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Original Article

Minimally invasive total hip arthroplasty versus minimally invasive hemiarthroplasty for geriatric femoral neck fractures: efficacy and impact on inflammatory and stress markers

Linwu Li[1], Chaoxu Li[2], Dongxu Chen[2], Wei Peng[2], Mingzhou Chen[2], Shibin Su[1], Bin Huang[2]

[1]*Second Ward of Orthopedics, The Second Affiliated Hospital of Guilin Medical University, Guilin 541199, Guangxi Zhuang Autonomous Region, China;* [2]*Department of Joint Surgery and Sports Medicine, Nanxishan Hospital of Guangxi Zhuang Autonomous Region, Xiangshan District, Guilin 541002, Guangxi Zhuang Autonomous Region, China*

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Abstract: Objective: To compare the clinical efficacy, inflammatory responses, and surgical stress between minimally invasive total hip arthroplasty (MIS-THA) and minimally invasive hemiarthroplasty (MIS-HA) in the treatment of femoral neck fractures (FNFs) in elderly patients. Methods: From December 2018 to December 2021, 98 elderly patients with FNFs were enrolled, with 50 undergoing MIS-THA (observation group) and 48 undergoing MIS-HA (reference group). The clinical efficacy, surgery-related parameters (including intraoperative blood loss, postoperative drainage volume, and operation time), postoperative recovery (hip joint recovery time and hospitalization), and complication rates were compared between the two groups. Interleukin-6 (IL-6), C-reactive protein (CRP), Harris Hip Score, and Visual Analog Scale (VAS) scores were assessed preoperatively and postoperatively. Cortisol (Cor) and malondialdehyde (MDA) levels were measured at four time points: preoperatively (T0), immediately postoperatively (T1), and at 24 hours (T2) and 72 hours (T3) post-surgery. Additionally, efficacy comparisons were conducted across different age groups and fracture types. Results: The observation group demonstrated significantly higher treatment efficacy, shorter hip recovery time, and better functional outcomes (as evidenced by higher Harris and lower VAS scores) compared to the reference group. MIS-THA was associated with longer operative time, greater blood loss, and increased drainage volume (P<0.05), while hospitalization time and complication rates were comparable between groups (P>0.05). Postoperative IL-6 and CRP levels were elevated in both groups, but remained lower in the observation group (P<0.05). Stress markers (Cor and MDA) peaked at T2 and declined thereafter, with milder fluctuations observed in the observation group (P<0.05). The total effectiveness rate didn't differ significantly between the two groups across different age groups and fracture types. Conclusion: MIS-THA provides superior efficacy, faster functional recovery, and more pronounced pain relief, along with a milder inflammatory and stress response, compared to MIS-HA in elderly patients with FNFs. Despite longer operation time, greater intraoperative blood loss, and higher postoperative drainage, MIS-THA and MIS-HA exhibit similar safety profiles, as evidenced by comparable hospitalization durations and complication rates.

Keywords: Minimally invasive technique, total hip arthroplasty, hemiarthroplasty, femoral neck fractures, inflammatory markers, stress markers

Introduction

Femoral neck fractures (FNFs) are a predominant type of hip injury in the elderly, accounting for approximately half of all hip fractures [1]. These fractures are frequently associated with severe complications, including nonunion, fixation failure, and avascular necrosis, significantly compromising patient outcomes [2]. Epidemiological data indicate that FNFs account for up to 40% of trauma cases, with postoperative mortality rates ranging from 14.7% to 71.1%, regardless of the type of surgical management employed [3, 4]. The etiology of FNFs is multifactorial, commonly involving falls, decreased mobility, osteoporosis, and prolonged

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medication use. These factors can increase the risk of severe consequences, including femoral head avascular necrosis, fracture nonunion, significantly impairing functional independence [5, 6]. Currently, prosthetic hip replacement, including total hip arthroplasty (THA) and hemiarthroplasty (HA), remains the standard surgical approach for FNFs [7]. Despite its procedural effectiveness, conventional arthroplasty is associated with large surgical incisions, massive intraoperative bleeding, and an increased risk of postoperative complications [8, 9]. Emerging minimally invasive techniques, such as minimally invasive THA (MIS-THA) and HA (MIS-HA), utilizing multiple surgical approaches like the anterolateral approach, direct anterior approach (DAA), and Supercapsular Percutaneously Assisted Total Hip (SuperPATH) technique, have demonstrated superiority including muscle-sparing dissection, accelerated postoperative rehabilitation, and improved cosmetic outcomes [10-12]. For instance, a comparative study by Alecci et al. [13] demonstrated that DAA-based MIS-THA resulted in reduced postoperative pain, fewer gastrointestinal side effects (nausea/vomiting), and shorter hospital stays.

Nonetheless, comparative evaluations between MIS-THA and MIS-HA specifically for geriatric FNFs remain limited. This study aims to fill this gap and provide evidence to inform optimal surgical selection for this high-risk population.

Materials and methods

Study population

A total of 98 elderly patients with FNFs treated at The Second Affiliated Hospital of Guilin Medical University between December 2018 and December 2021 were retrospectively enrolled. Patients were allocated into two groups based on clinical treatment, with 48 assigned to the reference group (MIS-HA) and 50 to the observation group (MIS-THA). Demographic characteristics (e.g., gender, age) showed no statistically significant differences between the groups (P>0.05), confirming group comparability. The study protocol was approved by the Institutional Review Board (IRB) of The Second Affiliated Hospital of Guilin Medical University.

Inclusion criteria: Radiologically confirmed FNFs [14]; Primary surgical management with either MIS-THA or MIS-HA; No treatment contraindications; Intact visual, hearing, communicative, and cognitive abilities; No severe cardiac, pulmonary, or renal dysfunction; Complete and available medical records.

Exclusion criteria: Concurrent hip diseases or multiple fracture sites; Active severe infections or coagulopathies; History of previous hip surgery or lower extremity deep vein thrombosis (DVT); Presence of active infectious foci; Diagnosed psychiatric or autoimmune disorders.

Treatment methods

Patients in the observation group received MIS-THA, while those in the reference group underwent MIS-HA. The surgical procedures were performed as follows:

Under general or combined spinal-epidural anesthesia, patients were placed in the standard lateral decubitus position. A small incision was made through DAA, accessing the hip joint through the intermuscular plane between the sartorius, rectus femoris, and tensor fasciae latae muscles to preserve muscle integrity and the joint capsule. A blunt retractor was carefully positioned around the femoral neck and intermittently released to minimize soft tissue trauma. Two parallel osteotomies, spaced approximately 1 cm apart, were performed at the femoral neck using an osteotomy guide, followed by removal of the intervening bone segment and femoral head. In the reference group, following femoral canal reaming, an appropriately sized cementless femoral stem and prosthetic head were implanted. In the observation group, debridement was first performed to remove the acetabular labrum, pulvinar fat pad, and ligamentum teres. The acetabulum was then reamed and shaped before the acetabular cup was secured in place. Following preparation of the femoral canal, a cementless femoral stem and prosthetic head were implanted. After prosthesis placement, hip range of motion and stability were assessed. The surgical field was irrigated, a drain was placed, and the wound was closed in layers (joint capsule, fascia lata, and skin).

Postoperatively, antibiotics were administered for 3 to 5 days, and low-molecular-weight heparin (LMWH) was continued for one month to prevent thrombosis. Drainage tubes were opened two hours after surgery and removed within 24 to 48 hours. Patient-controlled intravenous analgesia (PCIA) with hydromorphone was administered for pain management, with no significant difference in analgesic consumption observed between the two groups. Blood transfusion was administered on the postoperative day if hemoglobin levels dropped below 90 g/L.

Evaluation metrics

(1) Clinical efficacy assessment: Markedly effective: complete restoration of hip joint function with no residual postoperative pain. Effective: significant improvement in hip joint function with only mild residual pain. Ineffective: failure to achieve either of the above outcomes.

(2) Surgery-related parameters: The following intraoperative and postoperative metrics were recorded and compared between the two groups: intraoperative blood loss, postoperative drainage volume, and operative time.

(3) Postoperative recovery outcomes: Postoperative recovery was evaluated by assessing the time to hip joint recovery and length of hospitalization.

(4) Inflammatory marker analysis: Fasting venous blood samples (3 mL) were collected via antecubital venipuncture. Following centrifugation, serum concentrations of interleukin-6 (IL-6) and C-reactive protein (CRP) were quantified using enzyme-linked immunosorbent assay (ELISA) both preoperatively and on postoperative day 3.

(5) Stress response evaluation: Serum levels of cortisol (Cor) and malondialdehyde (MDA) were measured using ELISA at four time points: T0 (preoperative baseline), T1 (immediately following surgery), T2 (24 hours postoperatively), and T3 (72 hours postoperatively).

(6) Function and pain assessment: Hip function and pain intensity were assessed preoperatively and at the six-month postoperative follow-up using two validated scoring systems [15]: Harris Hip Score, a 100-point scale, was used to assess hip joint function, with higher scores indicating better functional capacity; Visual Analog Scale (VAS): a 10-point scale, was used to evaluate pain intensity, with higher scores indicating greater pain intensity.

(7) Adverse event monitoring: Postoperative complications were systematically recorded, including DVT, pulmonary infections, incisional infections, and joint dislocations. Incidence rates for each complication were subsequently calculated.

To address missing values, Multiple Imputation by Chained Equations (MICE) was applied, generating a series of imputed datasets for analysis.

Statistical analysis

All statistical analyses and visualization were conducted using GraphPad Prism 7.0. Categorical variables were presented as frequencies and percentages (n, %) and analyzed using chi-square (χ^2) tests. Continuous variables were reported as mean ± standard error of the mean (SEM). Between-group comparisons were conducted using independent-samples t-tests, while within-group longitudinal comparisons were analyzed using repeated measures analysis of variance (ANOVA). A two-tailed *P*-value <0.05 was considered statistically significant.

Based on priori sample size calculations, a minimum of 44 cases per group was required to achieve adequate statistical power. The final enrollment exceeded this threshold, with 48 subjects in the reference group and 50 in the observation group. The specific formula used for the sample size calculation is as follows:

$$n= \frac{(Z_{1-\alpha/2} + Z_{1-\beta})^2 \times (p_1(1-p_1) + p_2(1-p_2))}{(p_1 - p_2)^2}$$

Results

Baseline characteristics

No significant differences were observed between the two groups in terms of gender distribution, mean age, time from injury to surgery, underlying etiology, Garden classification of fractures, Singh Index scores (1-3), Charlson Comorbidity Index (CCI) scores, preoperative Harris Hip scores, or preoperative Parker Mobility scores (P>0.05), confirming baseline comparability between the two groups. Detailed

Table 1. Comparison of baseline characteristics between the two groups

Factors	n	Reference group (n=48)	Observation group (n=50)	χ^2/t	P
Gender				0.187	0.666
Male	43	20 (41.67)	23 (46.00)		
Female	55	28 (58.33)	27 (54.00)		
Mean age (years)	98	64.52±6.35	65.60±8.36		
Time from injury to surgery	98	1.71±1.13	1.80±0.81		
Underlying etiology				0.407	0.816
Walking-related falls	79	38 (79.17)	41 (82.00)		
Traffic accidents	16	8 (16.67)	8 (16.00)		
Falls from height	3	2 (4.17)	1 (2.00)		
Garden classification of fractures				1.440	0.487
II	29	13 (27.08)	16 (32.00)		
III	53	25 (52.08)	28 (56.00)		
IV	16	10 (20.83)	6 (12.00)		
Singh Index scores (1-3)	33	18 (37.50)	15 (30.00)	0.617	0.432
CCI scores	98	1.96±0.80	2.24±1.20	1.353	0.179
Preoperative Harris Hip Scores (points)	98	65.27±7.82	65.76±7.86	0.309	0.758
Preoperative Parker Mobility Scores (points)	98	4.71±1.96	5.34±1.65	1.724	0.088

Note: CCI, Charlson Comorbidity Index; FNF, femoral neck fractures.

Table 2. Comparison of clinical outcomes between the two groups [n (%)]

Category	Reference group (n=48)	Observation group (n=50)	χ^2	P
Markedly effective	25 (52.08)	32 (64.00)		
Effective	11 (22.92)	14 (28.00)		
Ineffective	12 (25.00)	4 (8.00)		
Total effectiveness	36 (75.00)	46 (92.00)	5.181	0.023

Note: FNF, femoral neck fractures.

Table 3. Comparison of clinical outcomes between patients stratified by age [n (%)]

Category	<65 years (n=42)	≥65 years (n=56)	χ^2	P
Markedly effective	24 (57.14)	33 (58.93)		
Effective	12 (28.57)	13 (23.21)		
Ineffective	6 (14.29)	10 (17.86)		
Total effectiveness	36 (85.71)	46 (82.14)	0.224	0.636

demographic and clinical characteristics are presented in **Table 1**.

Treatment efficacy

The observation group demonstrated significantly superior clinical efficacy, with 46 cases classified as effective (32 markedly effective and 14 effective), compared to 36 effective cases in the reference group (25 markedly effective and 11 effective) (P<0.05, **Table 2**).

Subgroup analysis by age revealed no significant differences in therapeutic efficacy between patients aged <65 and those ≥65 years (P>0.05, **Table 3**).

Similarly, stratified analysis by fracture type (Type II, III, and IV) revealed no statistical differences in therapeutic efficacy across different fracture types (P>0.05, **Table 4**).

Surgery-related parameters

The observation group experienced greater intraoperative blood loss, higher postoperative drainage volume, and longer operation time compared to the reference group (P<0.01, **Figure 1**).

Postoperative recovery following hip arthroplasty

Assessment of postoperative recovery, including hip joint recovery time and length of hospi-

Table 4. Comparison of clinical outcomes among patients stratified by fracture type [n (%)]

Category	Type II (n=29)	Type III (n=53)	Type IV (n=16)	χ^2	P
Markedly effective (n=57)	20 (68.97)	32 (60.38)	5 (31.25)		
Effective (n=25)	4 (13.79)	15 (28.30)	6 (37.50)		
Ineffective (n=16)	5 (17.24)	6 (11.32)	5 (31.25)		
Total effectiveness	24 (82.76)	47 (88.68)	11 (68.75)	3.598	0.165

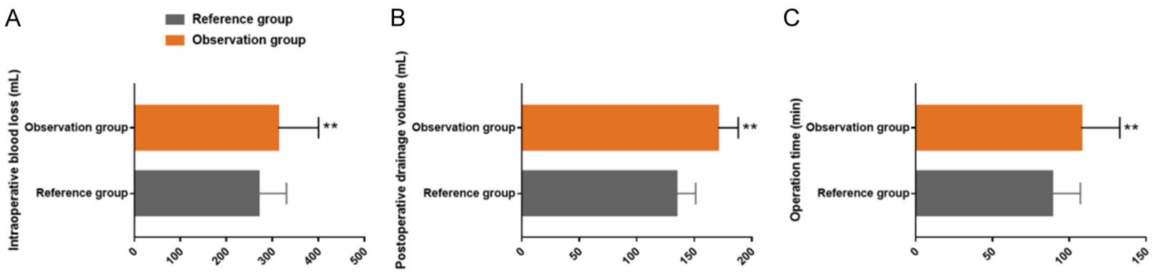

Figure 1. Comparison of surgery-related parameters between the two groups. A. Intraoperative blood loss; B. Postoperative drainage volume; C. Operative time. Note: **P<0.01.

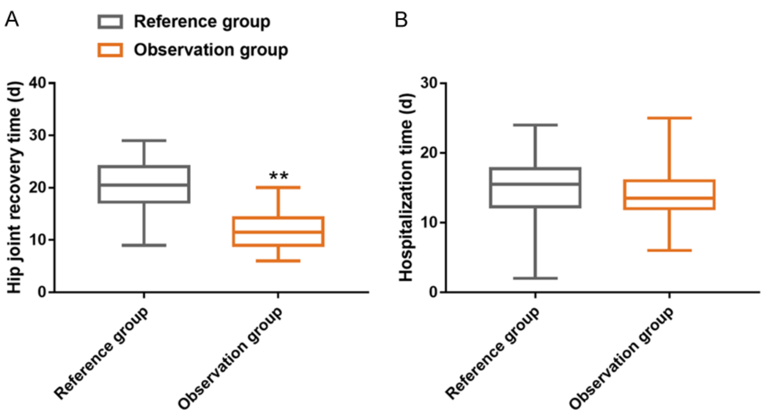

Figure 2. Comparison of postoperative recovery parameters between the two groups. A. Hip joint recovery time; B. Hospitalization duration. Note: **P<0.01.

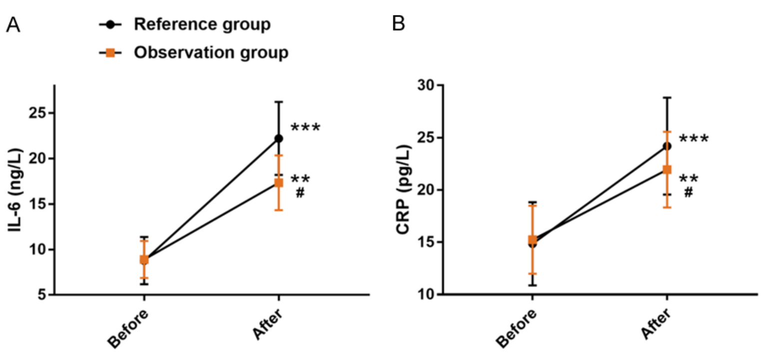

Figure 3. Comparison of inflammatory markers between the two groups before and after treatment. A. IL-6; B. CRP. Note: **P<0.01, ***P<0.001, compared to pre-treatment values; #P<0.05, compared to the reference group; IL-6, Interleukin-6; CRP, C-reactive protein.

talization, showed that patients in the observation group achieved significantly faster functional recovery compared to the reference group (P<0.01). However, no significant intergroup difference was observed in hospitalization duration (**Figure 2**).

Inflammatory markers

Analysis of inflammatory markers, including IL-6 and CRP, demonstrated no significant intergroup differences before treatment (P>0.05). Following treatment, both groups exhibited a significant increase in these two markers (P<0.05). Notably, post-treatment levels of IL-6 and CRP were significantly lower in the observation group compared to the reference group (P<0.05), as shown in **Figure 3**.

Stress response

No significant differences were observed between the two groups in serum levels of Cor and MDA at T0 (P>0.05).

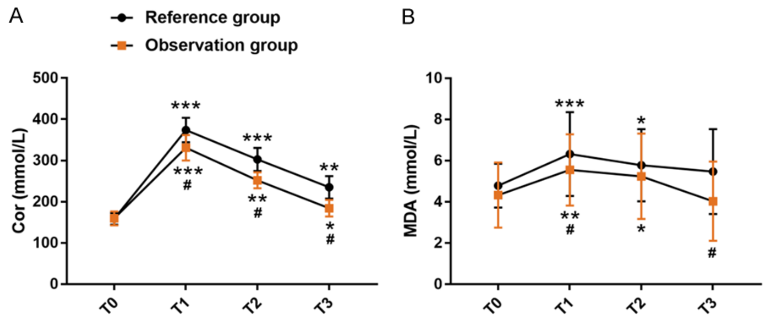

Figure 4. Comparison of stress markers between the two groups at different time points. A. Cor levels; B. MDA levels. Note: *P<0.05, **P<0.01, ***P<0.001, compared to baseline level; #P<0.05, compared to the reference group; Cor, Cortisol; MDA, Malondialdehyde.

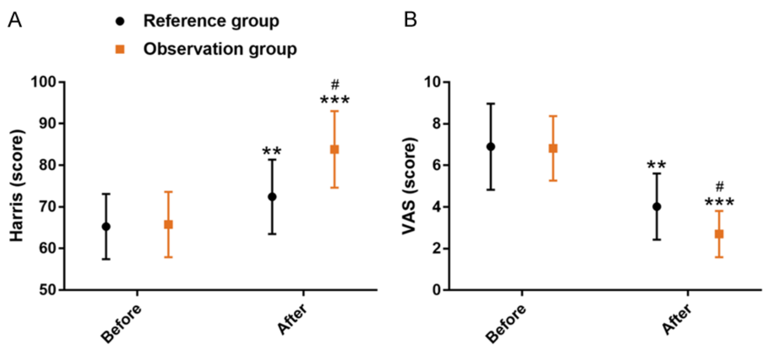

Figure 5. Comparison of Harris Hip scores and VAS scores between the two groups before and after treatment. A. Harris Hip scores; B. VAS scores. Note: **P<0.01, ***P<0.001, compared to pre-treatment; #P<0.05, compared to the reference group; VAS, Visual Analogue Scale.

In both groups, the levels of Cor and MDA peaked at T1 (P<0.001) and then progressively declined at T2 and T3. Additionally, the observation group exhibited significantly lower Cor levels at T1-T3 and lower MDA levels at T1 and T3 compared to the reference group (P<0.05). The details are presented in **Figure 4**.

Harris and VAS scores in hip arthroplasty patients

Baseline Harris Hip scores and VAS scores were comparable between the two groups (P>0.05). Post-intervention, both groups demonstrated significant improvements, with Harris scores increasing (P<0.05) and VAS scores decreasing (P<0.05). Importantly, the observation group achieved superior outcomes, reflected by higher Harris scores and lower VAS scores compared to the reference group (P<0.05, **Figure 5**).

Adverse reactions in hip arthroplasty patients

The incidence of adverse events, including DVT, pulmonary infections, incisional infections, and joint dislocations, showed no significant difference between the two groups (10.42% vs. 12.00%) (P>0.05, **Table 5**).

Discussion

FNFs pose significant challenges in orthopedic surgery, primarily due to their technical complexity and high complication rates [16]. Existing research has demonstrated the clinical superiority of minimally invasive hip arthroplasty over conventional approaches in elderly patients with FNFs. For example, Park et al. [17] demonstrated that minimally invasive two-incision THA is clinically superior to conventional HA in treating elderly patients with acute displaced FNFs, contributing to significantly better hip function and reduced disease severity. Similarly, Ramadanov et al. [18] reported that MIS-THA was associated with improved functional outcomes and lower complication rates in elderly patients, including those with FNFs. Further supporting these findings, Jin et al. [19] found that MIS-THA via the DAA facilitated faster functional recovery, minimized surgical trauma, and reduced postoperative dislocation rates compared to traditional THA in this patient population. For geriatric FNF management, existing evidence predominantly focuses on comparing minimally invasive hip arthroplasty with conventional approaches, while comparative evaluations between MIS-THA and MIS-HA remain limited. The present study specifically addresses this gap, aiming to refine surgical decision-making and optimize outcomes in the minimally invasive management of geriatric FNFs.

This study found that MIS-THA achieved better overall treatment efficacy compared to MIS-HA,

Table 5. Comparison of incidence of adverse reactions between the two groups [n (%)]

Adverse reactions	Reference group (n=48)	Observation group (n=50)	χ^2	P
DVT	3 (6.25)	4 (8.00)	-	-
Pulmonary infections	0 (0.00)	1 (2.00)	-	-
Incisional infections	1 (2.08)	0 (0.00)	-	-
Joint dislocations	1 (2.08)	1 (2.00)	-	-
Total	5 (10.42)	6 (12.00)	0.062	0.804

Note: DVT, deep venous thrombosis.

regardless of patient age or fracture type. In addition, although MIS-THA was associated with longer operative duration, greater intraoperative blood loss, and higher postoperative drainage compared to MIS-HA, it demonstrated superior efficacy in promoting hip functional recovery and mitigating pain, with a comparable hospitalization duration. The enhanced efficacy of MIS-THA may be attributed to several factors. First, the procedure involves acetabular cup replacement, which prevents further cartilage wear, a complication commonly found in HA, thereby minimizing pain and mobility limitations while maximizing treatment effectiveness [20]. Second, MIS-THA facilitates better restoration of normal hip biomechanics, allowing for more anatomically accurate reconstruction, even stress distribution, and superior recovery of gait patterns and mobility, all of which contribute to successful hip rehabilitation [21, 22]. Both groups experienced postoperative inflammatory and stress reactions. However, these reactions were less pronounced in the MIS-THA cohort, possibly due to the greater joint stability and reduced acetabular trauma. In contrast, MIS-HA retained native acetabulum, which is subjected to continuous mechanical friction from the prosthetic head, potentially exacerbating local inflammation [23, 24]. Importantly, the overall incidence of postoperative complications did not differ significantly between the two groups, indicating that such events are more likely attributable to intrinsic patient factors, such as advanced age and osteoporosis, rather than the surgical technique itself. Both MIS-THA and MIS-HA utilizes small incisions and muscle-sparing techniques, features that likely contribute to their similarly favorable safety profiles [25].

This research has certain limitations. First, the restricted sample size and single-center design may have introduced potential selection bias. Future investigations should include larger sample sizes and involve multicenter designs to enhance the generalizability of the results. Second, the lack of long-term follow-up data on clinical efficacy and patient prognosis limits the ability to evaluate sustained outcomes and durability of the two surgical approaches. Incorporating longitudinal outcome measures would strengthen the evidence supporting their clinical utility. Finally, this study did not develop an efficacy prediction model. Future prospective research integrating diverse clinical parameters is needed to establish valid predictive tools for broader clinical application.

In summary, MIS-THA offers dual clinical benefits for elderly patients with FNFs: (1) biological advantages through attenuated inflammatory and stress responses, and (2) functional advantages through superior joint reconstruction. Despite slightly greater surgical trauma, MIS-THA appears to be more clinically favorable for this patient population. These findings elucidate how different minimally invasive techniques modulate physiological stress responses and provide novel insights to inform surgical decision-making in geriatric FNF management.

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Disclosure of conflict of interest

None.

Address correspondence to: Bin Huang, Department of Joint Surgery and Sports Medicine, Nanxishan Hospital of Guangxi Zhuang Autonomous Region, Xiangshan District, Guilin 541002, Guangxi Zhuang Autonomous Region, China. Tel: +86-0773-2887889; E-mail: HuangBin1975@163.com

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