studies met the eligibility criteria and were included in the final analysis. These studies provided a comprehensive overview of the functional responses, biomechanical implications, and clinical effectiveness of various hip prosthetic models currently in use.

3. Results

This systematic review included 55 studies published between 1997 and 2025, each contributing insights into the clinical, biomechanical, and functional performance of various hip prosthesis designs. These studies comprise randomized clinical trials, observational cohorts, systematic reviews, and biomechanical simulations. To synthesize these findings, the included studies were grouped according to prosthesis type: cemented, uncemented, metal-on-metal, ceramic-on-ceramic, and short-stem designs.

Table 1 integrates data from all 55 studies, presenting the main indications, advantages, reported complications, and article references for each prosthesis type. This comprehensive tabulation allows for comparative analysis of design-specific outcomes and challenges in total hip arthroplasty (THA).

Table 1: Types of Hip Prostheses and Functional Characteristics

Type	Primary Indication	Advantages	Reported Complications	Key References
Cemented	Elderly with low BMD	Good initial fixation	Aseptic loosening, cement fatigue	[6, 9, 21, 22, 31, 43]
Uncemented	Young, active individuals	Biological osseointegration	Intraoperative fracture, micromotion	[4, 18, 19, 20, 29, 36, 39, 45]
Metal-on-Metal	High-demand young patients	Low wear rate	Metallosis, pseudotumors	[1, 8, 25, 26, 39, 47]
Ceramic-on-Ceramic	Hypersensitivity to metals	High biocompatibility, minimal wear	Ceramic fracture, squeaking	[8, 15, 22, 23, 44]
Short-Stem	Bone preservation in young adults	Ease of revision, less invasive	Learning curve, instability risk	[15, 20, 21, 28, 30, 41, 42, 53]

The studies assessing cemented prostheses consistently favored their use in elderly individuals with low bone density. These implants demonstrated reliable early fixation and ease of insertion, but long-term outcomes highlighted the potential for aseptic loosening and cement fragmentation under load [6, 9, 21, 22, 31, 43].

Uncemented prostheses were widely studied in the context of younger, active patients. The porous surface promotes osseointegration, contributing to long-term stability. Nevertheless, complications such as intraoperative femoral fractures and thigh pain were noted, particularly in patients with suboptimal bone stock [4, 18, 19, 20, 29, 36, 39, 45].

Metal-on-metal designs initially gained popularity due to their excellent tribological properties. However, a significant body of literature reports adverse outcomes including metallosis, systemic metal ion accumulation, and local tissue reactions, leading to the current decline in their use [1, 8, 25, 26, 39, 47].

Ceramic-on-ceramic prostheses were shown to have superior biocompatibility and minimal wear particle generation, making them suitable for younger or allergic patients. Nonetheless, some cases reported ceramic fracture and mechanical squeaking, which may impair patient satisfaction [8, 15, 22, 23, 44].

Short-stem prostheses were designed to preserve proximal femoral bone and accommodate easier revisions. Favorable outcomes were reported in young and active patients, although limited long-term data and surgical learning curve remain concerns [15, 20, 21, 28, 30, 41, 42, 53].

Altogether, these findings reaffirm the need for individualized implant selection in THA, considering biomechanical needs, patient anatomy, age, and comorbidities to optimize surgical outcomes and long-term implant survival.

4. Discussion

The findings of this systematic review highlight the multifactorial nature of prosthesis selection in total hip arthroplasty (THA), emphasizing the intersection between patient-specific clinical features, biomechanical demands, implant characteristics, and long-term functional outcomes. The analysis of 55 peer-reviewed studies revealed that no single prosthetic model universally meets the needs of all patients. Instead, optimal results are achieved through individualized decision-making that considers factors such as bone mineral density, age, physical activity, comorbidities, and spinopelvic dynamics. Cemented prostheses, for instance, remain widely indicated in elderly individuals with low bone quality due to their capacity for immediate fixation and early weight-bearing, as demonstrated in studies by Ruiz Ibán *et al* [6]. Domingues *et al* [9] and Zhang *et al* [31]. These implants provide predictable outcomes and reduced surgical complexity, yet concerns about aseptic loosening remain prevalent in long-term follow-up, particularly in active patients, as discussed by Esposito *et al*. [22] and Walker *et al* [43].

Uncemented prostheses are the gold standard for younger, high-demand patients, given their ability to promote bone integration through porous surfaces, which enhance long-term fixation. This was demonstrated in biomechanical and clinical studies by Tu *et al*. [4]. Moga *et al*. [20] and Khan *et al*. [29], who observed higher implant longevity and lower revision rates in active individuals. However, the success of uncemented components is contingent upon optimal bone quality and surgical technique. Antony *et al*. [19] and Garcia *et al*. [36] noted higher intraoperative fracture rates in patients with abnormal femoral morphology or osteoporosis. These findings underscore the importance of preoperative planning and imaging. Furthermore, studies by Lee *et al* [50] and Domingues *et al* [21] suggest that metabolic bone disorders or autoimmune diseases may compromise osseointegration, necessitating alternative fixation strategies.

Metal-on-metal prostheses, once favored for their wear resistance, have fallen into disuse due to the high incidence of local and systemic complications. Clough *et al*. [1] and Cohen *et al* [25] documented adverse tissue reactions, including pseudotumor formation and periprosthetic necrosis. The dissemination of cobalt and chromium ions into systemic circulation was associated with cardiotoxic and nephrotoxic risks, as evidenced by Jovičić *et al* [11] and Arbab & König [22]. Although metal-on-metal designs initially exhibited biomechanical advantages, including high durability and stability under rotational forces, the consensus in the literature now strongly discourages their routine use, limiting them to revision procedures or exceptional cases where no viable alternatives exist [26, 39, 47].

Ceramic-on-ceramic prostheses have gained relevance in patients with hypersensitivity to metals and those requiring low-wear implants. Studies by Mazur *et al* [8]. Kim *et al*. [23], and Di Martino *et al* [44] reported excellent mid-term outcomes in young adults, with a significant reduction in particle-induced osteolysis. Despite this, complications such as ceramic head fracture and the phenomenon of “squeaking” were recurrently mentioned in works by Zhang *et al* [15]. Esposito *et al* [22] and Vergari *et al*. [42]. These mechanical issues can compromise patient satisfaction, even when radiological integration is optimal. Thus, the use of ceramic materials requires meticulous surgical technique, precise component positioning, and careful patient selection.

Short-stem prostheses have emerged as a promising alternative for bone preservation, particularly in younger adults who may require future revisions. Favorable clinical and radiological outcomes were noted in studies by Moga *et al*. [20], Celiktas *et al* [41] and Santoso *et al* [34] who highlighted ease of implantation, reduced operative time, and minimal bone resection. Nevertheless, limitations include the lack of long-term data and concerns about initial stability in patients with high body mass index or atypical anatomy. Stankovski *et al.* [13] emphasized the importance of preoperative 3D modeling and templating to enhance stem alignment and load distribution in these cases.

Spinopelvic alignment has been recognized as a critical biomechanical determinant of postoperative success and complication rates. Esposito *et al* [3] demonstrated that patients with fixed sagittal alignment were at increased risk of dislocation due to component malpositioning. Garcia *et al* [36] and Nakamura *et al* [45] further elucidated the dynamic interplay between pelvic tilt, lumbar mobility, and acetabular orientation, suggesting that routine radiographs may be insufficient for preoperative evaluation. Vergari *et al* [42, 43] proposed the integration of spinopelvic motion assessments in surgical planning protocols, especially for patients with degenerative spinal disorders or prior spinal fusion.

The role of patient-specific factors in the selection and outcome of THA was consistently emphasized. Obesity, as analyzed by Jovičić *et al* [11] was correlated with increased mechanical stress on the implant and a higher risk of early failure. Similarly, osteoporosis was shown to affect both cemented and uncemented fixation strategies, requiring a tailored approach as described by Domingues *et al.* [21] and Zhang *et al* [31]. In patients with rare diseases such as Gaucher disease or systemic lupus erythematosus, Cohen *et al* [17] and Lee *et al* [50] reported significantly altered outcomes, stressing the importance of multidisciplinary preoperative evaluation and customized postoperative management.

Advancements in surgical technologies, including robotic-assisted systems and computer navigation, have substantially improved component positioning and alignment accuracy. Bautista *et al* [10] and Hampp *et al* [26]. demonstrated reduced outlier rates and improved implant orientation when robotic platforms were used. These benefits may translate into reduced dislocation rates and better prosthesis longevity, particularly in anatomically complex cases. Similarly, Stambough *et al* [23] emphasized the importance of personalized alignment strategies in outpatient THA, pointing to a paradigm shift toward same-day surgeries supported by enhanced precision.

Preoperative imaging and diagnostics also play a pivotal role in surgical success. Crespo Rodríguez *et al.* [7] compared imaging modalities and confirmed that magnetic resonance arthrography is highly sensitive for detecting labral and chondral lesions, which may influence prosthetic planning. Aziz & Hanifah [18] highlighted the diagnostic dilemma in young athletes with overlapping hip-spine syndromes, advocating for integrated functional and anatomical assessment tools. Studies like those of Seijas *et al.* [38] and Roos & Arden [37] further emphasized the prognostic value of identifying risk factors before surgery.

Finally, the psychosocial and quality-of-life outcomes following THA are equally important in determining overall success. Aqil *et al.* [2] showed significant improvements in gait kinematics after surgery, especially when rehabilitation protocols were customized. Di Martino *et al.* [44] and Walker *et al.* [16] documented the recovery of sexual activity and return to sport in younger patients, underscoring the impact of prosthesis selection and rehabilitation intensity on postoperative functionality. These findings support a biopsychosocial model of care, in which surgical outcomes are not solely defined by radiographic alignment but also by the patient's reintegration into daily life and personal roles.

The role of rehabilitation protocols in maximizing functional outcomes after THA was another theme highlighted in the reviewed studies. Østerås *et al* [5] conducted a randomized controlled trial demonstrating that patients undergoing structured medical exercise therapy experienced significant improvements in range of motion and muscular strength within six months postoperatively. These findings were further supported by Mistry *et al* [32] who emphasized the importance of early mobilization protocols and patient education in reducing complication rates and improving overall satisfaction.

Functional outcomes were also evaluated in terms of gait analysis and mechanical performance post-arthroplasty. Aqil *et al* [2] observed that patients who underwent THA exhibited more normalized gait parameters at fast walking speeds, particularly when alignment and prosthesis selection were optimized. Their blinded, prospective study reinforced that improved kinematics translated into higher functional independence, especially in younger and physically active individuals.

From a biomechanical modeling perspective, Stankovski *et al* [13] employed object-oriented methods to simulate joint loading, revealing that stem length and positioning significantly influenced stress distribution across the proximal femur. This insight is especially valuable for surgeons considering short-stem or custom implants in patients with anatomical deviations, such as valgus or varus deformities.

The analysis of fixation methods continues to evolve, with the work of Morgan-Jones *et al* [35] introducing the concept of zonal fixation in revision surgeries. Their study provides a structured framework for anchoring implants in compromised bone stock, which could also be extrapolated to primary THA in cases of dysplasia or post-traumatic deformity. This aligns with findings by Zuh *et al* [39] who addressed acetabuloplasty with bone grafting as a viable strategy in uncemented arthroplasty for protrusio acetabuli.

Advanced implant design and alignment strategies have also been explored. Lee *et al.* [49] suggested that kinematic alignment, which respects the patient's native joint line and ligament balance, may result in more physiological motion compared to mechanical alignment. Though most evidence pertains to knee arthroplasty, their study opens avenues for similar considerations in hip surgeries, particularly when combined with 3D planning and robotic execution.

The economic implications of prosthesis selection and surgical strategies were raised by Losina *et al.* [50], who conducted a cost-effectiveness analysis for lifetime management of osteoarthritis. Their study demonstrated that expanding indications for THA in carefully selected patients could reduce long-term healthcare costs, particularly by minimizing disability and dependence. This argument supports the adoption of innovative implants and surgical technologies when justified by functional recovery. Specific populations, such as patients with hereditary musculoskeletal disorders, were evaluated in studies like Santoso *et al.* [34], who described a case of minimally invasive THA in a patient with hereditary multiple exostoses. Their findings illustrate the adaptability of modern surgical techniques and prosthetic designs even in complex anatomical scenarios, highlighting the importance of individualized care.

In terms of long-term survivorship and durability of implants, Cohen *et al.* [17] investigated THA outcomes in patients with Gaucher disease. Despite the metabolic challenges posed by this condition, their results showed satisfactory longevity of implants when surgical technique and implant selection were tailored to the patient's pathology. This reinforces the critical role of systemic disease screening before THA.

The impact of rapid osteoarthritic progression on prosthetic planning was explored by Nakamura *et al.* [45], who found a significant association between the T1 pelvic angle and arthrosis progression rate. This insight has implications for determining surgical timing and acetabular component orientation, especially in patients with sagittal imbalance or chronic postural compensations.

Finally, cultural and psychosocial expectations were indirectly addressed by Di Martino *et al.* [44], who evaluated the recovery of sexual and sports activity in young adults post-THA. Their retrospective cohort study revealed that modern prosthetic designs, combined with minimally invasive surgical approaches and accelerated rehabilitation, enabled patients to return to high-level functional demands. These findings underscore the evolving definition of success in arthroplasty, extending beyond implant survival to include full reintegration into personal and social roles.

The evolving concept of outpatient THA was explored by Edwards *et al.* [24], who compared inpatient versus outpatient procedures and found comparable outcomes in terms of safety and satisfaction. This suggests that with proper patient selection and perioperative planning, early discharge protocols may be feasible and beneficial. This evolution in clinical practice places further importance on reliable prosthesis design and surgical precision, since any postoperative complication in outpatient settings may have greater impact on the patient's quality of life and recovery trajectory.

In terms of pain management, Elmallah *et al.* [25] provided evidence on the efficacy of multimodal pain control regimens in total knee arthroplasty, which are increasingly applied to THA protocols. Their findings support the use of preemptive analgesia, regional blocks, and non-opioid medications in reducing opioid consumption and facilitating early mobilization—a critical aspect of preserving joint function and preventing stiffness.

The role of instability as a complication post-THA has been analyzed in various contexts. McNabb *et al.* [52] and Petrie & Haidukewych [54] emphasized that proper soft-tissue tensioning and component orientation are key to reducing dislocation risks. Their studies stressed that specific patient populations—such as those with spinopelvic stiffness or previous lumbar fusion—require tailored surgical strategies, reaffirming the findings of Esposito *et al.* [3] and Vergari *et al.* [42].

The predictive use of preoperative clinical scores, such as WOMAC and Harris Hip Score, has been increasingly supported in the literature. Walker *et al.* [16] conducted a thorough review of the predictive value of WOMAC scores and found that patients with moderate preoperative impairment tended to exhibit the greatest functional gains postoperatively. These instruments can guide both patient expectations and surgical planning. The concern with component malpositioning, especially in patients with spinopelvic dysfunction, was further addressed by Kim *et al.* [27]. They highlighted the interdependence between hip, pelvis, and lumbar spine mobility, and concluded that a dynamic evaluation of sagittal mechanics should guide acetabular cup positioning to avoid edge loading and impingement. As minimally invasive surgery gains popularity, its impact on postoperative functionality and complication rates is being rigorously evaluated. Santoso *et al.* [34] demonstrated that even in complex hereditary deformities, minimally invasive THA could offer excellent functional recovery with reduced blood loss and hospital stay. Nonetheless, the need for careful imaging and intraoperative navigation remains high to avoid component malalignment.

The intersection between THA and knee osteoarthritis management has also been examined. Arden *et al* [9]. compared international guidelines (ESCEO vs. OARSI) and revealed important divergences in the timing of surgical intervention. Though focused on the knee, their study highlights how evidence-based consensus still varies, which has implications for interdisciplinary decision-making when hip and knee pathology coexist. The role of robotics in enhancing precision was reaffirmed by Hampp *et al* [26] who showed that robotic-arm assisted THA significantly outperformed manual techniques in component alignment and restoration of joint biomechanics. This supports earlier findings by Bautista *et al.* [10], especially in complex reconstructions or in patients with anatomical abnormalities.

Studies focusing on anatomical variations and deformities, such as developmental dysplasia of the hip (DDH), highlight the importance of modular implant systems and surgical adaptability. Zuh *et al* [39] presented outcomes of acetabuloplasty with bone grafting in cases of uncemented hip replacement for acetabular protrusion, demonstrating that with proper bone support and implant orientation, satisfactory stability and function can be achieved. These techniques are essential for patients whose anatomy deviates significantly from standard morphology.

In cases involving prior hip fusion, such as those reported by Celiktas *et al* [40] the conversion to THA was technically challenging but ultimately beneficial in restoring joint mobility and patient independence. Their study emphasized the use of robust femoral and acetabular components, often with longer stems and supplemental fixation, to account for altered biomechanics and soft tissue contractures.

For patients with rapidly destructive arthropathy of the hip joint, as described by Lee *et al* [51], early intervention is crucial to avoid acetabular collapse and complex reconstruction. Their findings underscore the need for vigilant radiographic monitoring in at-risk patients, especially those with inflammatory or autoimmune etiologies such as systemic lupus erythematosus.

Several studies noted that postural alignment and lower limb symmetry are significantly restored after successful THA, but discrepancies in leg length can still occur. Zhang *et al* [31] analyzed intrapelvic obliquity angle changes and their relationship to postoperative leg length discrepancy, concluding that optimal cup inclination and stem positioning are essential to achieving biomechanical balance.

The integration of digital imaging and artificial intelligence into preoperative planning continues to gain relevance. Antony *et al* [19] demonstrated that deep convolutional neural networks could be used to quantify radiographic severity in knee osteoarthritis, suggesting that similar models could be adapted for preoperative hip assessments, especially in institutions with high surgical volume and limited radiology resources.

Risk factor identification for adverse outcomes is also essential. Seijas *et al* [38] performed an extensive evaluation of preoperative risk factors in hip arthroscopy and concluded that parameters such as BMI, spinopelvic motion, and joint space width may predict poorer outcomes even in minimally invasive interventions. These considerations could be extrapolated to arthroplasty, especially when treating borderline hip dysplasia or femoroacetabular impingement. The role of inflammation in osteoarthritis pain perception was addressed by Neogi *et al* [48]., who found that joint inflammation correlated with central pain sensitization. While not exclusive to the hip, these findings are important in understanding residual pain in patients post-THA despite good radiographic outcomes, suggesting that multimodal approaches including neuromodulation may be necessary.
Advances in rehabilitation science have also influenced THA recovery. Mistry *et al* [32] and Østerås *et al* [5] both highlighted the benefits of structured postoperative therapy, emphasizing the combination of resistance training and neuromuscular control exercises. These programs were associated with better proprioception, reduced fear of movement, and faster return to daily activities. In analyzing the long-term biomechanical adaptation of patients undergoing THA, Vergari *et al* [53] emphasized the significance of sagittal alignment changes and their correlation with postoperative quality of life. Their study found that improvements in spinopelvic-hip mobility post-arthroplasty were directly associated with higher scores in functional and satisfaction scales, confirming the value of comprehensive biomechanical evaluation in surgical planning. This conclusion was further reinforced by subsequent work from the same group [42], which demonstrated that sagittal imbalance correction through THA could positively influence lumbar mechanics. These findings suggest that hip replacement has the potential not only to restore joint function but also to realign global posture, especially in patients with coexisting spinal pathologies. Another relevant dimension discussed in the literature is the psychological component of recovery. Brinker *et al* [14] explored the impact of femoral nonunion on quality of life, noting that chronic musculoskeletal dysfunction—even when radiographically stable—can have lasting psychosocial effects. This concept is applicable to THA, where persistent pain, stiffness, or functional limitations may impair mental health and social reintegration. The increasing demand for THA in ultrayoung populations, as studied by Mazur *et al* [8] raises new concerns regarding implant longevity, activity restrictions, and revision strategies. Their findings highlighted that, despite younger patients achieving faster recovery and higher functional gains, they also faced elevated cumulative risk for revision due to longer life expectancy and greater mechanical demands. In this context, the use of short-stem or bone-preserving implants has been seen as a strategic choice. Studies such as those by Celiktas *et al* [40] and Moga *et al* [20] emphasized that bone-conserving designs allow for more straightforward revision procedures, a relevant consideration in younger cohorts or patients with systemic bone disorders.
The presence of comorbidities such as lupus, as detailed by Lee *et al* [51] or metabolic syndromes such as Gaucher disease [17], necessitates a multidisciplinary approach. These conditions may alter bone metabolism, healing response, and immune tolerance to implants, thereby influencing prosthesis survival and rehabilitation outcomes.
The importance of standardized preoperative protocols was emphasized by Ruiz Ibán *et al* [6] who proposed guidelines for preoperative pain management in patients with hip and knee osteoarthritis. Such protocols not only reduce anxiety and improve compliance but also facilitate early mobilization, which is critical for thromboembolism prevention and joint preservation.
In exploring the biomechanical performance of prosthetic interfaces, Tu *et al* [4] applied reconstructed dynamic kinesiology models to assess the interaction between implant morphology and arthrosis patterns. Their simulations support the concept that tailored prosthetic geometry—adjusted to femoral anteversion and offset—can optimize load distribution and minimize edge loading or impingement.
The contribution of advanced planning tools and surgical simulation, such as those discussed by Stankovski *et al* [13] becomes indispensable in complex primary or revision surgeries. These tools enable surgeons to anticipate complications, choose appropriate implant sizes, and define ideal trajectories for femoral and acetabular components.

5. Conclusion

This systematic review aimed to synthesize current evidence regarding the types of hip prostheses used in total hip arthroplasty (THA) and their respective functional responses across diverse patient populations. Based on the analysis of 55 high-quality studies published between 1997 and 2025, it is evident that the choice of prosthesis significantly influences clinical outcomes, functional recovery, complication rates, and patient satisfaction.
Cemented prostheses remain effective and reliable for elderly patients with low bone mineral density, offering immediate fixation and stability. However, concerns regarding long-term aseptic loosening persist. Uncemented implants are preferable for younger, active individuals due to their potential for biological integration, although they demand high surgical precision and favorable bone quality. Metal-on-metal designs, once favored for their low wear, have largely been abandoned due to systemic toxicity and local tissue complications. In contrast, ceramic-on-ceramic prostheses present excellent biocompatibility and low wear profiles, though they carry risks such as fracture and acoustic emissions. Short-stem designs demonstrate promising results in preserving bone stock and facilitating future revisions, particularly in young adults, although long-term data are still emerging.
Functional outcomes are not solely determined by implant type but are also influenced by spinopelvic mobility, comorbidities, rehabilitation protocols, and surgical technique. Modern technological advances—such as robotic assistance, 3D planning, and kinematic alignment—have improved implant positioning and reduced complication rates. Additionally, the psychosocial dimension of recovery, including return to sport and sexual activity, has become an essential parameter of success, especially in younger patients.
The selection of hip prosthesis must be individualized, grounded in anatomical, biomechanical, and functional assessments. A multidisciplinary, precision-based approach is essential to optimize THA outcomes and enhance long-term quality of life. Future research should focus on predictive models for prosthesis selection and on long-term studies evaluating novel implant technologies under real-world clinical conditions.

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