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Correlations between the femoral neck osteotomy angle and radiologic and clinical outcomes analyzed in patients undergoing total hip replacement with metaphyseal fixation

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Abstract. – OBJECTIVE: This study will explore whether the femoral neck osteotomy angle (FNOA) has an effect on hip anatomical functional reconstruction and clinical outcomes after total hip arthroplasty (THA).

PATIENTS AND METHODS: The study included 254 patients (296 hips) who underwent primary total hip arthroplasty using the same uncemented short stem (Tri-Lock BPS) between December 2018 and December 2019. Correlations between FNOA and the radiologic and clinical outcomes of patients were analyzed.

RESULTS: Patients were divided into 3 groups according to different FNOA. FNOA ≤50° is Group A, 50°< FNOA <55° Group B, and FNOA ≥55° Group C. There were significant differences among the three groups in distal D1 (*p*=0.029), sitting proud (SP) (*p*<0.001), varus and valgus alignment (*p*<0.001), FO (*p*=0.001), and caput-collum-diaphysis angle (CCD) (*p*<0.001). There were significant differences in the incidence of complications among the three groups (*p*<0.007). There was a significant linear correlation with D1 (B=0.005, CI=0.002 to 0.008, *p*=0.004), SP (B=-0.266, CI=-0.286 to 0.166, *p*<0.001), the femoral stem varus-valgus alignment angle (B=-0.359, CI=-0.422 to -0.297, *p*<0.001), femoral offset (FO) (B=-0.500, CI=-0.795 to -0.205, *p*=0.001), and CCD (B=0.696, CI=0.542 to 0.849, *p*<0.001). In logistic regression analysis, inappropriate FNOA increased the risk of dislocation (OR=0.892, CI=0.812 to 0.979, *p*=0.016) and thigh pain (OR=0.920, CI=0.851 to 0.995, *p*=0.037).

CONCLUSIONS: The study demonstrates the relationship between FNOA and short-term radiological and clinical outcomes of patients after THA using a Tri-Lock femoral prosthesis. Inappropriate FNOA was significantly associated with failure of hip anatomical reconstruction and a higher risk of complications.

Key Words:

Total hip arthroplasty, Short stem, Femoral neck osteotomy, Metaphyseal fixation.

Introduction

Cementless prostheses are increasingly used in total hip arthroplasty with good results[1]. The age of the patients is gradually decreasing. However, younger patients often face a higher risk of complications later in life, leading to revision surgery[2]. Therefore, there is increasing enthusiasm for short stems to reduce surgical invasiveness, preserve more bone, and achieve proximal loading transfer[3,4]. Another advantage of the short femoral stem is the excellent reconstruction of the hip anatomy[5,6]. Several studies[7-9] have shown that the neck-shaft angle and femoral offset affect the postoperative range of motion of the hip joint and abductor function. Given these findings, correct reconstruction of hip anatomy is of high clinical relevance.

The Tri-Lock stem is a shorter, triaxial locking, wedge-shaped stem with a distally polished Gription-coated surface finish, that achieves proximal femoral fixation through a press-fit of the metaphysis[10] and provides good fixation strength[11]. The design effectively avoids combination with the surrounding bone and destruction due to the proximal stress load. The medium- and long-term follow-up results[12-15] showed excellent clinical manifestations and radiological osseointegration.

Femoral neck osteotomy is essential for the reconstruction of the hip anatomy with a short stem. Mihalko et al[16] concluded that a higher level of neck resection (+10 mm) was more likely to result in increased leg length and femoral offset. The caput-collum-diaphysis (CCD) angle was significantly higher at the 0 mm cervical osteotomy level, and the femoral offset was lower. Floerkemeier et al[17] found an increase in prosthesis varus and femoral excursion more easily guided with a high horizontal resection (+10 mm) compared

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with a low femoral neck osteotomy. Liu et al[18] reported that a decreased neck-preserving ratio may lead to a higher incidence of stem varus alignment and associated complications.

However, the relationship between Tri-Lock BPS stem femoral neck osteotomy and hip anatomical functional reconstruction and clinical outcomes remains unclear. Since the Tri-Lock stem uses the traditional femoral neck osteotomy, the femoral neck is only minimally preserved. Therefore, this study will explore whether the femoral neck osteotomy angle (FNOA)[19] affects hip anatomical functional reconstruction and clinical outcomes after THA.

Patients and Methods

Study Population and Design

Study population

The study retrospectively analyzed 254 patients (296 hips) who underwent primary total hip arthroplasty using the same uncemented short stem (Tri-Lock BPS) between December 2018 and December 2019.

Study design

Patients were divided into 3 groups according to different FNOA. FNOA ≤50° is Group A, 50°< FNOA <55° is Group B, and FNOA ≥55° is Group C. The study was approved by the Institutional Review Board of the Third Hospital of Hebei Medical University and was conducted in accordance with the Declaration of Helsinki. As this was a retrospective study, all patient information was de-identified prior to analysis, and informed consent was not needed.

Our inclusion criteria were as follows: (1) patients with osteonecrosis of the femoral head (ONFH) stages III and IV[20], osteoarthritis, and subcapital neck fracture; (2) patients older than 18 years old and younger than 70 years old; and (3) primary THA on one or both hips (if one patient received bilateral THA, the patient was considered as two separate individuals).

Exclusion criteria: (1) patients with hip dysfunction due to rheumatoid arthritis, intraoperative femoral fractures, developmental dysplasia of the hip (DDH)[21], or other disorders were excluded; (2) patients who received non-Tri-Lock prostheses in total hip arthroplasty; (3) patients followed up for less than 2 years; (4) patient who had undergone other surgery for ONFH prior to treatment.

Surgery and Treatment

All operations were performed by the same group of experienced surgeons. Surgical methods adopted a posterolateral approach to expose the hip joint. After adduction and internal rotation and dislocation of the hip joint, and osteotomy of the femoral neck, the front and back of the femoral neck osteotomy line were kept on the same plane, followed by full exposure of the acetabulum, and exploration of bony landmarks such as the acetabular rim, ischium, and lesser trochanter of the femur. After reaming the acetabulum, the biological acetabular prosthesis was placed, and then the lining was placed. The proximal femur was opened, the medullary cavity was ripped to an appropriate size with a medullary rasp, and the femoral prosthesis stem was installed. After installing the artificial femoral head, the hip joint was reset, and the joint movement was checked to ensure that the tightness was appropriate. The pa-

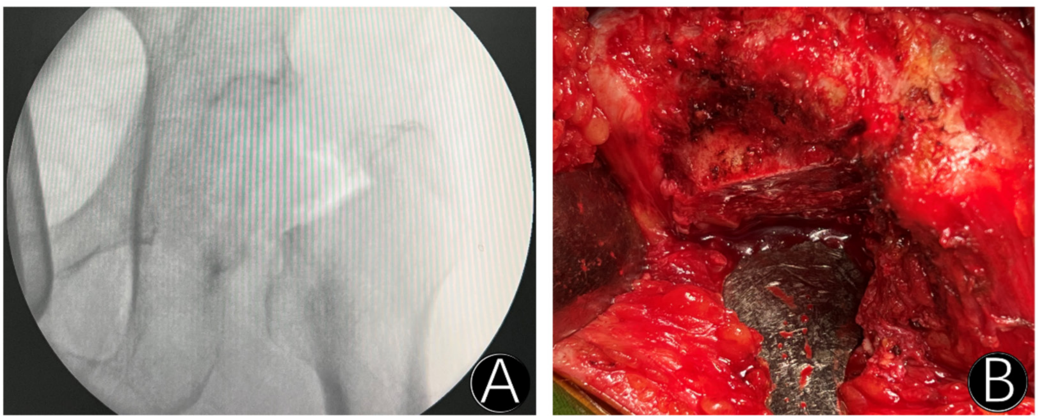

Figure 1. A-B, The front and back of the femoral neck osteotomy line were kept on the same plane during THA

tient was allowed to attempt full weight bearing immediately on the day after surgery (Figure 1).

Radiographic Assessment

We focused on the hip radiographs obtained preoperatively, at 7 days postoperatively, and at the 2-year postoperative mark. The preoperative and postoperative X-rays were acquired using the same standard (the patient was standing with double support, the foot spacing was equal to the shoulder width, and the bilateral toes were slightly inwards by approximately 15°) (Figure 2). All impact data are from the same center. A standardized approach was used to achieve reproducible projections.

Femoral morphology

According to the Dorr classification[22], the cortical index (CI) and canal-to-calcar ratio (CCR) were measured on the frontal and lateral pelvic X-rays, and the morphology of the femoral medullary cavity was divided into Dorr A type, Dorr B type, and Dorr C type. The canal flare index (CFI) was measured[23].

Canal filling ratio (CFR)

CFR was measured at the following four levels: (1) the lesser trochanter (LT): P1, 2 cm above the tip of the LT; (2) P2, at the level of the tip of the LT; (3) P3, 2 cm below the tip of the LT; (4) and D1, 7 cm below the tip of the LT[24].

Femoral component alignment

Femoral component alignment[25] was defined as the angle between the axis of the femoral shaft and the axis of the femoral stem on anterior and posterior radiographs and was considered varus alignment when the angle was $\geq$3° and valgus alignment when the angle was $\leq$-3°.

The caput-collum-diaphysis angle (CCD)

CCD is defined as the angle between the femoral neck axis passing through the center of the femoral head and the anatomical axis of the femoral shaft on anterior-posterior X-rays[26].

Femoral offset (FO)

FO is defined as the vertical distance from the center of rotation of the femoral head to the anatomical axis of the femur on an anteroposterior radiograph[27].

Sitting proud (SP)

SP is defined as the distance of the prosthesis beyond the level of the femoral neck osteotomy on the anteroposterior radiograph[28].

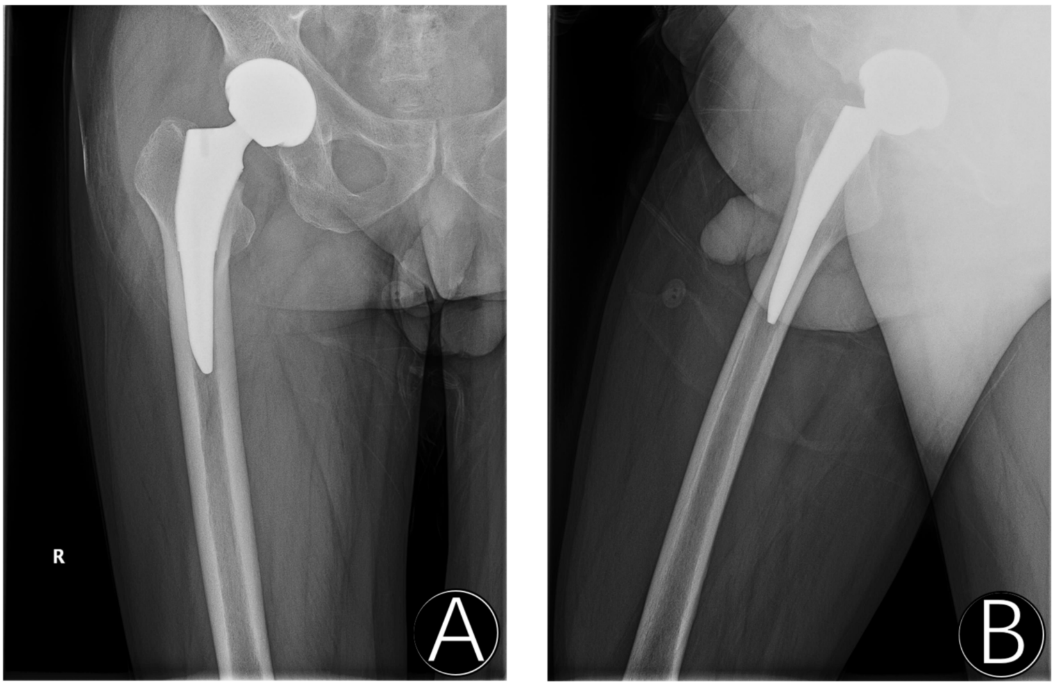

Figure 2. The postoperative frontal and lateral radiographs of a patient are presented. **A**, illustrates the front view, while image (**B**) displays the lateral view.

Femoral neck osteotomy angle (FNOA)

The femoral neck osteotomy angle (FNOA) is defined as the angle between the femoral neck osteotomy line and the anatomical axis of the femur on the anteroposterior pelvic radiograph (Figure 3).

Statistical Analysis

All radiological measurements were performed independently by 2 experienced surgeons using data obtained from our hospital's image archiving and communication system and then averaged. To test for intra- and interobserver reproducibility, 20 patients were randomly sampled, and each measurement was measured independently and repeated 1 week later. In this study, all intraclass correlation coefficients used to assess reproducibility were >0.9.

Descriptive and statistical analyses were performed using SPSS v. 26 (IBM Corp., Armonk, NY, USA). The normality of the distribution was verified using the Shapiro-Wilk test and the Kolmogorov-Smirnov test. Quantitative data between the three groups were determined using the Mann-Whitney U test to determine the significance of differences. The Chi-square test compares the differences between categorical variables. Normality criteria were not met for radiological indices, and Spearman's correlation coefficient was used to analyze correlations. Linear regression analysis was used to evaluate the relationship between FNOA and radiological indicators. Logistic regression analysis was used to determine the relationship between the angle of femoral neck osteotomy and the risk of complications. $p<0.05$ was considered statistically significant.

Results

Patient Characteristics

One Our study comprised 254 participants, of which 157 were males and 97 were females, with 114 hips in Group A, 99 hips in Group B, and 83 hips in Group C. The average age of the participants was 50.98±11.73 years, with a mean body mass index (BMI) of 26.23±2.23 kg/m^2. The diagnosed conditions of the participants included ONFH ACRO III and IV (n=198), osteoarthritis (n=90), and subcapital neck fracture (n=8). Demographic factors such as age, sex, BMI, and diagnosed conditions were not significantly different among the three groups (refer to Table I for more details).

Prosthetic Material

The head-to-cup ratio and stem size did not significantly differ among the three groups. The PINNACLE Gription Sector 52 mm cup was the most commonly utilized, along with the DELTA ceramic ball 32 mm femoral head and size 4 femoral stem (Table II).

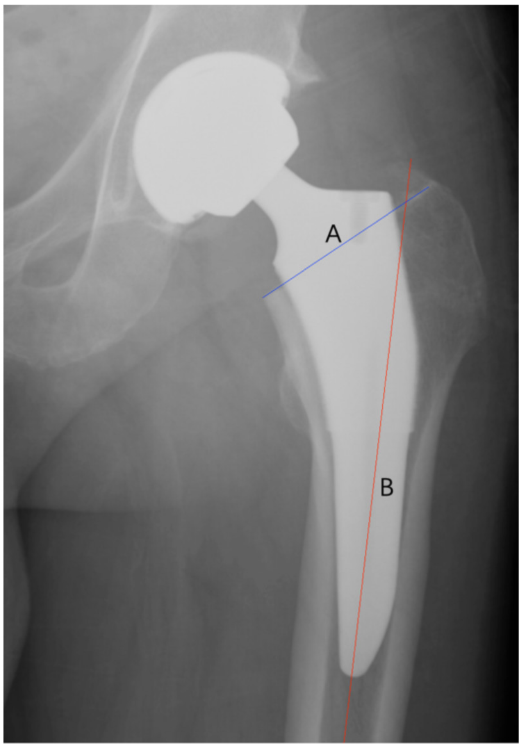

Figure 3. Line A is the osteotomy line of the femoral neck, and line B is the anatomical axis of the femur. The angle formed by the AB line is defined as FNOA.

Femur Morphology

There was a total of 84 Dorr type A hips, 183 Dorr type B hips, and 29 Dorr type C hips in our study. The mean CI of anterior and posterior (AP) hip radiographs was 0.53±0.08, while the mean CI of lateral hip radiographs was 0.44±0.10. Additionally, the mean CCR was 0.67±0.10, and the mean CFI was 3.27±0.56. Interestingly, there was no significant difference in femoral morphology among the three groups (refer to Table III).

Radiological Assessment

The average FNOA was 51.97°±5.74°, with Group A having a mean of 46.54±3.07°, Group B having a mean of 52.41±1.57°, and Group C having a mean of 58.89±3.59°. P1, P2, and P3 did not differ significantly between the three groups, but there were differences among the groups in D1 ($p=0.029$). The mean SP was

Table I. Patient characteristics in different groups.

Variables	Group A	Group B	Group C	*p*
Gender				
male	60 (61.86%)	49 (56.98%)	48 (67.61%)	0.394
female	37 (38.14%)	37 (43.02%)	23 (32.39%)	
Age (yr)‡	50.61±11.59	50.65±11.54	51.87±12.22	0.599
BMI (kg/m^2)‡	26.42±1.91	25.62±3.04	26.64±2.31	0.647
Disease‡				
ONFH ARCO III and IV	89 (78.07%)	61 (61.62%)	48 (57.83%)	0.058
Osteoarthritis	24 (21.05%)	34 (34.34%)	32 (38.55%)	
Femoral neck fracture	1 (0.88%)	4 (4.04%)	3 (2.70%)	

BMI = Body Mass Index; Group A = FNOA ≤50°, Group B = 50°< FNOA <55°, Group C = FNOA ≥55°; ‡Kruskal-Wallis test.

Table II. Femoral components in different groups.

Variables	Group A	Group B	Group C	*p*
Head to cup ratio‡	0.66±0.03	0.66±0.03	0.67±0.03	0.564
Median Stem size	4	4	4	

Group A = FNOA ≤50°, Group B = 50°< FNOA<55°, Group C = FNOA ≥55°; ‡Kruskal-Wallis test.

Table III. The indicators of femoral morphology.

Variables	Group A	Group B	Group C	*p*
Dorr type†				
A	33	29	22	0.682
B	72	57	54	
C	9	13	7	
Cortical index‡				
AP X-ray	0.54±0.08	0.53±0.08	0.53±0.08	0.630
Lateral X-ray	0.44±0.10	0.43±0.09	0.43±0.10	0.723
Canal to calcar ratio‡	0.66±0.08	0.68±0.10	0.66±0.11	0.236
Canal flare index‡	3.30±0.51	3.27±0.63	3.23±0.54	0.556

Group A = FNOA ≤50°, Group B = 50°< FNOA <55°, Group C = FNOA ≥55°; †Chi-squared test, ‡Kruskal-Wallis test.

4.95±3.26, and there was a significant difference among the three groups ($p<0.001$). Varus and valgus alignment occurred in 42 (14.19%) and 62 (20.95%) stems, respectively. A total of 192 (64.86%) femoral implants remained neutral, and there was a significant difference between the three groups ($p<0.001$). The mean FO was 5.86±4.23, and the mean CCD was 130.52±5.89. Moreover, significant differences were observed among the three groups in FO ($p<0.001$) as well as in CCD ($p<0.001$) (refer to Table IV).

Clinical Outcome

Among the 296 hips, there were 10 cases (3.38%) of dislocation, 19 cases (6.42%) of thigh pain, and 1 case (0.34%) of periprosthetic fracture. There were significant differences in the incidence of complications among the three groups (Group A: 96.49%: 3.51%, Group B: 91.92%: 8.08%, Group C: 78.31%: 21.69%, $p<0.007$) (Table V).

Correlation and Regression Analysis

We also investigated the correlation of the femoral neck osteotomy angle with radiological parameters. In the canal filling ratio, only D1 showed a very weak positive correlation with FNOA (R=0.161, $p=0.005$). There was a moderate negative correlation between varus (valgus) alignment and FNOA (R=-0.557, $p<0.001$), while there was a weak negative correlation between stem-sitting proud and FNOA (R=-0.381, $p<0.001$). There was a weak positive correlation between femoral offset and FNOA (R=0.429, $p<0.001$) and a strong correlation between neck shaft angle and FNOA (R=0.805, $p<0.001$) (Table VI).

Table IV. Radiological evaluation of hip anatomical functional reconstruction.

Variables	Group A	Group B	Group C	*p*
Canal filling ratio‡				
P1	0.70±0.06	0.68±0.07	0.69±0.07	0.306
P2	0.81±0.08	0.80±0.09	0.83±0.08	0.096
P3	0.82±0.08	0.81±0.08	0.81±0.10	0.292
D1	0.76±0.20	0.80±0.14	0.83±0.12	0.029*
Sitting proud (mm)‡	6.25±3.26	4.55±2.82	3.64±3.11	<0.001**
Femoral offset (mm)‡	9.81±3.45	5.47±2.82	2.29±2.47	<0.001**
Caput-collum-diaphysis angle (°)‡	124.02±2.11	131.99±4.09	135.55±3.64	<0.001**
Femoral component alignment†				
Non-Varus	81 (71.05%)	91 (91.92)	82 (98.80%)	<0.001**
Varus	33 (28.95%)	8 (8.08%)	1 (1.20%)	

Group A = FNOA ≤50°, Group B = 50°< FNOA<55°, Group C = FNOA ≥55°; Varus ≥3°, 3°< Neutral <-3°, valgus ≤-3°; †Chi-squared test, ‡Kruskal-Wallis test; *p<0.05, **p<0.001.

Table V. Complications in three groups.

Variables	Group A	Group B	Group C	*p*
No†	110 (96.49%)	91 (91.92%)	65 (78.31%)	0.007*
Yes	4 (3.51%)	8 (8.08%)	18 (21.69%)	
Periprosthetic fracture	1 (0.88%)	0	0	
Dislocation	0	3 (3.03%)	7 (8.43%)	
Thigh pain	3 (2.63%)	5 (5.05%)	11 (13.25%)	

Group A = FNOA ≤50°, Group B = 50°< FNOA <55°, Group C = FNOA ≥55°; †Chi-squared test; *p<0.05.

Table VI. Relation between the femoral neck osteotomy angle and some indicators of the femoral prosthesis position.

	R	*p*
Canal filling ratio		
P1	-0.066	0.260
P2	0.102	0.076
P3	-0.084	0.151
D1	0.161	0.005
Femoral component alignment angle	-0.557	<0.001**
Sitting proud	-0.381	<0.001**
Femoral offset	0.429	0.001*
Caput-collum-diaphysis angle	0.805	<0.001**

Group A = FNOA ≤50°, Group B = 50°< FNOA <55°, Group C = FNOA ≥55°; *p<0.05, **p<0.001.

Finally, we aimed to further clarify the effects of the femoral neck osteotomy angle on postoperative radiological indicators and complications through linear regression and binary logistic regression. For every 1° increase in the osteotomy angle, the canal filling ratio at D1 increased by 0.005 (B=0.005, CI=0.002 to 0.008, p=0.004), the femoral stem varus angle increased by -0.359 (B=-0.359, -0.422 to -0.297, p<0.001), the stem sitting proud increased by -0.226 (B=-0.266, CI=-0.286 to 0.166, p<0.001), the femoral offset increased by approximately -0.500 (B=-0.500, CI=-0.795 to -0.205, p=0.001), and the neck shaft angle increased by approximately 0.696 (B=0.696, CI=0.542 to 0.849, p<0.001). In logistic regression analysis, excessive femoral neck osteotomy angle increased the risk of dislocation (OR=0.892, CI=0.812 to 0.979, p=0.016) and thigh pain (OR=0.920, CI=0.851 to 0.995, p=0.037) (Table VII).

Discussion

The precise reconstruction of hip anatomy in total hip arthroplasty (THA) is crucial and plays an important role in determining clinical outco-

Table VII. Linear (or logistic) regression analyses of radiological evaluation and complications.

Variables	*B (OR)*	*95% CI*	*p*
Canal filling ratio†			
D1	0.005	0.002 to 0.008	0.004*
Femoral component alignment angle†	-0.359	-0.422 to -0.297	<0.001**
Sitting proud†	-0.226	-0.286 to -0.166	<0.001**
Femoral offset†	-0.500	-0.795 to -0.205	0.001*
Caput-collum-diaphysis angle †	0.696	0.542 to 0.849	<0.001**
Periprosthetic fracture‡			
No	reference	reference	reference
Yes	0.931	0.657 to 1.321	0.689
Dislocation‡			
NO	reference	reference	reference
Yes	0.892	0.812 to 0.979	0.047*
Thigh pain‡			
No	reference	reference	reference
Yes	0.920	0.851 to 0.995	0.037*

Group A = FNOA ≤50°, Group B = 50°< FNOA <55°, Group C = FNOA ≥55°; †test Linear regression analyses; ‡logistic regression analyses; *$p<0.05$, **$p<0.001$.

mes[29-31]. Nonetheless, it remains unclear whether FNOA impacts hip anatomical reconstruction and complications following THA. Consequently, the study aims to compare postoperative varus and valgus alignment of the femoral stem, FNOA, CCD, and SP between different groups.

The findings of the study reveal a moderate negative correlation between varus alignment of the femoral stem and FNOA (B=-0.359, CI=-0.422 to -0.297, $p<0.001$), while valgus alignment shows the opposite correlation. Furthermore, SP is negatively associated with FNOA. A more vertically oriented femoral neck osteotomy leads to a decrease in the amount of medial femoral neck remnant, which in turn leads to an increase in the SP. Our hypothesis is that an increase in SP caused by a more vertical osteotomy may lead to a weaker press-fit force in the medial cortex compared to the lateral cortex, making it more susceptible to varus alignment during prosthesis implantation.

Although implant malalignment is generally believed to be associated with load transfer and stress-shielding patterns, Hayashi et al[32] proposed that varus alignment is significantly negatively associated with bone mineral density (BMD) changes in Gruen area 1 and positively correlated with BMD changes in Gruen area 7. Vresilovic et al[33] demonstrated that for uncemented stems, varus misalignment of the implant was related to loosening. However, our study found no evidence of stem loosening or sinking in all three groups, which is consistent with the low loosening and high survival rate of the Tri-Lock stem reported in the literature.

Albers et al[14] reported a 99.2% survival rate for the Tri-Lock BPS stem with at least 4 years of follow-up. Ulivi et al[15] reported a 99% survival rate for the Tri-Lock BPS stem at a mean follow-up of 5.7 years, with only one patient undergoing revision surgery for dislocation. Additionally, Peng et al[34] reported no indication of stem loosening during the 2-year follow-up period. This high survival rate may be attributed to the rough porous coating[14]. The porous coating at the proximal end preserves mechanical integrity under shear, compression, torsion, and tension[35]. Furthermore, the shorter length and narrower distal end allow for greater proximal stress transfer and prevent distal stress overload[15]. As a result, we contend that FNOA is not a risk factor for loosening or sinking.

In addition, CCD was positively correlated with FNOA (B=0.696, CI=0.542 to 0.849, $p<0.001$). This occurs because the angle of the femoral stem neck axis is fixed, and the varus alignment of the femoral stem tends to increase as the osteotomy angle of the femoral neck decreases. This varus alignment of the femoral stem increases the angle between the femoral neck and the prosthesis neck, resulting in a decrease in CCD, which is also responsible for other clinical and radiological changes. Shoji et al[9] demonstrated that a low CCD and horizontal offset increase the range of motion in hip flexion and internal rotation, while a high CCD and vertical offset increase the range of motion in external rotation. They[9] also confirmed that the proper position of the implant could prevent the risk of THA dislocation. Our study found that the femoral offset decreased with increasing FNOA (B=-0.500, CI=-0.795 to -0.205, p=0.001). The restoration of femoral offset is closely related to the balance of the muscles around the hip and the recovery of hip function after surgery. Increased soft tissue tension and offset result in an increased range of motion, abductor strength, and stability[36-38]. Forde et al[39] reported that the restoration of femoral offset is an important factor in preventing dislocations after total hip arthroplasty. When the femoral offset was at least 3 mm greater than that of the contralateral hip, the risk of dislocation was lower (OR=0.94, CI 0.89-0.99, p=0.0192). Ogawa et al[40] reported that despite a small sample size and wide variability among the subjects, the unstable THA group showed a significantly smaller femoral offset on the affected side than on the healthy side. This is consistent with our results. In this study, we found that the risk of dislocation after THA increased with increasing FNOA (OR=0.892, CI=0.812 to 0.979, p=0.047). We attribute the dislocation to inadequate tension of the soft tissues surrounding the hip joint, which is caused by insufficient recovery of the femoral offset resulting from an inappropriate femoral neck osteotomy angle.

Mihalko et al[16] reported that following femoral neck resection at the level of +10 mm, the femoral offset of the Metha stem, CCD, and leg length discrepancy (LLD) increased by 4.7±3.4 mm, 5.6°±7.4°, and 9±3.1 mm, respectively, compared to their presurgical values. Furthermore, they[16] hypothesize that high-level femoral neck resection results in an increased femoral offset restoration and a reduction in CCD and LLD compared to low-level resection (0 mm). Floerkemeier et al[17] concluded that femoral neck osteotomy with a lower level of the Metha stem resulted in a more similar stress pattern to the nonimplanted state and that a lower level and more distal femoral neck resection reduced Metha stem femoral deviation and signs of varus dislocation. Our findings indicate that FNOA can significantly affect the final position of the femoral stem, as well as the CCD angle and femoral offset. An incorrect FNOA is not conducive to hip anatomical reconstruction. Therefore, we suggest that joint surgeons should meticulously select the appropriate FNOA during surgery (Figure 4).

In logistic regression analysis, we found that the risk of thigh pain increased with increasing FNOA (B=0.920, CI=0.851 to 0.995, p=0.037). Hayashi et al41 reported that thigh pain occurred in 16.7% of patients with short, tapered-wedge stems, attributing the risk factors to high activity levels, Dorr type C femoral bone shape, and stem tip-to-distal bone surface contact. Chen et al[42] suggested that poor implant alignment causing distal contact between the stem tip and the medial cortical bone increased local stress, contributing to the development of thigh pain. While our findings align with these studies[41,42], we believe that implant misalignment due to FNOA is not the sole factor influencing thigh pain risk. A meta-analysis[43] revealed that chronic postoperative pain after THA occurs in 7-23% of patients, indicating that persistent thigh pain following short-stem THA is a complex multidimensional pain experience rather than a simple transmission of nociception.

Previous studies[44,45] have shown that the Tri-Lock BPS stem has a lower incidence of periprosthetic fractures. Mlli et al[44] reported a 0.4% incidence of periprosthetic fractures during short stem surgery, while Nishioka et al[45] observed a 0.7% periprosthetic femoral fracture rate during a 2-year follow-up period, concluding that stem varus alignment was not associated with periprosthetic fractures. In our study, only 1 case of periprosthetic femoral fracture was identified in Group A, and regression analysis showed that FNOA was not a risk factor for periprosthetic fractures. Moreover, our study identified a potential concern: lower FNOA may result in an inadequate filling of the distal medullary cavity, consequently impacting the proper positioning of the femoral stem.

Limitations

It is essential to acknowledge the limitations of our retrospective analysis, including the relatively small sample size and potential bias in radiographic measurements due to the quadrilateral cross-section of the femoral stem. Additionally, our study only included a two-year follow-up, and a more extended period of observation is necessary to validate the correlation between the femoral neck osteotomy angle and both radiological and clinical outcomes. Finally, all measurements are based on 2D X-rays, and 3D measurements are subject to further certification.

Conclusions

The study demonstrates the relationship between FNOA and short-term radiological and clinical outcomes of patients after THA using a Tri-Lock femoral prosthesis. Inappropriate FNOA was significantly associated with failure of hip anatomical

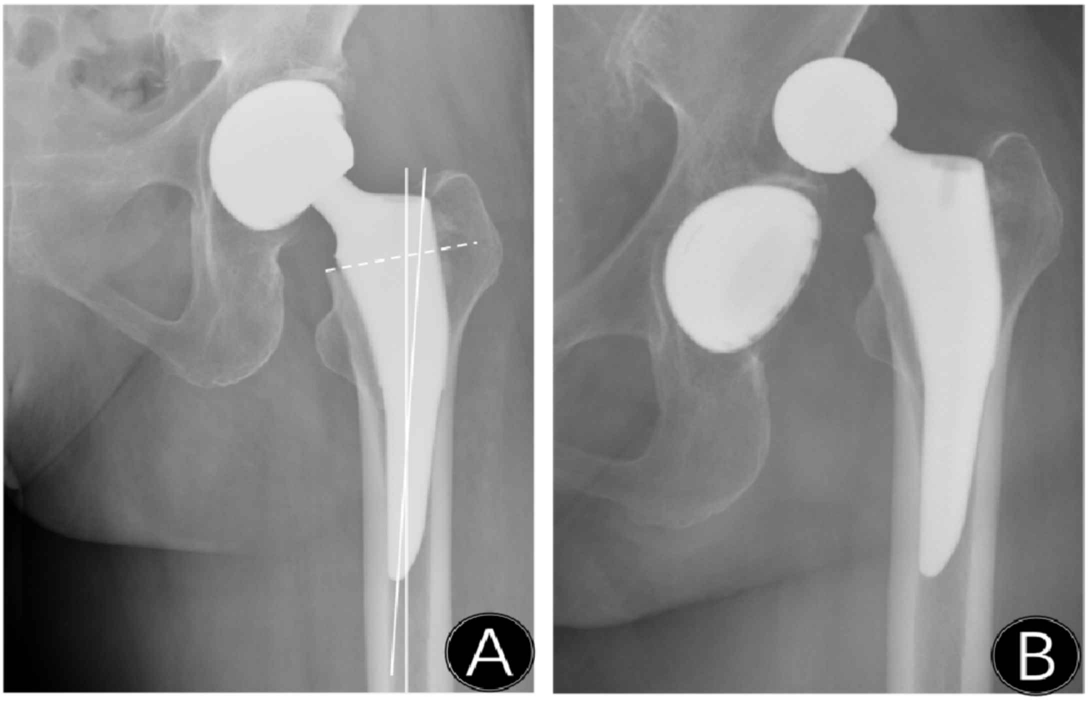

Figure 4. **A-B**, A 68-year-old female patient underwent total hip replacement for ONFH. This patient had an FNOA of 77.13° and had a postoperative dislocation. Our study shows that excessive FNOA increases the risk of postoperative dislocation.

reconstruction and a higher risk of complications. Therefore, clinical orthopedic surgeons should be more cautious in FNOA to improve the postoperative prognosis of patients.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Ethics Approval

The study was started prospectively after the approval of the Ethics Evaluation Committee of our faculty (188/04.06.2020).

Funding

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Informed Consent

Written informed consent was obtained from all participants.

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