

General

Anatomical features of Vietnamese hip joints and assessment of the efficacy of short-stem hip arthroplasty in patients with avascular necrosis of the femoral head, 2011-2022

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Introduction

Spiron short-stem hip arthroplasty for the treatment of avascular necrosis of the femoral head (AVNFB) in young patients preserves the bones, resulting in favorable and easy conditions when the hip is replaced again. The purpose of this study is to describe several anatomical features of the hip joint in adult Vietnamese people and to assess the efficacy of Spiron short-shaft hip arthroplasty.

Methods

129 healthy hips and 64 hips of 46 AVNFB patients underwent Spiron short-stem arthroplasty and were followed up from Jan-2012 – Dec-2022. Patients were performed digital X-rays to determine anatomical parameters in order to select the proper joint size. Patients' clinical outcomes and complications were evaluated at 12, 36, and 48 months after arthroplasty.

Results

Among the 46 patients, only 4.4% were women. The patients had an average age of 40.6 years and a mean preoperative Harris score of 45.9. AVNFB patients' anatomical indices were all lower than those of healthy people. After 48 months of arthroplasty, severe pain symptoms decreased from 71.9% to 3.1%, walking limitation decreased from 59.4% to 4.7%, and Harris score good and excellent (80-100 points) increased from 0.0% to 78.2%. Complications included 1.6% wound infection and 3.1% acetabular displacement after 48 months. Other complications, such as lateral popliteal nerve injury, decreased from 6.3% (12 months) to 1.6% after 48 months, while bone loss and periarticular lumina increased from 3.1% (12 months) to 18.8-21.9% (48 months). After 48 months, 12.5% of patients underwent re-arthroplasty.

Conclusion

Although Spiron short-stem hip arthroplasty for young Vietnamese patients has significantly improved clinical symptoms and bone preservation, the rate of complications and re-arthroplasty remains relatively high due to the skill and surgical indication selection of surgeons. Therefore, surgeons need to receive careful and closely monitored training in the Spiron hip arthroplasty technique.

INTRODUCTION

Avascular necrosis of the femoral head (AVNFB) is a disease caused by a lack of blood supply to the femoral head, resulting in the necrosis of bone cells and bone marrow.¹

² AVNFB is prevalent among young and middle-aged people.^{2,3} The exact cause of the disease has yet to be determined, so treatment remains difficult. AVNFB progresses through several stages, and in the latter stages, joint arthroplasty is recommended.⁴⁻⁶

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Despite many advancements in materials and surface coatings, the most recent generations of joints have an average lifespan of 15-25 years, so young patients who have undergone hip arthroplasty will face the issue of re-replacement.⁷ Re-replacement is more technically difficult, with a higher rate of accidents and complications, so short-stem hip joints have recently been used for primary arthroplasty to overcome the aforementioned difficulties.⁷⁻⁹

There are several classifications for short-stem hip joints. The American Society for Joint Research and Surgery categorizes short-stem hip joints into two groups: neck-fixed and metaphyseal-fixed.¹⁰ The femoral neck-fixed joints, such as the Cut, Silent, and Spiron joints,¹⁰ are the short-stem joints that preserve the most bone. The Spiron short-stem joint was created in 1989 in Germany.¹¹ The joint shaft, shaped like a conical screw, features a sharp spiral thread and longitudinal grooves that increase the shaft's contact area with the bone, resulting in a more stable and solid joint. When replacing the Spiron joint, only the femoral head is removed, leaving the neck and upper head of the femur intact, so that if the joint needs to be replaced again, it will be as convenient and easy as the first time.¹¹

The purpose of using short-stem hip joints in general, and Spiron joints in particular, is to preserve bone.¹¹ However, using this type of joint presents some challenges. That is, the narrow surgical field caused by femoral neck obstruction interferes with acetabulum reaming and placement. It is difficult to select and precisely position the joint shaft on the femoral neck in the desired position. As a result, it is necessary to study the hip joint anatomy of Vietnamese people in order to determine the joint size, position, and angle at which the Spiron joint shaft should be placed, restoring the anatomy and restoring the joint's maximum function following arthroplasty.

Although the Spiron joint has been clinically used since 2001 worldwide and since 2011 in Vietnam, there have only been a few studies evaluating short-term outcomes with a small number of patients.¹² Another issue that must be addressed today is that many surgeons in Vietnam do not plan before surgery and instead rely on a set of available measuring devices with a glass ball applied to the X-ray film to estimate joint size.¹³ This has many errors because the magnification ratio of the film does not match the magnification ratio of the measuring device, or because the measurement is done entirely by hand and with the naked eye, so the errors are even greater, negatively affecting arthroplasty outcomes. The use of digital X-rays instead of traditional X-rays, as well as the development of specialized software for joint replacement in medicine, have made measuring anatomical indicators and pre-operative planning on X-ray films more convenient and accurate. The objectives of this study are to describe several anatomical features of the hip joint in Vietnamese adults who were performed short-stem hip arthroplasty and to assess the outcomes of spiron short-stem hip arthroplasty in the treatment of avascular necrosis of the femoral head from 2012 to 2022.

PATIENTS AND METHODS

PATIENTS

From January 2011 to December 2022, 46 patients were diagnosed with AVNHF, with 18 having both hips and 28 having only one. The patients underwent Spiron short-stem cementless total hip arthroplasty (18 for bilateral arthroplasty and 28 for unilateral arthroplasty) at the Institute of Trauma and Orthopedics, 108 Central Military Hospital. The selection criteria were: 1) Patients diagnosed with AVNHF stages IV, V, or VI according to Steinberg's classification; 2) Age ≥ 18 - 50 years old; 3) Femoral neck bone shape and quality are still good. The femoral neck is not deformed, there was no lesion on the femoral neck MRI (no necrosis, the femoral neck has no necrosis calculated based on the intended position of the femoral neck in the preoperative plan); 4) The patient's general and local condition does not preclude surgery or anesthesia; 5) The patient is pre-operatively planned on 2D software; 6) The patient has a Spiron short-stem hip arthroplasty. The exclusion criteria include: 1) The patient's leg or foot cannot be straightened or rotated inward (not ensuring the correct position for the required scan); 2) The patient lacks complete medical records and X-ray films, fails to return for a follow-up appointment, or the follow-up period is less than 48 months.

Furthermore, between February 2012 and August 2016, 129 hips of healthy volunteers aged 18-50 were chosen to participate in a study to compare the anatomical indexes of the hip joint with those of patients with AVNHF. These people had straight hip X-rays. Inclusion criteria: Normal hip X-rays without any intervention in this area. Exclusion criteria include non-compliant X-rays, as well as deformed or pathological hip bones.

STUDY INDICATORS

ACETABULAR INDICES

- Acetabular diameter: is the diameter of the circle with an arc that fits into the acetabular socket ([Figure 1A](#)).
- Acetabular tilt angle: is the angle formed by two straight lines, one passing through the lower medial bone edge (teardrop) of the acetabulum on both sides and one passing through the upper edge of the acetabulum and the lower medial bone edge (teardrop) of the acetabulum on the same side ([Figure 1B](#)).

FEMORAL NECK INDICES

- The length of the upper border of the femoral neck
The length of the upper border of the femoral neck is the distance between points X and C ([Figure 2A](#)).
- The length of the femoral neck's lower border is the distance between points Y and D ([Figure 2B](#)).
- The distance above, below, and in the middle of the femoral neck is the distance between the two points O and P ([Figure 2C](#)).

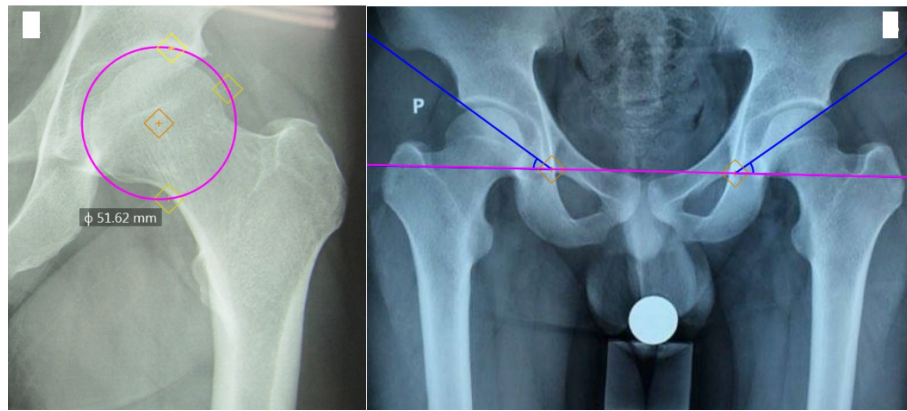


Figure 1. Acetabular indices of the hip joint.

A) acetabular diameter; B) acetabular inclination angle.

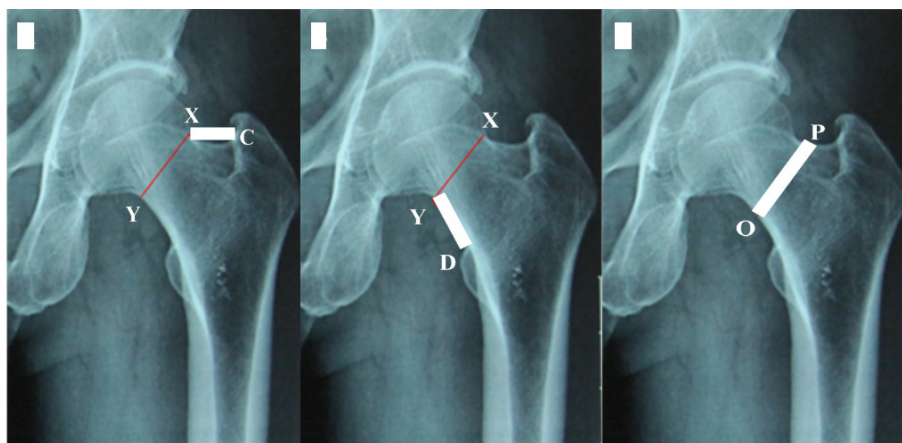


Figure 2. Femoral neck indices.

A) Length of the upper border of the femoral neck; B) Length of the lower border of the femoral neck; C) Distance above, below, and in the middle of the femoral neck.

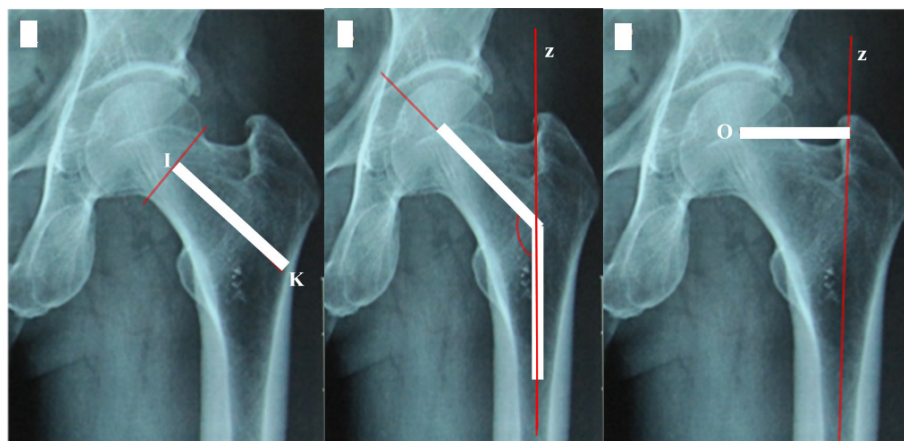


Figure 3. Parameters for selecting and positioning the Spiron articular handle.

A) the distance from the base of the head to the medial border of the lateral femoral wall; B) the angle of the femoral neck shaft; and C) the distance from the center of the head to the bone's anatomical center.

INDICATORS RELATED TO THE SELECTION AND PLACEMENT OF SPIRON JOINT SHAFTS

- Distance between the base of the head (close to the head) and the inner edge of the lateral femoral wall (along the mid-axis of the femoral neck): Is the distance between points I and K ([Figure 3A](#)). Point I represents the XY segment's midpoint, while point K represents the intersection of the longitudinal axis between the femoral neck and the inner edge of the lateral femoral wall.
- The femoral neck angle is the angle formed by the axis of the neck (Line IK) and the anatomical axis of the femoral shaft (Line z) ([Figure 3B](#)).
- The offset is the distance from the center of the head to the anatomical axis of the femur. Is the distance between point O (the centre of the head) and line z ([Figure 3C](#)).

SPIRON SHORT-STEM HIP ARTHROPLASTY

- Preoperative computer planning: uses 2D software to plan surgery, including measuring acetabular diameter, temporarily determining femoral neck incision position, measuring distance from the base of the head to the hard bone shell, measuring distance above and below the center of the femoral neck, and measuring the angle of the femoral neck shaft.
- Preoperative patient preparation: includes all routine tests, an explanation of the patient's condition, surgical plan, and expected outcomes.

PERFORMING ARTHROPLASTY

The patients were anesthetized (spinal anesthesia), and the patient was lying on his side at 90°, with the operated limb above and the vertical margin of surgery behind the replaced joint.

- Step 1: Cut the skin to expose the hip joint, then cut the femoral head.
 - Using the posterolateral ([Figure 4A](#)) and anterolateral incisions, the fascia was incised along the skin incision, the gluteus maximus muscle was separated, the gluteus medius muscle was left intact, and the leg was adducted and slightly internally rotated to expose the iliofemoral muscle group ([Figure 4B](#)).
 - Cut a portion of the external rotator cuff and quadratus femoris muscle, the L-shaped joint capsule, expose the hip joint, rotate the leg inward to dislocate the hip posteriorly, and measure the upper and lower borders of the femoral neck ([Figure 4C](#)).
 - Cut the femoral neck with a saw so that the cutting plane is perpendicular to the femoral neck axis, then use a knife to clean the surrounding bone spurs.
- Step 2: Reaming and Installing the Acetabulum:

- Examine the acetabular cartilage, round ligament, and osteolysis (if present). Ream and place the artificial acetabulum as you would with a standard hip arthroplasty.
- Place the Hohmann bone elevator, then resect the cartilage, clean the bone spurs, and clean the remaining round ligament.
- Remove the base of the acetabulum with a small reamer, then gradually increase the diameter until all of the cartilage has been removed. Place the acetabulum in a trial position and compare to the preoperative plan.
- Place the acetabulum at a 45° angle to the horizontal plane and tilt 15° forward. A surface roughener has been used to fix the acetabulum. If the bone quality is poor, 2-3 more fixing screws may be added ([Figure 4D](#)).
- Step 3: Prepare the femoral neck:
 - Determine the center of the femoral neck, insert the blunt-headed Kirschner nail along the femoral neck's axis near the hard bone wall, and measure the length of the articular shaft to be replaced.
 - Determine the diameter of the articular shaft by using specialized coins with different diameters of 18, 20, 22, 24 mm to measure the diameter of the femoral neck.
 - Ream bone marrow, install a trial shank and cap, reset the hip joint, and measure leg length.
- Step 4: Insert the handle, replace the head, realign the joint, and close the incision:
 - Place the Spiron joint handle: Using the measured length and diameter, turn the handle clockwise by hand until the small tabs on the handle plate are firmly embedded in the hard bone shell ([Figure 4F](#)).
 - Select the crown: S (Small) is -5, M (Medium) is +0, and L (Large) is +5. Try the crown, inspect the movement, perform the piston test, measure the length of both legs, install the crown, and realign the joint ([Figure 4G](#)).
 - Irrigate, stop bleeding, do not insert a drain (only if absolutely necessary), and suture the incision.

POST-OPERATIVE MONITORING AND EXERCISE

- Take bilateral hip X-rays ([Figure 4H](#)), and remove drains 24 hours after surgery (if applicable).
- Monitor and evaluate post-operative progress.
- Exercise as prescribed by Birkenhauer B. following short-stem Spiron hip arthroplasty. The patient begins passive and active exercise on the second day after surgery to regain joint range of motion, which includes flexion, extension, abduction, and hip joint. Exercise gradually increases muscle strength in key muscles such as the iliopsoas muscle, gluteal muscle, and quadriceps.
- Remove the stitches 12-14 days after surgery.

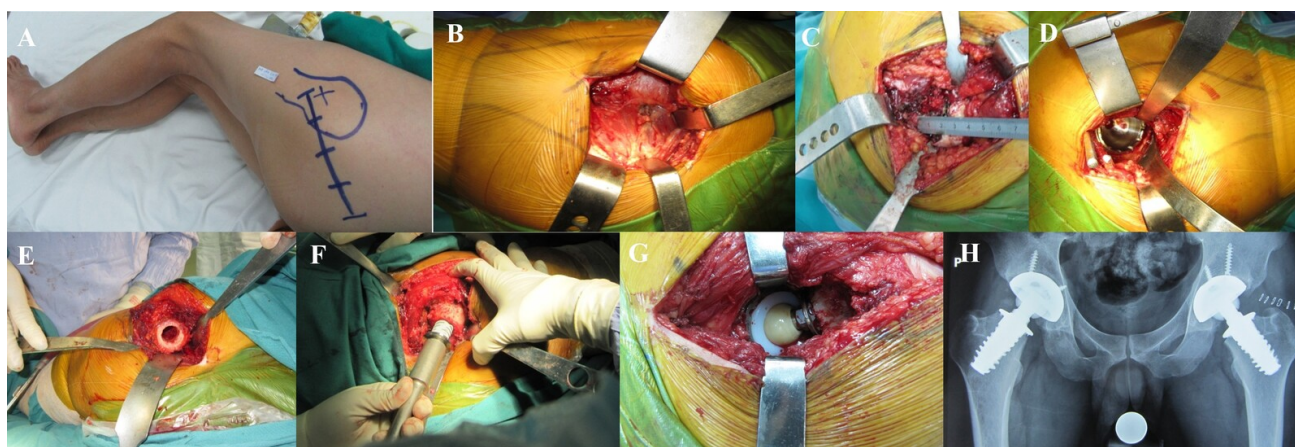


Figure 4. Spiron short-stem hip arthroplasty.

A) posterolateral incision; B) separation of gluteus maximus, exposure of iliofemoral trochanter muscles; C) measurement of superior and inferior border length; D) reaming and placement of acetabulum; E) reaming of marrow canal; F) implantation of prosthesis; G) hip replacement; H) Postoperative X-ray.

- Patients use two crutches for 6-8 weeks after surgery to reduce the impact force on the joint shaft because there is no biological connection between the bone, joint shaft, and acetabulum.

POSTOPERATIVE OUTCOME ASSESSMENT AND DATA COLLECTION

- Post-operative check-up intervals include: immediately after surgery, 8-12 weeks after surgery, 12 months, 36 months, and 48 months.
- Evaluate hip joint function using the Harris score at three time points: before surgery, 12 months, 36 months, and 48 months after surgery.
- Assessment contents include surgical wound progress, complications, X-ray changes, acetabular position, joint rotation, Harris-scale artificial hip function, pain level, walking ability, and range of motion.
- Patient, clinical, and paraclinical data are obtained from the patient's medical records.

DATA ANALYSIS

Data were entered into Epidata 3.0 software and analyzed using medical statistical algorithms in SPSS 22.0 software to calculate experimental parameters such as mean, standard deviation, and correlation between two quantitative variables. Qualitative variables were presented as percentages. For qualitative variables, use the Chi-square test (χ^2) (adjusted with Fisher's exact test, Phi, and Cramer's V as needed). For quantitative variables with normal (or relatively normal) distributions, use the t-test, paired test, or ANOVA test.

RESULTS

Of the 46 patients who had Spiron short-stem hip arthroplasty, 44 (95.6%) were men and only 4.4% were women. Patients aged 41-50 years accounted for 59.7%, followed by

those aged 31-40 years (37.5%) and 25-30 years (2.8%), with a mean age of 40.6 years. Out of the 46 patients, 18 underwent bilateral hip arthroplasty (39.1%), 13 underwent right hip arthroplasty (28.3%), and 15 underwent left hip arthroplasty. Of the 64 hips that were operated on, 46.9% had stage IV AVNFB, 45.3% stage V, and 7.8% stage VI. In terms of pain severity, 57.8% of the joints were in severe pain, 39.1% in moderate pain, and 3.1% in mild pain. In terms of mobility, 59.4% of the joints had severe limitations, while 40.6% had moderate limitations. The Harris score of 64 hips revealed that 30 hips (46.9%) were in stage IV, with a mean Harris score of 48.3, 29 hips (45.3%) were in stage V, with a mean Harris score of 44.2, and 5 hips (7.8%) were in stage VI, with a mean Harris score of 41. The average Harris score across all AVNFB stages was 45.9 points ([Table 1](#)).

THE ANATOMICAL INDEXES OF THE HIP JOINT OF AVNFB PATIENTS AND HEALTHY PEOPLE ([TABLE 2](#))

- Acetabular diameter: Patients with AVNFB had an average acetabular diameter of 48.2 mm, compared to 49.4 mm for healthy people. AVNFB patients had a higher rate of acetabular attachment diameters between 48 and <50 mm compared to healthy people (40.6% vs 34.1%).
- Acetabular tilt angle: patients with AVNFB had an average of 44.1°, while the healthy people had 41.8°. At tilt angles > than 40 – 45°, AVNFB patients had a higher rate than the healthy group (64.1% vs. 59.7%).
- Upper femoral neck length: the average length of AVNFB patients was 15.3 mm, while the healthy people measured 17.6 mm. AVNFB patients had a higher rate for lengths between 8.3 and 15 mm, but lower rates for lengths between 19 and 26.8 mm compared to healthy people (32.8% vs 24.0%; 18.8% vs 27.9%).
- Lower femoral neck length: The average length of AVNFB patients was 21.6 mm, while healthy people had 23.3 mm. AVNFB patients had higher levels from

Table 1. Several features of Vietnamese patients with femoral head necrosis who underwent Spiron short-stem hip arthroplasty

Characteristics	Number of patients	Proportion (%)
Gender (n=46)		
Male	44	95.6
Female	2	4.4
Age (year) (n=46)		
25 – 30	2	4.4
31 – 40	17	36.9
41 – 50	27	58.7
> 50	0	0
$\bar{X} \pm SD$	40.6 $\pm$ 4.7	
Arthroplasty position (n=46)		
Right	13	28.3
Left	15	32.6
Both sides	18	39.1
AVNFH stages (n=64)		
IV	30	46.9
V	29	45.3
VI	5	7.8
Preoperative pain level (n=64)		
Mild pain	2	3.1
Moderate pain	25	39.1
Severe pain	37	57.8
Walking ability (n=64)		
Moderate Restriction	26	40.6
Severe Restriction	38	59.4
Harris score (n=64)		
IV (48.3 $\pm$ 2.2)	30	46.9
V (44.2 $\pm$ 2.1)	29	45.3
VI (41.0 $\pm$ 2.1)	5	7.8
$\bar{X} \pm SD$	45.9 $\pm$ 3.2	

14.3 to <20 mm (31.2% vs 24.8%), but lower levels from >25 to 34.2 mm (20.4% vs 27.9%).

- Distance above and below the center of the femoral neck: The average distance between AVNFH and healthy people was 32.9 mm and 34.5 mm, respectively. There was little difference in the distance levels between AVNFH patients and healthy people.

INDICATORS FOR SELECTING AND PLACING SPIRON ARTICULATING SHAFTS (TABLE 3)

- The average distance between the base of the head and the medial edge of the lateral femoral wall was 50.1 mm in AVNFH patients and 51.2 mm in healthy people.
- Femoral neck-shaft angle: The average femoral neck-shaft angle in AVNFH patients was 131.6o, while healthy people had 132.1o.

- The distance between the center of the femoral head and the shaft: The average distance between AVNFH and healthy patients was 36.4 mm and 37.9 mm, respectively.

THE SPIRON JOINT INDEXES USED DURING SURGERY FOR PATIENTS INCLUDED (TABLE 3)

- The 50 mm acetabulum was the most commonly used (51.6% of patients), followed by the 48 mm acetabulum (32.8%), the 46 mm acetabulum, and the 52 mm acetabulum (7.8%).
- Number of screws used to fix the Spiron joint: 57.8% of patients did not require screws for fixation, 40.7% used two screws, and 1.5% used three screws.
- The joint head with diameter -5 (S-small) was used by 76.6% of patients, followed by type 0 (M-medium) (18.7%) and type 5 (L-large) (4.7%).
- 59.4% of patients used a 20-mm diameter articulating shaft, followed by 22-mm (31.5%) and 18-mm (9.1%).
- 54.7% of patients used 50 mm joint shafts, followed by 45 (31.3%), 55 (12.5%), and 60 mm (1.5%).

Clinical and X-ray indicators of patients underwent Spiron short-stem hip arthroplasty at four time points: prior to surgery, 12 months, 36 months, and 48 months after surgery (Table 4).

CLINICAL FEATURES

- Pain level: Prior to surgery, 25.0% and 71.9% of patients experienced moderate to severe pain, respectively; after 12 and 36 months, these rates decreased to 1.6% and 0.0%. However, after 48 months of surgery, it increased to 4.7% and 3.1%, respectively.
- Walking ability: Before surgery, 40.6% and 59.4% of patients had mild and severe limitations, respectively; 12 months after surgery, this rate was 23.4% and 3.1%, followed by 36 months (34.4% and 1.6%) and 48 months (37.5% and 4.7%).
- Total range of motion: before surgery, mild and severe limited motion were 43.8% and 56.2%, respectively; 12 months after surgery, this rate dropped to 25.0% and 0.0%, 36 months (26.6% and 1.6%), and 48 months (39.1% and 4.7%).
- Harris score: prior to surgery, the average Harris score was 46.8, 12 months after surgery was 92.2, 36 months (91.6), and 48 months (81.2). The Harris score for stage IV was higher than for stages V and VI.

X-RAY FEATURES

- There was no difference in acetabular tilt angle between preoperative (40.2o) and postoperative (12, 36, 48 months) (39.9-40.1o). However, the distance from the center of the head to the anatomical axis of the femur (35.2 mm) and limb deviation (9.2 mm) before surgery differed from those after surgery (37.2 - 39.6 mm and 3.1 - 3.6 mm).

Table 2. Characteristics of basic hip joint anatomical indices of AVNFH patients and healthy people.

Hip joint anatomical indices	AVNFH patients (n=64) (n, %)	Healthy people (n=129) (n, %)
Acetabular indices		
<i>Acetabular diameter (mm)</i>		
42.2 – < 48	8 (12.5)	19 (14.7)
48 – < 50	26 (40.6)	44 (34.1)
50 – 52	24 (37.5)	54 (41.9)
> 52 – 52.9	6 (9.4)	12 (9.3)
$\bar{X} \pm SD$	48.2 $\pm$ 2.0	49.4 $\pm$ 1.7
<i>Acetabular tilt angle (degree)</i>		
34.1 – 40	17 (26.6)	40 (31.0)
> 40 – 45	41 (64.1)	77 (59.7)
> 45 – 50	5 (7.8)	11 (8.5)
> 50 – 52.9	1 (1.5)	1 (0.8)
$\bar{X} \pm SD$	43.1 $\pm$ 2.4	41.8 $\pm$ 2.9
Femoral neck indices		
<i>Length of the upper border of the FH (mm)</i>		
8.3 – < 15	21 (32.8)	31 (24.0)
15 – 19	31 (48.4)	62 (48.1)
> 19 – 26.8	12 (18.8)	36 (27.9)
$\bar{X} \pm SD$	15.3 $\pm$ 2.9	17.6 $\pm$ 3.5
<i>Length of the lower border of the FC (mm)</i>		
14.3 – < 20	20 (31.2)	32 (24.8)
20 – 25	31 (48.4)	62 (48.1)
> 25 – 34.2	13 (20.4)	35 (27.1)
$\bar{X} \pm SD$	21.6 $\pm$ 2.7	23.3 $\pm$ 3.7
<i>Distance above and below the center of FH (mm)</i>		
27.8 – < 32	17 (26.1)	30 (23.3)
32 – 36	31 (48.4)	62 (48.1)
> 36 – 43.7	16 (25.5)	37 (28.7)
$\bar{X} \pm SD$	32.9 $\pm$ 2.9	34.5 $\pm$ 2.8

- The occurrence of bone support pillar and bone platform support after surgery at 12 months was 4.6% and 15.6%, respectively, at 36 months (7.8% and 48.4%) and 48 months (15.6% and 65.6%). The indexes for bone joint connection area, cortical bone hypertrophy, and heterotopic ossification increased from 1.5% after 12 months to 3.3-4.4% after 36 months and 6.3-9.4% after 48 months.
- Preoperative Harris scores were good and excellent in 0.0% of patients, but increased to 20.3% and 78.1% after 12 months of surgery, 17.8% and 76.1% after 36 months, and 14.1% and 64.1% after 48 months, respectively.

COMPLICATIONS FOLLOWING SPIRON SHORT-STEM HIP ARTHROPLASTY (TABLE 5)

- There was one femoral neck fracture (1.6%) during Spiron hip arthroplasty (Figure 5).

Table 3. Characteristics of indicators used in the selection and placement of Spiron joint shafts

Indicators	AVNFH patients (n=64) (n, %)	Healthy people (n=129) (n, %)
Distance from the base of the head to the medial border of the lateral femoral wall (mm)		
39.9 – < 45	0 (0.0)	11 (8.5)
45 – < 50	22 (34.4)	35 (27.1)
50 – < 60	39 (60.9)	80 (62.0)
60 – 64.8	3 (4.7)	3 (2.3)
$\bar{X} \pm SD$	50.1 $\pm$ 3.5	51.2 $\pm$ 4.1
Femoral neck-shaft angle (°)		
120.9 – < 125	4 (6.2)	7 (5.4)
125 – 135	48 (75.0)	95 (73.6)
> 135 – 140.4	12 (18.8)	27 (20.9)
$\bar{X} \pm SD$	131.6 $\pm$ 5.2	132.1 $\pm$ 2.6
Distance from the center of the head to the axis of the femur (mm)		
27.1 – < 34	13 (19.9)	26 (20.2)
34 – 40	29 (45.7)	59 (45.7)
> 40 – 51.6	22 (34.4)	44 (34.1)
$\bar{X} \pm SD$	36.4 $\pm$ 3.9	37.9 $\pm$ 5.2
Diameter of acetabulum (mm)		
46	5 (7.8)	-
48	21 (32.8)	-
50	33 (51.6)	-
52	5 (7.8)	-
Number of screws		
0	37 (57.8)	-
2	26 (40.7)	-
3	1 (1.5)	-
Diameter of articular head (mm)		
-5 (S-small)	49 (76.6)	-
0 (M – medium)	12 (18.7)	-
5 (L-large)	3 (4.7)	-
Diameter of joint shafts (mm)		
18	6 (9.1)	-
20	38 (59.4)	-
22	20 (31.5)	-
Length of joint shafts (mm)		
45	20 (31.3)	-
50	35 (54.7)	-
55	8 (12.5)	-
60	1 (1.5)	-

- Acetabular displacement occurred in one joint (1.6%) 36 months after surgery, and in two joints (3.1%) 48 months later.
- The proportion of joints with surgical site infections 12 months after surgery was 1.6%.
- The proportion of joints with lateral popliteal nerve injury was 6.3% after 12 months of surgery, 3.1% after 36 months, and 1.6% after 48 months.

Table 4. Assessment of Spiron short-stem hip arthroplasty outcomes in Vietnamese patients with femoral head avascular necrosis.

Characteristics	Prior surgery (n=64)	After surgery (month)			p
		12 (n=64)	36 (n=64)	48 (n=64)	
Clinical features					
Pain level					
No pain	0 (0.0)	62 (96.9)	61 (95.3)	55 (85.9)	-
Mild pain	2 (3.1)	1 (1.6)	2 (3.1)	4 (6.3)	-
Moderate pain	16 (25.0)	1 (1.6)	1 (1.6)	3 (4.7)	-
Severe pain	46 (71.9)	0 (0.0)	0 (0.0)	2 (3.1)	-
Walking ability					
Normal	0 (0.0)	47 (73.4)	41 (64.1)	28 (43.8)	-
Mild limitation	26 (40.6)	15 (23.4)	22 (34.4)	24 (37.5)	-
Severe limitation	38 (59.4)	2 (3.1)	1 (1.6)	3 (4.7)	-
Total range of motion					
Normal	0 (0.0)	48 (75.0)	46 (71.9)	35 (54.7)	-
Mild limitation	28 (43.8)	16 (25.0)	17 (26.6)	25 (39.1)	-
Severe limitation	36 (56.2)	0 (0.0)	1 (1.6)	4 (6.3)	-
Hariss score					
Stage IV	48.3 ± 2.2	93.1 ± 3.7	92.8 ± 5.6	83.6 ± 4.5	< 0.05
Stage V	44.2 ± 2.1	91.4 ± 2.7	91.1 ± 4.1	80.3 ± 4.2	< 0.05
Stage VI	41.0 ± 2.1	90.3 ± 1.2	89.6 ± 1.2	79.8 ± 3.4	< 0.05
$\overline{X} \pm SD$	46.8 ± 2.9	92.2 ± 3.2	91.6 ± 4.6	81.2 ± 3.4	< 0.05
X-ray features					
Acetabular tilt angle ($\overline{X} \pm SD$)	40.2 ± 4.5	39.9 ± 7.5	40.1 ± 7.4	39.9 ± 6.3	> 0.05
Distance from the center of the head to the anatomical axis of the femur (offset)	35.2 ± 4.3	39.5 ± 6.6	39.6 ± 5.4	37.2 ± 4.5	< 0.05
Distance from the end of the handle to the hard bone wall ($\overline{X} \pm SD$)	-	5.5 ± 0.4	5.1 ± 0.9	4.2 ± 0.8	< 0.05
Femoral neck angle ($\overline{X} \pm SD$)	133.2 ± 4.3	136.4 ± 6.5	135.2 ± 6.6	131.2 ± 4.5	> 0.05
Deviation ($\overline{X} \pm SD$)	9.2 ± 2.5	9.4 ± 2.6	3.6 ± 2.3	3.1 ± 1.9	< 0.05
Bone and joint junction area	0 (0.0)	1 (1.5)	3 (3.3)	4 (6.3)	< 0.05
Cortical hypertrophy	0 (0.0)	1 (1.5)	3 (3.3)	4 (6.3)	< 0.05
Ectopic ossification	0 (0.0)	1 (1.5)	4 (4.4)	6 (9.4)	< 0.05
Bone support pillar	0 (0.0)	3 (4.6)	7 (7.8)	10 (15.6)	< 0.05
bone platform support	0 (0.0)	10 (15.6)	31 (48.4)	42 (65.6)	< 0.05
Harris score level (point)					
Poor (< 70)	42 (65.6)	0 (0.0)	2 (3.1)	9 (14.1)	< 0.05
Average (70 – 79)	22 (34.4)	1 (1.6)	2 (3.1)	5 (7.7)	< 0.05
Good (80 – 89)	0 (0.0)	13 (20.3)	12 (17.8)	9 (14.1)	< 0.05
Excellent (90 – 100)	0 (0.0)	50 (78.1)	49 (76.7)	41 (64.1)	< 0.05

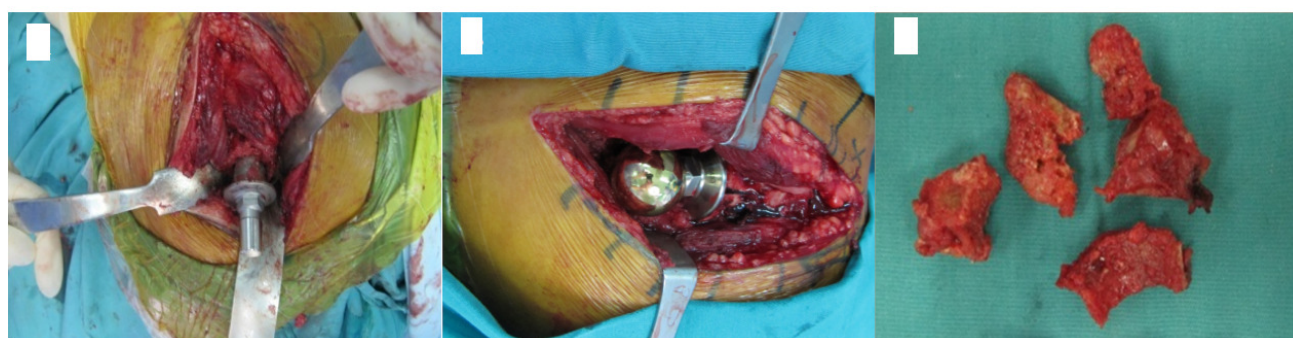
- The number of joints with partial osteolysis around the joint handle was 3.1% after 12 months of surgery, 7.8% after 36 months, and 18.8% after 48 months.
- The number of joints with a clear border around the joint was 3.1% after 12 months of surgery, 15.6% after 36 months, and 21.9% after 48 months.
- The number of joints that needed to be replaced was 1.6% after 12 months of surgery, 1.6% after 36 months, and 12.5% after 48 months.

DISCUSSION

In our study, patients ranged in age from 25 to 50 years old, with an average of 40.6 years. The question is whether joint arthroplasty is truly necessary for younger patients. The majority of the patients in the study had been treated with internal medicine for an extended period of time, resulting in muscle atrophy and deformed femoral heads. In many cases, the acetabulum degenerated, the joint space narrowed, and the constant pain caused physical and mental damage. Therefore, it is reasonable to prescribe hip replacement for these patients. Spiron short-stem hip arthroplasty is recommended for patients aged 18 to 50 years old

Table 5. Complications in Vietnamese patients with femoral head necrosis underwent Spiron short-stem hip arthroplasty.

Type of complications	Time after surgery (month)			p
	12 (n=64)	36 (n=64)	48 (n=64)	
Femoral neck broken	1 (1.6)	0 (0.0)	0 (0.0)	-
Femoral neck fracture	0 (0.0)	0 (0.0)	0 (0.0)	-
Acetabular displacement	0 (0.0)	1 (1.6)	2 (3.1)	-
Large blood vessel injury	0 (0.0)	0 (0.0)	0 (0.0)	-
Bleed	0 (0.0)	0 (0.0)	0 (0.0)	-
Surgical site infection	1 (1.6)	0 (0.0)	0 (0.0)	-
Deep vein thrombosis	0 (0.0)	0 (0.0)	0 (0.0)	-
Hip dislocation	0 (0.0)	0 (0.0)	0 (0.0)	-
Crack at the upper end of the femur	0 (0.0)	0 (0.0)	0 (0.0)	-
Lateral popliteal nerve injury	4 (6.3)	2 (3.1)	1 (1.6)	< 0.05
Partial osteolysis around the joint shaft	2 (3.1)	5 (7.8)	12 (18.8)	< 0.05
Bright rim around joint	2 (3.1)	10 (15.6)	14 (21.9)	< 0.05
Hip replacement	1 (1.6)	1 (1.6)	8 (12.5)	< 0.05

**Figure 5. Complications during and after hip replacement surgery.**

A) femoral neck fracture during articulation; B) femoral neck fracture during repositioning; C) broken femoral neck fragment.

because the lifespan of a standard hip joint is only 15 to 25 years, which increases the risk of having to replace the hip again. As a result, prescribing Spiron hip arthroplasty for these patients is more appropriate and advantageous for their next joint arthroplasty. The average age of patients with spiron hip arthroplasty by Birkenhauer¹¹ (average age 60.1), Lueder¹⁴ (average age 51), Ender¹⁵ (average age 50). Thus, the average patient age in this study is significantly lower. Because these countries' life expectancy is higher than that of Vietnamese people, owing in part to better nutritional conditions, the bone quality of people of the same age in developed countries is frequently higher.

The femoral neck angle of Vietnamese adults is frequently measured on dry femurs, with little variation. According to studies on Vietnamese people, the femoral neck angle ranged from 129° to 132° in men and 128.32° to 128.41° in women.^{16,17} Our findings are quite similar to those of other studies conducted in Vietnam.^{16,17} However, the average femoral neck angle in Indians is 126.55°,¹⁸ while in Europeans it is 136° for men and 133° for women.¹⁹ Vietnamese people have a higher femoral neck angle than

Indians, but lower than Europeans. Jerosch et al.²⁰ indicated that the average change in the femoral neck angle after surgery was (-0.5°) (SD: 4.1°), with the largest increase at 11° and the largest decrease of 16°. The patient's femoral neck angle was restored after surgery, as opposed to before. In a study of Nanos short-stem joint replacement patients, Ettinger et al.²¹ found that the average femoral neck angle after surgery was 134.6° (± 4.3°), higher than the pre-surgery angle of 133.8° (± 4.8). Thus, the change in the femoral neck angle before and after surgery of the patients in this study is consistent with previous studies.

Birkennheuer et al.¹¹ advised against using Spiron short-stem hip arthroplasty in patients with a femoral neck angle of less than 122°. However, in this study, no case of a pre-operative femoral neck angle less than 122° was found. Birkennheuer et al.¹¹ found that if the femoral neck angle is too low, the shaft is likely to be displaced and penetrate the hard bone wall. In this study, four patients had a femoral neck angle ranging from 120°-125°; clearly, these cases should be considered and addressed when replacing the Spiron joint. The data showed that the patients' post-oper-

ative femoral neck angles increased by an average of 3.2° when compared to before surgery. Another study in Vietnam¹² found that the average post-operative femoral shaft angle and anatomical axis was $143.85^\circ \pm 8.02^\circ$ (95% of values were between $141.78^\circ - 145.92^\circ$), which was higher than the pre-operative 134.43° (95% of values were between $133.1^\circ - 135.7^\circ$). Setting the femoral neck angle higher postoperatively than preoperatively is preferable to setting it lower. However, these studies have not determined how many degrees higher the allowable limit is.^{11,18,19,21}

Restoring the distance from the center of the head to the anatomical axis of the femur, as well as limb length, is an important goal of hip arthroplasty and hip function restoration.^{22,23} Our data show that the average distance from the center of the head to the anatomical axis of the femur is 38.3 mm, distributed unevenly in the range of 27.1 - 51.2 mm, which is consistent with the Roy²⁴ and Siwach²⁵ studies. Since the early days of hip arthroplasty, there has been much debate in the medical literature about whether to raise or lower this index.²⁶ Jerosch et al.²⁰ reported that the distance from the center of the head to the anatomical axis of the femur increased by 0.28 cm (SD 0.45 cm), and hip function was fully restored. Amenabar²⁷ also found that after surgery, the distance between the center of the head and the anatomical axis of the femur increased by 0.6 mm compared to the opposite side. In terms of biomechanics, increasing the distance from the center of the head to the anatomical axis of the femur expands the lever arm, reducing the load on the joint, lowering the risk of collision, and expanding the artificial joint's free range of motion.^{26,28} The disadvantage is an increase in load at the distal end of the articular shaft.²⁶ In this study, the distance from the center of the head to the anatomical axis of the femur after surgery was larger than before surgery and comparable to that of healthy people. The distance between the center of the head and the anatomical axis of the femur after surgery and at the last check was equal. Jerosch et al.²⁰ reported that when replacing a short-shaft hip, the ideal is to restore this index to its original value, but the general trend is for the distance from the center of the head to the anatomical axis of the femur to increase following surgery.

Limb discrepancy is a common problem following hip arthroplasty, and it can be caused by a variety of factors.^{29,30} First and foremost, the surgeon fails to consider the length of the limb during the surgery when installing the prosthetic shaft and head. Patients who do not have surgery for a long time may have atrophied muscles on the side of the hip joint with AVNFB, causing the joint to be loose when the hip joint is replaced and the two legs are equal, and when the head index is increased to make the joint stable, the two limbs become uneven. Many studies, particularly for patients with bilateral AVNFB, prioritize making the joint stable in the first surgery, with the next surgery adjusting to restore limb balance for the patient. Therefore, when examining patients between two surgeries, the rate of limb discrepancy is higher.^{20,21,27} Previous studies reported that a difference of 10mm or more between the two limbs following hip arthroplasty affects gait, pain, and

rapid acetabulum wear, so patients must wear orthopedic shoes.^{31,32} Furthermore, studies have found a correlation between the condition of limb lengthening after surgery and sciatic nerve damage, lateral popliteal nerve palsy, and sciatic nerve palsy when the difference between the two limbs is large.^{31,32} The primary cause of limb imbalance is incorrect placement of the joint shaft, and the reduction in the distance from the center of the head to the anatomical axis of the femur (offset) is due to incorrect placement of both the joint shaft and the acetabulum.³³⁻³⁵ Therefore, in hip arthroplasty, special attention should be paid to balancing the limb and restoring the distance from the center of the head to the anatomical axis of the femur, avoiding a limb deviation of more than 10mm and reducing this distance by more than 5mm compared to the healthy side.²²

Our findings indicate that the rate of complications in patients undergoing short-stem hip arthroplasty is quite high compared to previous studies.³⁶ Spiron short-stem hip arthroplasty has some complications similar to standard hip replacement. However, the most concerning aspect of short-stem hip arthroplasty is the rate of re-replacement and displacement of the joint shaft.^{36,37} Complications that can occur after surgery, such as fractures around the short shaft, fractures of the joint shaft, deep infection, bone loss..., can necessitate hip replacement; previous studies have also documented the occurrence of these complications after surgery.^{5,38,39} In this study, there was one femoral neck fracture and one acetabular fracture. We had to fix three acetabular screws and allow the patient to compress late; after examination, the bone healed well and the acetabular was not displaced. There was one case of superficial wound infection after 12 months. In addition, lateral popliteal nerve injuries, partial osteolysis around the joint shaft, and periarticular lucency occur more frequently over time. As a result, 48 months after surgery, 8 cases of hip replacement were reported due to these complications. Because the short-stem hip joint has a relatively short history of development, surgeons are often concerned about the rate of replacement. Oldenrijk⁴⁰ and Steens¹⁵ found that 2.5% and 11.0% of joints required replacement after more than three years of follow-up, respectively. The rate of joint replacement among the patients in this study is quite high. The Spiron hip arthroplasty technique is more difficult than standard hip arthroplasty; additionally, Spiron hip arthroplasty was first performed in Vietnam, so the initial surgeons were not yet adapted, so Spiron hip arthroplasty was incomplete, the rate of complications and re-joint replacement was still high. Later, as surgeons improved their techniques, the rate of complications and re-joint replacements decreased significantly. To improve the efficiency of hip arthroplasty, surgeons must be trained and supervised technically.

CONCLUSION

Spiron short-stem hip arthroplasty for young Vietnamese patients revealed many outstanding benefits because the upper head and metaphysis structure remain intact, making standard hip replacement later quite simple. Furthermore,

it demonstrates that if the surgeon's surgical indication selection and technique, as well as the measurement of hip joint anatomical indicators and computer planning, are not perfected and strictly adhered to the pre-operative plan, the risk of complications and re-joint replacement is extremely high.

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AUTHOR CONTRIBUTIONS

Mai Duc Thuan: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Visualization, Writing – review & editing, Visualization, Supervision. **Nguyen Quoc Dung:** Conceptualization, Methodology, Validation, Resources, Data curation, Writing – review & editing.

ETHICAL STATEMENT

This study was approved by the ethics committee of the 108 Military Central Hospital. This study was conducted in accordance with the Declaration of Helsinki and the guidelines and regulations of the Vietnamese Ministry of Health. All the patients consented to participate in this study, and informed consents were signed by themselves in all instances.

PATIENT'S CONSENT

The patients were informed that data from the research would be submitted for publication, and gave their consent.

FINANCIAL DISCLOSURE

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

CONFLICT OF INTEREST

The authors declare no competing interests.

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REFERENCES

1. Barney J, Piuizzi NS, Akhondi H. Femoral Head Avascular Necrosis. In: *StatPearls*. StatPearls; 2025.
2. Afetse EK, Kopolovich D, Jochl OM, et al. Arthroscopic Treatment of Avascular Necrosis of the Femoral Head. *Arthrosc Tech*. 2025;14(2):103233. doi:[10.1016/j.eats.2024.103233](https://doi.org/10.1016/j.eats.2024.103233). PMID:40041349
3. Beck DM, Park BK, Youm T, Wolfson TS. Arthroscopic treatment of labral tears and concurrent avascular necrosis of the femoral head in young adults. *Arthrosc Tech*. 2013;2(4):e367-371. doi:[10.1016/j.eats.2013.06.005](https://doi.org/10.1016/j.eats.2013.06.005). PMID:24400184
4. Binh LT. *Clinical and Imaging Studies of Avascular Necrosis of the Femoral Head in Adults*. Doctoral Thesis in Medicine. Military Medical Academy; 2011.
5. Floerkemeier T, Budde S, Gronewold J, et al. Short-stem hip arthroplasty in osteonecrosis of the femoral head. *Arch Orthop Trauma Surg*. 2015;135(5):715-722. doi:[10.1007/s00402-015-2195-9](https://doi.org/10.1007/s00402-015-2195-9)
6. Mont MA, Cherian JJ, Sierra RJ, C JL, R LJ. Nontraumatic osteonecrosis of the femoral head: Where do we stand today? A ten-year update. *J Bone joint Surg Am*. 2015;97(19):1604-1627. doi:[10.2106/JBJS.O.00071](https://doi.org/10.2106/JBJS.O.00071)
7. Meek RM, Garbuz DS, Masri BA, Greidanus NV, Duncan CP. Intraoperative Fracture of the Femur in Revision Total Hip Arthroplasty with a Diaphyseal Fitting Stem. *Journal of Bone & Joint Surgery - American Volume*. 2004;86-A(3):480-485. doi:[10.2106/00004623-200403000-00004](https://doi.org/10.2106/00004623-200403000-00004)
8. Thach NV. Preliminary results of Spiron-type hip replacement in young patients. *Vietnam Journal of Orthopedics and Traumatology*. 2013;3:22-26.
9. Morrey BF, Kavanag BF. Complications with revision of the femoral component of total hip arthroplasty. 1992;7(1):71-79. doi:[10.1016/0883-5403\(92\)90035-O](https://doi.org/10.1016/0883-5403(92)90035-O)
10. McTighe T, David S, Louis K, et al. Short-stem designs for total Hip Arthroplasty: neck Stabilized Femoral components. *Orthopaedic and Trauma Surgery*. 2015;64:823-849.
11. Birkenhauer B, Kistmacher H, Ries J. Conception and first results of the Spiron cementless femoral neck screw prosthesis. *Orthopade*. 2004;33(11):1259-1266. doi:[10.1007/s00132-004-0719-z](https://doi.org/10.1007/s00132-004-0719-z)
12. Nam BH. *Evaluation of the Results of Short-Shaft Cementless Total Hip Replacement Surgery at Viet Duc Hospital*. Hanoi Medical University; 2015.
13. Hung DT. *Research on the Application of Some Technical Improvements in Cementless Total Hip Replacement Surgery*. Doctoral Thesis in Medicine. Military Medical Academy; 2015.
14. Luger A, Häring E, Müller A, Dorste P, Zeichen J. Total hip arthroplasty with the cementless spiron femoral neck prosthesis. *Operative Orthopädie und Traumatologie*. 2013;25:45-59. doi:[10.1007/s00064-012-0163-x](https://doi.org/10.1007/s00064-012-0163-x)
15. Ender SA, Machner A, Pap G, Hubbe J, Graßhoff H, Neumann HW. Cementless CUT femoral neck prosthesis: increased rate of aseptic loosening after 5 years. *Acta Orthopaedica*. 2007;78(5):616-621. doi:[10.1080/17453670710014301](https://doi.org/10.1080/17453670710014301)
16. Le Gia V, Tran ĐCN. Formula for calculating the size of the neck and head of the femur in Vietnamese adults. *Journal of the Vietnam Morphological Society, Vietnam Medical and Pharmaceutical Association*. 2001;16(7):49-55.
17. Thang NH. *Study on Treatment of Intertrochanteric and Subtrochanteric Femoral Fractures in Adults with AO Angle Braces of 95 and 130 Degrees*. PhD thesis in medicine. Institute of Clinical Medicine and Pharmacy Research 108; 2009.
18. Ravichandran D, Muthukumaravel N, Jaikumar R, Das H, Rajendran M. PROXIMAL FEMORAL GEOMETRY IN INDIANS AND ITS CLINICAL APPLICATIONS. *J Anat Soc India*. 2011;60(1). doi:[10.1016/S0003-2778\(11\)80003-1](https://doi.org/10.1016/S0003-2778(11)80003-1)
19. Hoaglund F, Low W. Anatomy of the femoral neck and head, with comparative data from Caucasians and Hong Kong Chinese. *Clin Orthop Relat Res*. 2009;467(4):876-885. doi:[10.1007/s11999-008-0473-3](https://doi.org/10.1007/s11999-008-0473-3). PMID:18758876
20. Jerosch J, Grasselli C, Kothny PC, Litzkow D, Hennecke T. Postoperative changes of offset, CCD angle and leg length after implantation of a metadiaphyseal fixed short-term prosthesis - a radiological examination. *Hip Arthroplasty*. 2012;150:20-26. doi:[10.1055/s-0030-1270965](https://doi.org/10.1055/s-0030-1270965)
21. Ettinger M, Ettinger P, Ezechieli M, et al. CCD and offset after Nanos short stem in total hip arthroplasty. *Technol Health Care*. 2013;22(2):149-155. doi:[10.3233/THC-130716](https://doi.org/10.3233/THC-130716)

22. Amiry BA, Mahmood S, Krupic F, Noor AS. Leg lengthening and femoral-offset reduction after total hip arthroplasty: Where is the problem-stem or cup positioning. *Acta Radiologica*. Published online 2017;1-7.
23. Rubin PJ, Leyvraz PF, Aubaniac JM, Argenson JN, Esteve P, Roguin BD. THE MORPHOLOGY OF THE PROXIMAL FEMUR A THREE-DIMENSIONAL RADIOGRAPHIC ANALYSIS. *J Bone Joint Surg [Br]*. 1992;74-B:28-32. doi:[10.1302/0301-620X.74B1.1732260](https://doi.org/10.1302/0301-620X.74B1.1732260)
24. Roy S, Kundu R, Medda S, Gupta A, Nanrah BK. Evaluation of Proximal Femoral Geometry in Plain Anterior-Posterior Radiograph in Eastern-Indian Population. *J Clin Diagn Res*. 2014;8(9):AC01-AC03. doi:[10.7860/JCDR/2014/9269.4852](https://doi.org/10.7860/JCDR/2014/9269.4852). PMID:25386412
25. Siwach RC, Dahiya S. Anthropometric Study of proximal femur geometry and it's clinical application. *Indian J Orthop*. 2003;37:247-251.
26. Boese CK, Bredow J, Ettinger M, et al. The Influence of Hip Rotation on Femoral Offset Following Short Stem Total Hip Arthroplasty. 2016;31(1):312-316. doi:[10.1016/j.arth.2015.07.027](https://doi.org/10.1016/j.arth.2015.07.027)
27. Amenabar T, Marimuthu K, Hawdon G, Gildone A, McMahon S. Total hip arthroplasty using a short-stem prosthesis: restoration of hip anatomy. *Journal of Orthopaedic Surgery*. 2015;23(1):90-94. doi:[10.1177/230949901502300121](https://doi.org/10.1177/230949901502300121)
28. Schmidutz F, Beirer M, Weber P, Mazoochian F, Fottner A, Jansson V. Biomechanical reconstruction of the hip: comparison between modular short-stem hip arthroplasty and conventional total hip arthroplasty. *Int Orthop*. 2012;36:1341-1347. doi:[10.1007/s00264-011-1477-2](https://doi.org/10.1007/s00264-011-1477-2). PMID:22262250
29. Desai AS, Dramis A, Board TN. Leg length discrepancy after total hip arthroplasty: a review of literature. 2013;6(4):336-341. doi:[10.1007/s12178-013-9180-0](https://doi.org/10.1007/s12178-013-9180-0). PMID:23900834
30. Edeen J, H FSP, H AA. Clinical significance of leg-length inequality after total hip arthroplasty. *Am J Orthop (Belle Mead NJ)*. 1995;24(4):347-351.
31. Edwards BN, Tullos HS, Noble PC. Contributory factors and etiology of sciatic nerve palsy in total hip arthroplasty. *Clin Orthop Relat Res*. 1987;218:136-141. doi:[10.1097/00003086-198705000-00019](https://doi.org/10.1097/00003086-198705000-00019)
32. Mahmood SS, al CSe SMS. The influence of leg length discrepancy after total hip arthroplasty on function and quality of life: a prospective cohort study. *J Arthroplasty*. 2015;30:1638-1642. doi:[10.1016/j.arth.2015.04.012](https://doi.org/10.1016/j.arth.2015.04.012)
33. Kersic M, D D. AVea: The impact of leg length discrepancy on clinical outcome of total hip arthroplasty: comparison of four measurement methods. *J Arthroplasty*. 2014;29:137-141. doi:[10.1016/j.arth.2013.04.004](https://doi.org/10.1016/j.arth.2013.04.004)
34. Mahmood SS, al SM, et al. CSe: Association between changes in global femoral offset after total hip arthroplasty and function, quality of life, and abductor muscle strength. A prospective cohort study of 222 patients. *Acta Orthop*. 2016;87:36-41. doi:[10.3109/17453674.2015.1091955](https://doi.org/10.3109/17453674.2015.1091955). PMID:26471772
35. Mahmood SS, B AA, al MSS, et al. Validity reliability and reproducibility of plain radiographic measurements after total hip arthroplasty. *Skeletal Radiol*. 2015;44:345-351. doi:[10.1007/s00256-014-2055-7](https://doi.org/10.1007/s00256-014-2055-7)
36. Molli RG, Lombardi AV, Berend KR, Adams JB, Sneller MA. A Short Tapered Stem Reduces Intraoperative Complications in Primary Total Hip Arthroplasty. *Clin Orthop Relat Res*. 2012;470(2):450-610. doi:[10.1007/s11999-011-2068-7](https://doi.org/10.1007/s11999-011-2068-7). PMID:21971877
37. Kutzner KP, Kovacevic MP, Freitag T, Fuchs A, Reichel H, Bieger R. Influence of patient-related characteristics on early migration in calcar-guided short-stem total hip arthroplasty: a 2-year migration analysis using EBRA-FCA. *J Orthop Surg Res*. Published online 2016. doi:[10.1186/s13018-016-0363-4](https://doi.org/10.1186/s13018-016-0363-4). PMID:26951069
38. Banerjee S, Pivec R, Issa K, Harwin SF, Mont MA, Khanuja HS. Outcomes of Short Stems in Total Hip Arthroplasty. *Orthopedics*. 2013;36(9):700-707. doi:[10.3928/01477447-20130821-06](https://doi.org/10.3928/01477447-20130821-06)
39. Ishaque BA, Stürz H, Basad E. Fatigue Fracture of a Short Stem Hip Replacement: A Failure Analysis With Electron microscopy and Review of the Literature. *The Journal of Arthroplasty*. 2011;26(4):17-20. doi:[10.1016/j.arth.2010.05.021](https://doi.org/10.1016/j.arth.2010.05.021)
40. Oldenrijk J v., Molleman J, Klaver M, Poolman RW, Haverkamp D. Revision rate after short-stem total hip arthroplasty. *Acta Orthopaedica*. 2014;85(3):250-258. doi:[10.3109/17453674.2014.908343](https://doi.org/10.3109/17453674.2014.908343). PMID:24694271