

# Effect of placement of acetabular prosthesis on hip joint function after THA

Guang Fan, MS, Chuan Xiang, MD\*, Shuaijie Li, MS, Zhenzhong Gao, MS, Xiaohu Liu, MS, Dongdong He, MS, Jian Sun, MS

## Abstract

The good recovery of hip function after THA depends on reconstruction of acetabular prosthesis accurately. So we investigated the effect of acetabular prosthesis placement on hip joint function after THA and analyzed the clinical data of 432 patients with unilateral THA retrospectively. The patients were followed-up to evaluate the Harris score and hip range of motion (ROM). The hip ROM, the Harris score and the good rate of Harris score were compared between different groups. Comparison of the good rate of Harris score showed that 85%~100% group of the rotation center horizontal position ratio was higher than >100% group; 80%~120% group of the rotation center vertical position ratio was higher than >160% group; and the 90%~110% group and 110%~130% group of femoral offset ratio were higher than 90% and >130% groups. Comparison of Harris score showed that 85%~100% and 70%~85% groups of rotation center horizontal position ratio were higher than 70% and >100% groups; 80%~120% group of rotation center vertical position ratio was the highest; and 90%~110% group and 110%~130% groups of femoral offset ratio were higher than >130% and 90% groups. Comparison of hip ROM showed that 85%~100% and 70%~85% groups of the rotation center horizontal position ratio were higher than 70% and >100% groups; 80%~120% group of the rotation center vertical position ratio was the highest; and hip ROM from high to low are 90%~110%, 110%~130%, >130% and 90% groups of femoral offset ratio. These findings indicated that during the early follow-up period of THA, if the horizontal position of femoral head rotation center was reconstructed in 0.85 to 1 times of healthy side when compared with reconstruction >1 times of the healthy side and if the vertical position of femoral head rotation center was reconstructed in 0.8 to 1.2 times of the healthy side when compared with reconstruction in >1.6 times of the healthy side, better hip function recovery and optimal hip ROM were obtained. The optimal reconstruction range of femoral offset is 0.9 to 1.3 times of the healthy side.

**Abbreviations:** ROM = range of motion, THA = Total hip arthroplasty.

**Keywords:** acetabular prosthesis position, hip function, total hip arthroplasty

## 1. Introduction

With the increasing trend of social population aging, the incidence of hip disorders has been increasing with each year. Total hip arthroplasty (THA) is an effective treatment for end-stage disease of hip joint, and so it is favored by majority of orthopaedic surgeons. Although THA relieves hip pain and restores hip function, some patients still had unsatisfactory

results after surgery.<sup>[1-3]</sup> Few studies reported that improper placement of acetabular prosthesis is one of the main factors that lead to the poor recovery of hip function after THA.<sup>[4-6]</sup> In this study, patients who underwent unilateral THA were followed-up to observe the effect of acetabular prosthesis placement on hip function recovery. Hence, this study explored a reasonable range of the position parameters of acetabular prosthesis as a reference for the placement orientation of acetabular prosthesis in THA.

## 2. Material and methods

### 2.1. Study subjects

Clinical data of 432 patients who underwent unilateral THA were retrospectively analyzed. Of the 432 patients, 192 are male and 240 are female, with an age range of 45 to 79 years old and mean age of 59.5 years.

### 2.2. Inclusion criteria

- (1) patients who underwent THA for the first time due to unilateral hip diseases such as femoral neck fracture, femoral head necrosis and hip osteoarthritis and the contralateral hip joint was normal;
- (2) patients with at least half a year after THA;
- (3) a standard pelvic positive radiograph was obtained after surgery.

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GF and CX contributed equally to this work.

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Department of Orthopedics, Second Hospital of Shanxi Medical University, Taiyuan, China.

\* Correspondence: Chuan Xiang, Department of Orthopedics, Second Hospital of Shanxi Medical University, Taiyuan, China (e-mail: chuanxiang@sxmu.edu.cn).

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**2.3. Exclusion criteria**

- (1) patients with incomplete clinical data and follow-up;
- (2) patients with congenital or developmental hip disease or hip revision surgery;
- (3) patients with severe cardiopulmonary and cerebrovascular diseases before or after surgery.

**2.4. Method**

- (1) Measurement of the position of the acetabular prosthesis
 

The position parameters in this study included: horizontal position of the femoral head rotation center, vertical position of the femoral head rotation center and femoral offset. The standard pelvic positive radiographs after THA were taken and the position parameters of acetabular prosthesis were measured by SIEMENS imaging software, which were as follows:

  - (a) Horizontal distance and vertical distance of the rotation center: A circle was drawn coinciding with the edge of the femoral head prosthesis of the operation side. The software automatically generates the circumference length and then finds the diameter. A horizontal diameter intersecting with a vertical diameter at the center O was drawn, which is the rotation center of the femoral head of the operation side. The same method can be used to determine the center of rotation of the healthy femoral head O1. Through the lowest point M of the teardrop on the operation side, a horizontal line intersecting with a vertical line perpendicularly was drawn. The vertical distance from the two lines to O was then measured. OD is the horizontal distance of the rotation center of the operation side and OC is the vertical distance of the rotation center of the operation side. The same method can be used to measure the horizontal distance and the vertical distance of the rotation center of the healthy side, as shown in Figure 1.

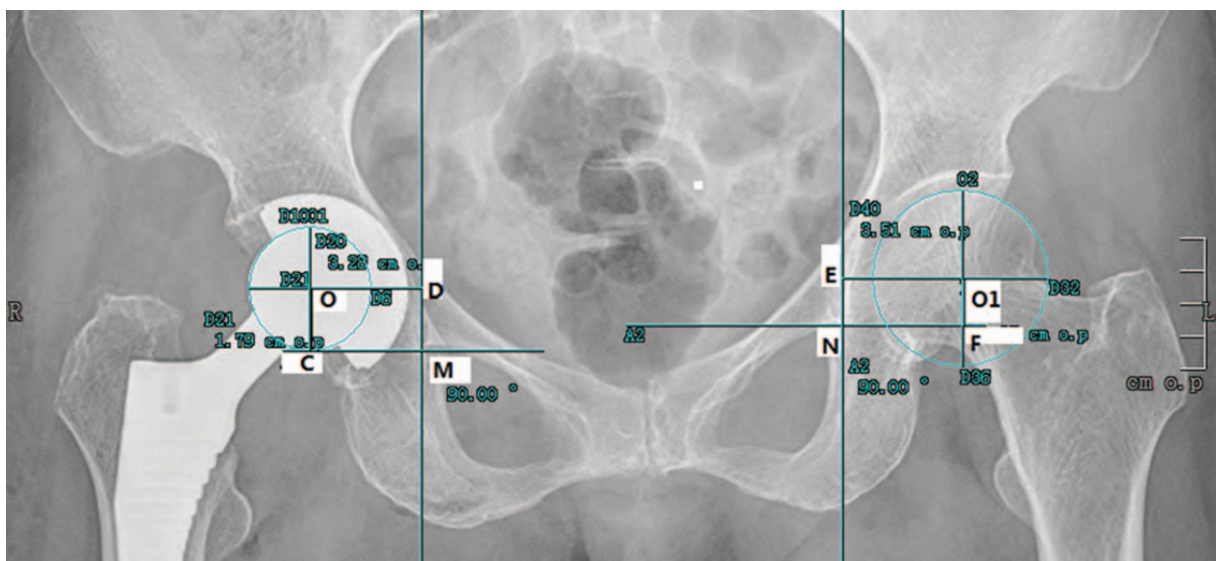
- (b) Femoral offset: the vertical distance from the center of rotation of the femoral head to the longitudinal axis of the femur (the method for determining the center of rotation of the femoral head is described above), as shown in Figure 2.
- (2) Grouping of acetabular prosthesis position parameters (Note: Both groups 2 and 3 did not contain the minimum value) (Table 1)
- (3) Ethical approval of the study was not necessary, because the study only retrospectively followed the patients with unilateral THA for postoperative hip ROM and Harris score. Due to retrospective nature of the study, the study does not involve patient consent and informed consent was not given.

**2.5. Observation items and evaluation indicators**

The sum of flexion angle, extension, abduction, adduction, internal and external rotation was measured, which was hip range of motion (ROM) after THA. The ratio (the operation side/the healthy side) of horizontal position and vertical position of the rotation center of the femoral head, and the femoral offset were calculated. The postoperative appointment review and telephone follow-up were performed after surgery. The follow-up period was 0.5 years to 3.5 years. Hip function evaluation after THA was performed using a modified Harris function score. The hip modified Harris function score was 100 points (where  $\geq 80$  points is good and  $< 80$  points is not good). Then the good rate of each group of acetabular prosthesis position parameters was calculated.

**2.6. Statistical methods**

Data were processed using SPSS 22.0 software. The measurement data were expressed by mean  $\pm$  standard deviation, and the count data was expressed by rate. For measurement data, the normality test was first carried out. If the normal distribution was met, then the paired sample *t* test was used for comparison between the 2 samples, and the variance analysis was used for comparison



**Figure 1.** Schematic diagram of the horizontal distance and the vertical distance of the rotating center.

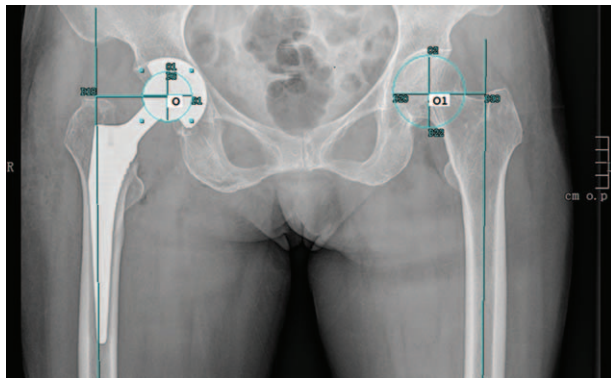


Figure 2. Schematic diagram of femoral offset measurement.

between the groups. If normal distribution was not met, then Wilcoxon signed rank test was used to compare the paired samples. The Kruskal-Wallis H test was used to compare multiple groups. For the count data, the comparison between multiple groups was performed by  $\chi^2$  test of line  $\times$  list data, and the test level was  $\alpha = 0.05$ .

### 3. Results

The mean follow-up time was  $(23.1 \pm 7.3)$  months. The average Harris score during the last follow-up visit was  $(90.6 \pm 6.4)$  points and the good rate of Harris score was 89.8%. A total of 477 patients who underwent THA between April 2015 and April 2018 were enrolled in this study according to the eligibility criteria. In 7 patients with dislocation after operation, 3 patients had due to inappropriate physical activity and 4 patients had due to weak muscle strength around the hip joint. Thirty-eight patients were lost to follow-up during the follow-up period. All 432 patients were followed-up for a complete follow-up examination.

#### 3.1. Acetabular prosthesis position parameters

##### (1) Horizontal position of rotation center

The horizontal position of femoral head rotation center of surgical side and healthy side were compared by paired sample *t* test, and the results showed statistically significant differences ( $P < .05$ ). (Table 2)

##### (2) Vertical position of rotation center

The vertical position of femoral head rotation center of surgical side and healthy side were compared by paired sample *t* test, and the results showed statistically significant differences ( $P < .05$ ). (Table 3)

**Table 1**  
Grouping range of position parameters of acetabular prosthesis.

Prosthesis position parameter	A group	B group	C group	D group
Rotation center horizontal position ratio (%)	$\leq 70$	70~85	85~100	$> 100$
Prosthesis position parameter	E group	F group	G group	H group
Rotation center vertical position ratio (%)	$\leq 80$	80~120	120~160	$> 160$
Prosthesis position parameter	I group	J group	K group	L group
Femoral offset ratio (%)	$\leq 90$	90~110	110~130	$> 130$

**Table 2**  
Comparison of the horizontal position of the rotation center of the femoral head between the surgical side and the healthy side.

Item	n	$\bar{x} \pm s$	t	P
Surgical side	432	$3.36 \pm 0.43$	-20.170	.000
Healthy side	432	$3.89 \pm 0.39$		

**Table 3**  
Comparison of the vertical position of the rotation center of the femoral head between the surgical side and the healthy side.

Item	n	$\bar{x} \pm s$	t	P
Surgical side	432	$2.12 \pm 0.44$	14.803	.000
Healthy side	432	$1.77 \pm 0.30$		

##### (3) Femoral offset

The femoral offset of surgical side and healthy side were compared by paired sample *t* test, and the results showed statistically significant differences ( $P < .05$ ). (Table 4)

The relationship between the position parameters of acetabular prosthesis and good rate of Harris score

##### (1) Horizontal position ratio of rotation center and good rate of Harris score

The comparison of good rate of Harris scores among the 4 groups of the horizontal position ratio of the rotation center was performed by  $\chi^2$  test. The good rate of Harris scores of the 4 groups showed statistically significant differences ( $P < .05$ ). The  $\chi^2$  division method was used to compare the good rate of Harris score between any 2 groups among the 4 groups. The results showed that the good rate of Harris scores of 85% to 100% group was higher than  $> 100\%$  group, and the difference was statistically significant ( $P < .007$ ). (Table 5)

##### (2) Vertical position ratio of rotation center and good rate of Harris score

The comparison of the good rate of Harris scores among the 4 groups of vertical position ratio of the rotation center was performed by  $\chi^2$  test. The good rate of Harris scores of the 4 groups showed statistically significant differences ( $P < .05$ ). The  $\chi^2$  division method was used to compare the good rate of Harris score between any two groups among the 4 groups. The results showed that the good rate of Harris score of the 80% to 120% group was higher than that of  $> 160\%$  group, and the difference was statistically significant ( $< .007$ ). (Table 6)

##### (3) Femoral offset ratio and good rate of Harris score

The comparison of the good rate of Harris scores among the 4 groups of femoral offset ratio was performed by  $\chi^2$  test. The good rate of Harris scores of the 4 groups showed statistically significant differences ( $P < .05$ ). The  $\chi^2$  division method was used to compare the good rate of Harris score

**Table 4**  
Comparison of the femoral offset between the surgical side and the healthy side.

Item	n	$\bar{x} \pm s$	t	P
Surgical side	432	$4.18 \pm 0.46$	9.495	.000
Healthy side	432	$3.90 \pm 0.44$		

**Table 5**  
**Comparison of good rate of Harris scores among the 4 groups of the horizontal position ratio.**

Horizontal position ratio	Good number of cases (good rate)	Non-good number of case (non-good rate)	total	$\chi^2$	P
A group	75 (88.2%)	10 (11.8%)	85	11.040	.012
B group	133 (91.7%)	12 (8.3%)	145		
C group	125 (94.0%)	8 (6.0%)	133		
D group	55 (79.7%)	14 (20.3%)	69		
Total	388 (89.8%)	44 (10.2%)	432		

**Table 6**  
**Comparison of the good rate of Harris scores among the 4 groups of vertical position ratio.**

Vertical position ratio	Good number of cases (good rate)	Non-good number of case (non-good rate)	total	$\chi^2$	P
E group	67 (88.2%)	9 (11.8%)	76	10.686	.014
F group	169 (93.9%)	11 (6.1%)	180		
G group	101 (90.2%)	11 (9.8%)	112		
H group	51 (79.7%)	13 (20.3%)	64		
Total	388 (89.8%)	44 (10.2%)	432		

between any two groups among the 4 groups. The results showed that the good rate of Harris scores of the 90% to 110% group and the 110% to 130% group were higher than  $\leq 90\%$  and  $>130\%$  groups, showing statistically significant differences ( $P < .007$ ). (Table 7)

**3.2. Relationship between position parameters of acetabular prosthesis and Harris score**

- (1) Horizontal position ratio of rotation center and Harris score  
 The comparison of the Harris scores among the 4 groups of horizontal position ratio was performed by Kruskal-Wallis H test. The results showed that the Harris scores of the 4 groups were not the same. The Bonferroni correction test was used to compare the Harris scores between any 2 groups among the 4 groups. The results showed that the Harris scores of 70% to 85% group and 85% to 100% group were higher than that of  $\leq 70\%$  group and  $>100\%$  group, showing statistically significant differences ( $P < .05$ ). (Table 8).
- (2) Vertical position ratio of rotation center and Harris score  
 The comparison of the Harris scores among the 4 groups of vertical position ratio was performed by Kruskal-Wallis H test. The results showed that the Harris scores of the 4 groups were not the same. The Bonferroni correction test was used to compare the Harris scores between any two groups among the 4 groups. The results showed that the Harris scores of 80% to 120% group were the highest and the Harris scores of 120% to 160% group was higher than that of  $>160\%$  group,

showing statistically significant differences ( $P < .05$ ). (Table 9)

- (3) Femoral offset ratio and Harris scores  
 The comparison of the Harris scores among the 4 groups of femoral offset ratio was performed by Kruskal-Wallis H test. The results showed that the Harris scores of the 4 groups were not the same ( $P < .05$ ). The Bonferroni correction test was performed to compare the Harris scores between any 2 groups among the 4 groups. The results showed that the Harris scores of 90% to 110% group and 110% to 130% group were higher than that of  $>130\%$  group and  $\leq 90\%$  group, showing statistically significant difference ( $P < .05$ ). (Table 10)

**3.3. Relationship between position parameters of acetabular prosthesis and hip ROM**

- (1) Horizontal position ratio of rotation center and hip ROM  
 The comparison of hip ROM among the 4 groups of horizontal position ratio was performed by Kruskal-Wallis H test. The results showed that hip ROM of the 4 groups were not the same. The Bonferroni correction test was performed to compare hip ROM between any 2 groups among the 4 groups. The results showed that the hip ROM of 85% to 100% group and 70% to 85% group were higher than that of  $\leq 70\%$  group and  $>100\%$  group, showing statistically significant differences ( $P < .05$ ). (Table 11)
- (2) Vertical position ratio of rotation center and hip ROM

**Table 7**  
**Comparison of the good rate of Harris scores among the 4 groups of femoral offset ratio.**

Femoral offset ratio	Good number of cases (good rate)	Non-good number of case (non-good rate)	total	$\chi^2$	P
I group	52 (78.8%)	14 (21.2%)	66	26.605	.000
J group	171 (95.5%)	8 (4.5%)	179		
K group	121 (93.1%)	9 (6.9%)	130		
L group	44 (77.2%)	13 (22.8%)	57		
Total	388 (89.8%)	44 (10.2%)	432		



**Table 8**  
Comparison of the Harris scores among the 4 groups of horizontal position ratio.

Horizontal position ratio	$\bar{x} \pm s$	t	P
A group	88.1 ± 5.6	85	.000
B group	91.8 ± 6.1	145	
C group	93.2 ± 5.7	133	
D group	86.3 ± 6.3	69	

The comparison of hip ROM among the 4 groups of vertical position ratio was performed by Kruskal-Wallis H test. The results showed that the hip ROM of the 4 groups were not the same. The Bonferroni correction test was performed to compare hip ROM between any 2 groups among the 4 groups. The results showed that the hip ROM of 80% to 120% group was the highest and the hip ROM of 120% to 160% group were higher than that of >160% group, showing statistically significant differences ( $P < .05$ ). (Table 12)

(3) Femoral offset ratio and hip ROM

The comparison of hip ROM among the 4 groups of femoral offset ratio was performed by Kruskal-Wallis H test. The results showed that the hip ROM of the 4 groups were not the same. The Bonferroni correction test was performed to compare hip ROM between any 2 groups among the 4 groups. The results showed that the hip ROM of each group of hip offset ratio from high to low were 90% to 110% group, 110% to 130% group, >130% group and ≤90% group, showing statistically significant differences ( $P < .05$ ). (Table 13)

**4. Discussion**

Among several factors that affect the hip function recovery after THA, the success rate of acetabular prosthesis placement is considered to be the most important factor.

Proper reconstruction of the hip rotation center plays an extremely important role in the recovery of joint function after THA.<sup>[7-9]</sup> Improper reconstruction of hip rotation center directly leads to limited hip ROM, unequal length of the lower limbs, dislocation, loosening of acetabular prosthesis and osteolysis. Anatomical reconstruction of hip rotation center in situ remains to be an ideal reconstruction site that has been widely recognized.<sup>[10-12]</sup> With the popularity of uncemented prostheses, the performers frequently undergo grinding off the partial acetabular bone during surgery in order to achieve good compression, and so the hip rotation center inevitably shifts inwards and upwards. Consequently, the upward movement of the greater trochanter of the femur can lead to poor stretching of

**Table 9**  
Comparison of the Harris scores among the 4 groups of vertical position ratio.

Vertical position ratio	$\bar{x} \pm s$	t	P
E group	89.3 ± 6.4	76	.000
F group	92.5 ± 5.8	180	
G group	90.6 ± 6.3	112	
H group	86.9 ± 6.6	64	

**Table 10**  
Comparison of the Harris scores among the 4 groups of femoral offset ratio.

Femoral offset ratio	$\bar{x} \pm s$	t	P
I group	87.0 ± 6.2	66	.000
J group	92.7 ± 5.5	179	
K group	91.6 ± 6.0	130	
L group	86.1 ± 6.4	57	

the gluteus medius attached to it, affecting the abduction and rotation of the hip joint.<sup>[13-15]</sup> Weight gravity and abductor muscles work together on the hip joint, playing an important role in body balance maintenance. Horizontal inward displacement of rotation center will appropriately increase the arm force of the abductor muscles which is surely at a disadvantage, reducing the load of the abductor muscles and the stress conduction of the hip joint surface.<sup>[16]</sup> Conversely, the horizontal outward movement of the rotation center shortened the arm force of the abductor muscle, causing fatigue and damage. In the literature reports,<sup>[17,18]</sup> postoperative effect of reconstruction of femoral head rotation center in true acetabular or slight inward horizontal shifting position was superior to outward horizontal shifting position. Internal movement of the cup can increase the contact area between the acetabular prosthesis and the acetabular bone, improving the coverage of femoral head by acetabular prosthesis. In the meantime, it can reduce the arm force of the body gravity, resulting in increasing the forces on the hip. Outward displacement of the rotation center causes non-physiological traction of abductor muscle, which may lead to abnormal hip pain and femoral trochanter bursitis. The results of this study suggested the good rate of Harris score of 85% to 100% group of horizontal position ratio was higher than that of >100% group. In the hip ROM and Harris score, 85% to 100% group and 70% to 85% group of horizontal position ratio were higher than ≤70% group and >100% group. This was consistent with the studies discussed above.

The results of this study also showed that the good rate of Harris score of 80% to 120% group of vertical position ratio was higher than that of >160% group. In the hip ROM and Harris score, 80% to 120% group of the vertical position ratio was the highest and 120% to 160% group was higher than >160% group. This indicated that the postoperative effect of reconstruction of the vertical position of femoral head rotation center in the true orthotopic acetabular or slight upward vertical shifting position was superior to that of reconstructing more than 1.6 times of the healthy side.

Reconstruction of femoral offset is another important factor in the recovery of hip function after THA. Previously, it has been reported<sup>[19-21]</sup> that improper reconstruction of femoral offset

**Table 11**  
Comparison of hip ROM among the 4 groups of horizontal position ratio.

Horizontal position ratio	$\bar{x} \pm s$	t	P
A group	178.2 ± 9.6	85	.000
B group	189.6 ± 8.6	145	
C group	192.4 ± 10.0	133	
D group	174.2 ± 9.8	69	

**Table 12**  
Comparison of hip ROM among the 4 groups of vertical position ratio.

Vertical position ratio	$\bar{x} \pm s$	t	P
E group	182.0 ± 14.2	76	.000
F group	189.5 ± 11.4	180	
G group	185.5 ± 10.2	112	
H group	180.1 ± 8.4	64	

affects the abduction function of the hip joint, increasing the risk of collision between the femoral neck and the cup. Then the stress between femoral head and cup increases abnormally and the wear and tear of polyethylene liner is aggravated, which eventually leads to osteolysis, loosening and dislocating the prosthesis. If the femoral offset is too small, the femoral trochanter easily impacts the edge of the acetabular cup, reducing the range of adduction and internal rotation.<sup>[22]</sup> At the same time, the femoral offset is insufficiently reconstructed, bringing about the gluteus medius contracture and decreasing the arm force of the abductor muscles. When the abductor muscle strength is not balanced with the body's gravity, the hip joint cannot maintain the body balance. Hence, there appears a limp and instability in standing and walking.<sup>[23,24]</sup> If the femoral offset is too large, then the affected limb tends to adduct as a whole. In addition, there is an abnormal stress concentration and severe stress shielding in the medial cortical and femoral prosthesis of the proximal femur, which in turn leads to fatigue fracture of prosthesis, dislocation, and fracture around the prosthesis. According to the previous literature,<sup>[25]</sup> the reasonable femoral offset reconstruction range is within  $\pm 4$  mm of the contralateral femoral offset. The results of this study showed that the femoral offset of the operation side was increased by about 2.8 mm when compared with that of the healthy side, conforming to the above safety scope. Shi Zhencai<sup>[26]</sup> found that as the femoral offset increases, the arm force of the hip abductor muscle increases and the strength of the abductor muscle also increases. There is a positive correlation between the above three factors. The results of this study showed that in all the three aspects, that is, the good rate of Harris score, the hip ROM and the Harris score, 90% to 110% group and 110% to 130% group of the femoral offset ratio were higher than  $\leq 90\%$  group and  $> 130\%$  group. This indicated that anatomical reconstruction or appropriate increase of femoral offset can achieve better clinical results than excessive reconstruction or insufficient reconstruction of femoral offset. The reason for this may also be related to the pain caused by excessive hip muscle tension, the swelling appearance of the hip and the excessive limb length due to excessive offset. In addition, this study showed that the postoperative effect of reconstructing femoral head rotation center in the true orthotopic acetabular or slightly inward horizontal shifting position was better. Therefore, it is reasonable

**Table 13**  
Comparison of hip ROM among the 4 groups of femoral offset ratio.

Femoral offset ratio	$\bar{x} \pm s$	t	P
I group	173.7 ± 8.6	76	.000
J group	191.5 ± 11.1	180	
K group	187.3 ± 9.1	112	
L group	178.2 ± 8.3	64	

to increase the partial femur offset to offset the partial internal movement of the femoral head rotation center in order to better maintain the strength of the abductor muscle.<sup>[27,28]</sup>

In summary, the good recovery of hip function after THA depends on reconstruction of acetabular prosthesis accurately. By doing so, we can reduce the prosthesis impact and joint dislocation after THA, minimizing the wear of the friction interface, prolonging the service life of the artificial hip joint and obtaining satisfactory hip ROM. Therefore, the results of this study assist in guiding the placement of acetabular and femoral prostheses during THA and the recovery of postoperative hip function.

### Author contributions

**Conceptualization:** Guang Fan, Chuan Xiang.

**Data curation:** Guang Fan, Chuan Xiang.

**Formal analysis:** Shuaijie Li, Zhenzhong Gao.

**Writing – original draft:** Zhenzhong Gao, Xiaohu Liu, Jian Sun.

**Writing – review & editing:** Dongdong He.

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