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Postoperative Valgus Deformity and Progression of Ostheoarthritis in Non-Displaced Femoral Neck Fractures

Hyungtae Kim, MD, Ji Su Kim, MD, Yerl Bo Sung, MD, PhD
Department of Orthopedic Surgery, Inje University Sanggye Paik Hospital, Inje University College of Medicine, Seoul, Korea

Purpose: Nondisplaced femoral neck fractures have traditionally been treated with in situ fixation. However, poor surgical and clinical outcomes have been reported for fractures with valgus deformity >15˚, and the reduction of valgus impaction has recently been emphasized. In addition, early degenerative osteoarthritis can be caused by cam-type femoroacetabular impingement after healing of femoral neck fractures. This study was designed with the objective of confirming the difference in progression of radiographic osteoarthritis according to the severity of the valgus deformity.
Materials and Methods: Patients who underwent internal fixation using multiple cannulateld screws for management of nondisplaced femoral neck fractures were divided into two groups: high valgus group (postoperative valgus angle ≥15˚) and low valgus group (postoperative valgus angle <15˚). Evaluation of demographic data and changes in the joint space width from the immediate postoperative period to the latest follow-up was performed.
Results: A significant decrease in joint space width in both hip joints was observed in the high valgus group when compared with the low valgus group, including cases with an initial valgus angle less than 15˚ and those corrected to less than 15˚ of valgus by reduction. No complications requiring surgical treatment were observed in either group; however, two cases of avascular necrosis, one in each group, which developed in the low valgus group after reduction of the fracture, were followed for observation.
Conclusion: Performing in situ fixation in cases involving a valgus deformity ≥15˚ in non-displaced femoral neck fractures may cause accelerated narrowing of the hip joint space.

Key Words: Femur neck, Femoral neck fractures, Internal fracture fixation, Osteoarthritis of hip

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Address reprint request to
Yerl Bo Sung, MD, PhD
(https://orcid.org/0000-0002-6628-0530)
Department of Orthopedic Surgery, Inje University Sanggye Paik Hospital, 1342 Dongil-ro, Nowon-gu, Seoul 01757, Korea
TEL: +82-2-950-1032
E-mail: S1134@paik.ac.kr

INTRODUCTION

In situ fixation has traditionally been regarded as the treatment of choice for nondisplaced femoral fractures of the neck. Reduction of the fracture in cases of valgus impaction has been contraindicated, particularly in valgus-impacted femoral fractures of the neck (VI-FNF), due to destabilization of the fracture configuration[1]. However, several authors have recently reported poor outcomes for patients with fractures having more than 15˚ of valgus deformity or posterior tilt larger than 15 to 20 who underwent treatment with *in situ* fixation[2-4]. Careful reduction of the fracture has been recommended by some surgeons, including Steinberg et al.[5]. Park et al.[6], who compared shortening of the femoral neck, clinical outcomes, and Harris hip score between patients treated with *in situ* fixation and those who had undergone closed reduction and internal fixation in severe VI-FNF, reported that the reduction group showed better overall outcomes.

Meanwhile, retrotorsion after a femoral neck fracture, a common occurrence in VI-FNF, has been reported to cause anterior or anterolateral femoro-acetabular impingement (FAI)[7]. Considering the well-known association between FAI and early degenerative arthritis[8], it can be reasonably presumed that the resultant cam-type FAI after VI-FNF may result in a poor functional prognosis as well as early onset arthritis. To the best of our knowledge, there is no report in the literature providing radiographic evidence of arthritis in cases of severe VI-FNF treated with *in situ* fixation.

Therefore, our objective was to examine the influence of the degree of postoperative valgus deformity on the progression of early osteoarthritis in patients treated with multiple screws for non-displaced femoral fractures of the neck after follow-up of more than one year.

MATERIALS AND METHODS

1. Study Population

This study was approved by the Institutional Review Board (IRB) of Inje University Sanggye Paik Hospital (IRB No. 2022-02-016), and the written informed consent was waived by the IRB due to the retrospective nature of the study. From January 2010 to December 2019, 119 patients aged under 70 with femoral fractures of the neck underwent treatment with internal fixation using three cannulated screws at our hospital. Ninety-one patients with anteroposterior (AP) plain radiographs of both hips that were available for review at the time of surgery and at least one year after surgery were selected. A review of medical records and radiographs was conducted for exclusion of patients with displaced fractures (Garden III, IV), neglected fractures (time interval from injury to surgery >3 weeks), or concomitant fractures in the ipsilateral leg, past medical histories that might impede or cause altering of normal ambulation and weight-bearing, such as cerebral palsy, lower extremity amputation, and fracture fixation or arthroplasties on the contralateral side. After completion of the exclusion process, a total of 38 patients had undergone multiple screw fixation for management of a non-displaced femoral fracture of the neck and were followed up for more than one year.

2. Grouping

Enrolled patients were classified according to two groups based on the femoral neck valgus angle measured on the immediate postoperative radiograph: the high valgus group with a valgus deformity angle of more than 15° and the low valgus group, with deformity of less than 15°. Patients with an initial valgus angle greater than 15° but corrected below 15° after reduction of the fracture during surgery were assigned to the low valgus group for analysis.

3. Surgical Technique

All patients were placed on a fracture table and fixation was performed using three 6.5 mm cannulated screws (Zimmer) within 24 hours after the injury in principle; the procedures were performed by an experienced senior surgeon. All patients were instructed to maintain non-weight-bearing for six weeks after surgery (Fig. 1).

Fig. 1. An example of successful internal fixation of valgus-impacted femoral neck fracture. Three 6.5 mm-diameter cannulated screws were percutaneously inserted, parallel to each other. The inferior screw was inserted first through the calcar femorale, followed by the insertion of the postero-superior and antero-superior screws.

4. Data Collection

1) Demographic data

Patients' demographic data, including age, sex, direction of the operated hip, follow-up duration, body mass index (BMI), and bone mineral density (BMD), were collected for comparison. A comparison of surgical outcomes and incidences of adverse events, including osteonecrosis of the femoral head (ONFH), reoperation, and screw sliding, between the two groups was also performed.

2) Radiographic measurements

AP and cross-table radiographs of the lateral hip were obtained according to the institutional protocols. Radiographic measurements were performed by one orthopedic surgery fellow and a senior orthopedic surgery resident. Patients' personal information was anonymized, and the images were presented in a random order for the measurements.

3) Independent factors

For accurate evaluation of the degree of valgus deformity in femoral fractures of the neck, the valgus angle was defined as the difference between the angle formed by the longitudinal axis of the femoral shaft and a line connecting the center of the femoral head and the deepest portion of the fovea capitis of both hips in the immediate postoperative AP image, as proposed by Moon et al.[9] (Fig. 2). Valgus deformity, where the angle was larger on the operated side than on the contralateral side, was defined as a positive value, and varus deformity, where the angle was smaller on the operated side than on the contralateral side, was defined as a negative value.

Using the method proposed by Palm et al.[3], the posterior tilt was defined as the angle between the mid-collum line crossing the center of three different points on the femoral neck and the line drawn from the center of the best-fit caput circle to the intersection with the mid-collum line on immediate postoperative lateral pelvic radiographs (Fig. 3).

The lateral center edge angle (LCEA) was defined as the angle between the vertical axis drawn over the center of the femoral head and the line from the center of the head to the most lateral point of the acetabular roof, according to the method described by Wiberg[10] (Fig. 4).

The postoperative alpha angle was determined in a cross-table lateral image using the method reported by Nötzli et

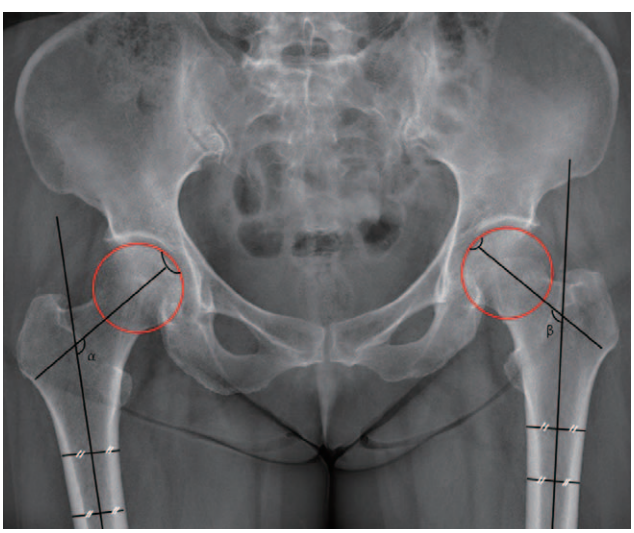

Fig. 2. Measurement of the valgus angle. The angle between the femoral shaft axis and the line connecting femoral head to the deepest point of the fovea capitis femoris is defined as the valgus angle. α angle is measured for the fractured side and β angle for the opposite side. The extent of valgus deformity is calculated as (β-α). The figure is shown with the preoperative image for better visualization.

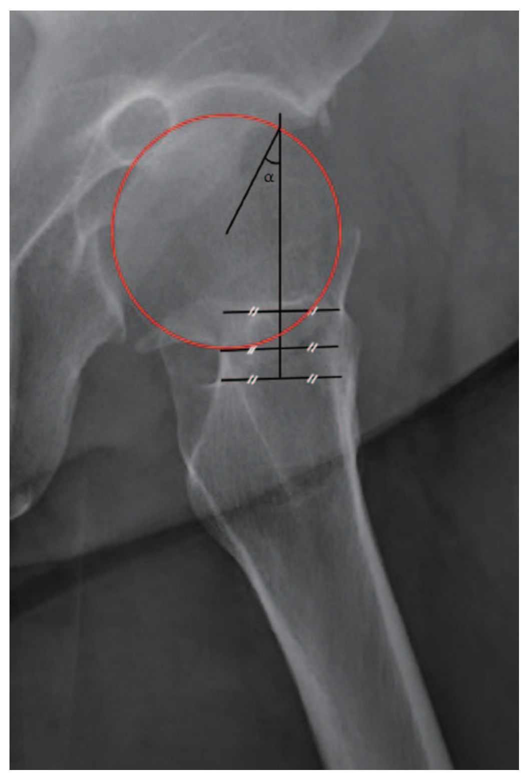

Fig. 3. Measurement of the posterior tilt. The mid-collum line is drawn by connecting the midpoints of three parallel lines along the femoral neck. A best-fitted circle is then drawn over the femoral head, and a line is drawn from the center of the circle to the intersecting point between the circle and the mid-collum line in order to measure the posterior tilt angle. The figure is shown with the preoperative image for better visualization.

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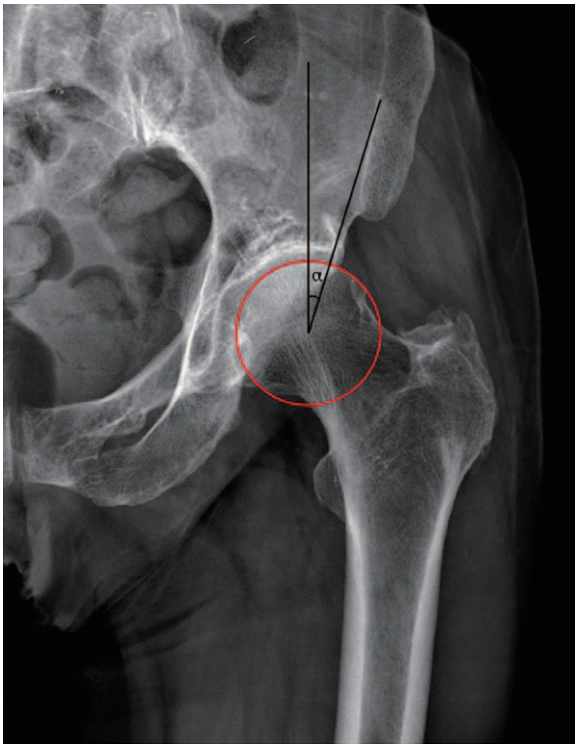

Fig. 4. Measurement of lateral center edge angle. The lateral center edge angle was determined using two lines: one running from the center of the femoral head parallel to the long axis of the body, and the other passing through the most lateral point of the acetabular sourcil.

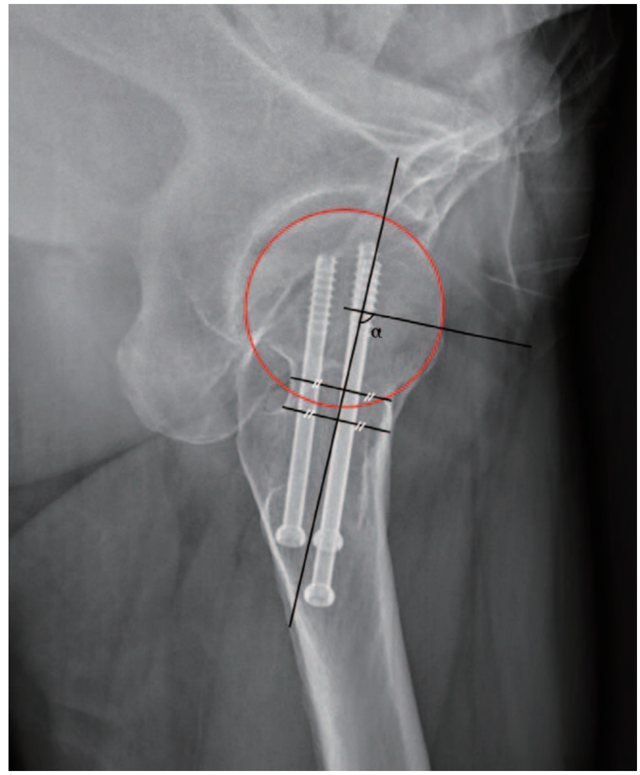

Fig. 5. Measurement of alpha angle. The alpha angle was defined as the angle between the mid-collum line and the line drawn from the center of the femoral head to the point where the contour of the femoral head exits the best-fitting circle around it.

al.[11] with minor modifications considering the alteration of geometry due to the fracture itself. The first arm of the alpha angle, originally described as the line drawn between the center of the femoral head and the midpoint of the narrowest portion of the femoral neck, is defined as the mid-collum line not including the center of the femoral head, as it is displaced by the injury. The second line is drawn from the center of the head to the point where it loses its sphericity (Fig. 5).

4) Dependent factors

Measurement of joint space width (JSW) of both hip joints on bilateral AP images taken immediately after surgery and at the final clinical visit was performed using the measurement function of the institution's picture archiving and communication system, INFINITT M6 (INFINITT Healthcare). For evaluation of hip joint arthritis, measurement of the JSW of the operated and contralateral hips on bilateral AP pelvic radiographs was performed using the imaging system's distance measurement tool (Fig. 6). JSW was defined as the minimum distance between the weight-bearing portion of the acetabulum (sourcil) and the femoral head. To

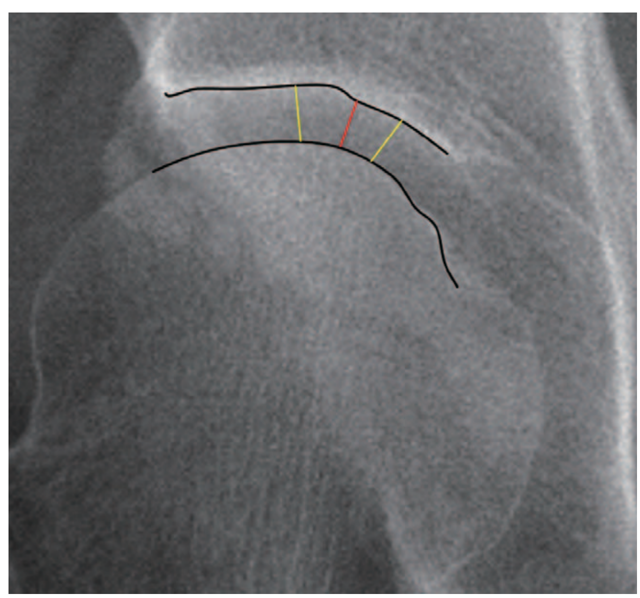

Fig. 6. Measurement of the joint space width. The fine lines demarcating the acetabular sourcil and the cortical bone of the femoral head are drawn. The narrowest distance between these two lines was measured and marked as a red line.

ensure accurate measurements, the measured values for JSW were adjusted, considering that the actual diameter of the cannulated screws was 6.5 mm.

5. Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics software (ver. 26; IBM). Analysis of differences in age, sex, BMI, and BMD between the high valgus (≥15°) and low valgus (<15°) groups was performed using chi-square tests and the Mann–Whitney U test. The rates of fixation failure, ONFH, and reoperation were compared between the two groups. Narrowing of the JSW of the operated hip in the high-valgus group was compared with that in the low-valgus group. A comparison of contralateral hips between the two groups was also performed using the Mann–Whitney U test. Calculation of Spearman's rho correlation coefficient for the postoperative valgus angle, posterior tilt, and narrowing of the JSW in both hips was performed. $P<0.05$ was considered statistically significant.

RESULTS

In principle, surgery was performed within 24 hours of the injury, with the exception of nine patients who presented to the hospital 24 hours after the injury but had undergone surgical fixation within 24 hours from the time of the visit. In the delayed group, the time from injury to surgery was within 48 hours for four patients, less than 72 hours for three patients, and two patients received treatment within two weeks.

Of the 38 patients with non-displaced femoral fractures of the neck, 10 patients were assigned to the high valgus group and 28 patients to the low valgus group. The mean postoperative valgus angle was 23.5° and 5.0° in each group, ranging from 15.5° to 37.0° in the high valgus group and from –3.5° to 11.7° in the low valgus group (Table 1). There was no significant difference in sex, age, direction of surgery, follow-up period, BMI, and BMD between the two groups (Table 2). The mean follow-up period for the entire study population was 41 months, ranging from 12-131 months. There were no cases of fixation failure, such as cannulated screw sliding or protrusion, in either group. There were two cases of ONFH after intraoperative manual reduction in the low valgus group; however, both cases were Ficat stage 2 or below without femoral head collapse or serious symptoms; hence, management consisted of observation only without joint replacement in both cases. Reoperation was not required for any of the patients in either group.

The mean postoperative posterior tilt angles in the cross-table lateral images were 4.6° and 4.4° in each group, respec-

Table 1. Comparison of VA and JSW

	Postoperative VA		*P*-value
	≥15° (n=10)	<15° (n=28)	
Valgus angle (°)	23.5 (15.5 to 37.0)	5.0 (–3.5 to 11.7)	<0.001*
Posterior tilt angle (°)	4.6 (–2.9 to 11.0)	4.4 (–15.4 to 17.5)	0.948
LCEA (°)	25.3 (8.2 to 36.9)	23.2 (8.4 to 31.8)	0.573
Alpha angle (°)	60.1 (38.5 to 83.8)	57.4 (33.9 to 96.7)	0.378
Postoperative JSW (mm)			
Operated side	5.66 (4.09 to 7.39)	5.36 (3.18 to 7.44)	0.482
Contralateral side	5.12 (4.18 to 6.45)	4.67 (2.78 to 6.86)	0.272
Last JSW (mm)			
Operated side	4.95 (3.10 to 6.54)	5.06 (3.36 to 7.26)	0.757
Contralateral side	4.50 (3.21 to 6.04)	4.60 (2.75 to 6.77)	0.708
JSW narrowing (mm)			
Operated side	0.71 (–0.21 to 1.86)	0.30 (–0.68 to 1.78)	0.040*
Contralateral side	0.62 (–0.02 to 2.25)	0.07 (–0.60 to 1.08)	0.003*
JSW narrowing per year (mm)			
Operated side	0.21 (–0.18 to 0.58)	0.09 (–0.38 to 0.57)	0.218
Contralateral side	0.26 (–0.01 to 0.79)	0.02 (–0.38 to 0.38)	0.018*

Values are presented as mean (range).
VA: valgus angle, JSW: joint space width, LCEA: lateral center edge angle.
* $P<0.05$.

tively, with no significant difference (P=0.948). The mean postoperative alpha angles of 60.1° and 57.4° in the high- and low-valgus groups, respectively, did not reach significance (P=0.378). The mean LCEA values were 25.3° and 23.2°, respectively (P=0.573).

The immediate postoperative JSW on the operated side was 5.66 mm and 5.36 mm in the high and low valgus group, respectively. In the non-operated hip, JSW was 5.12 mm and 4.67 mm in each group, with no statistical difference in either hip, with a P-value of 0.482 and 0.272, respectively. There were no cases of preoperative osteoarthritis (Table 1).

The mean change of JSW on the operated side from immediately after surgery to final follow-up was 0.71 mm in the high valgus group and 0.30 mm in the low valgus group. The mean change on the contralateral side was 0.62 mm and 0.07 mm, respectively, and significant differences for both operated and contralateral sides were observed between the two groups (P=0.040 and P=0.003, respectively) (Table 1, Fig. 6).

Correlation analysis showed a significant correlation between the postoperative valgus angle and narrowing of the JSW in the contralateral hip with a Spearman's rho of 0.402 (P=0.012) and 0.280 (P=0.089) in the operated hip (Table 3). No significant correlation was observed between the postoperative posterior tilt and narrowing of the JSW in either hip.

DISCUSSION

Nondisplaced femoral fractures of the neck (Garden I, II) have traditionally been treated with *in situ* fixation using multiple cannulated screws or sliding hip compression screws[12]. However, several authors have emphasized that performing *in situ* fixation in patients with severe valgus deformity or posterior tilt may be related to fixation failure or ONFH as well as a higher rate of reoperation[2,13,14].

Meanwhile, Eijer et al.[7] suggested that retrotorsion and varus malunion, which is relatively uncommon, might be a cause of anterior or anterolateral FAI after a femoral fracture of the neck. According to Wendt et al.[15], anterior FAI was observed on approximately 75% of radiographs of patients who had undergone surgical treatment for a femoral fracture of the neck, and Mathew et al.[16] also reported that cam-type FAI was radiographically confirmed in 72% of Garden I and II cases and 85.9% of Garden III and IV cases. Clinically, this bump like lesion located on the femoral head-neck junction has been suggested as a potential cause of nonunion and decreased functional outcome after healing of a nondisplaced femoral fracture of the neck[2,13,14]. In addition, FAI can cause injury to the acetabular rim and joint cartilage, leading to development of early degenerative

Table 2. Demographic Data

	Postoperative VA		P-value
	≥15° (n=10)	<15° (n=28)	
Sex, male/female	2/8	11/17	0.095
Age (yr)	58.4 (41 to 70)	51.7 (21 to 69)	0.611
Direction, right/left	5/5	17/11	0.871
Follow-up duration (mo)	50.6 (12 to 131)	37.5 (12 to 78)	0.457
BMI (kg/m^2)	22.9 (19.2 to 28.9)	21.4 (16.3 to 32.9)	0.159
BMD*	–1.30 (–2.7 to –0.5)	–1.65 (–3.3 to 0.8)	0.237

Values are presented as mean (range).
VA: valgus angle, BMI: body mass index, BMD: bone mineral density.
* BMD data was not obtained for 3 and 10 patients in each group, respectively.

Table 3. Correlation Coefficient in Spearman's Rho

	JSW narrowing	
	Operated side	Contralateral side
Postoperative valgus angle	0.280 (0.089)	0.402 (0.012)
Postoperative posterior tilt	–0.017 (0.921)	0.029 (0.862)

Values are presented as rho (P-value).
JSW: joint space width.

osteoarthritis[8,17], with an adjusted odds ratio of 3.67 and 9.66 in the development of osteoarthritis in moderate and severe cam-type deformities, respectively[18].

Consequently, the importance of anatomical reduction has been emphasized in recent years, and several reduction techniques have been proposed. Steinberg et al.[5] recommended internal rotation and traction and correction of posterior tilt by application of AP pressure on the femoral neck as necessary for reducing the fracture. A minimally invasive reduction technique using a Steinmann pin or Kirschner wire was introduced by Yoon et al.[19] and Noda et al.[20]. Park et al.[6], who compared the clinical outcomes, shortening of the femoral neck, and Harris hip score between patients with VI-FNF who underwent *in situ* fixation and post-reduction fixation, confirmed that more favorable outcomes were achieved in the post-reduction fixation group.

Although cam-type FAI is radiographically characterized by a pistol grip deformity or an α angle $\geq 50°$, clear narrowing of the JSW is not observed until osteoarthritis has progressed[18]. When evaluating arthritis of the hip, quantitative measurement of the JSW has an advantage in that it can enable more accurate assessment of the clinical progression of osteoarthritis compared with qualitative methods such as the Kellgren–Lawrence classification, which assesses the severity of arthritis based on the size of osteophytes[21,22]. Goker et al.[23] measured the narrowest distance between the acetabulum and femoral head cortical bone, while Conrozier et al.[24] reasoned that measuring the minimum joint space rather than the mean joint space or joint space at a specific location is the most appropriate method for evaluating the progression of osteoarthritis. In this study, following Conrozier's method, we measured the narrowest joint space between the acetabular sourcil and femoral head cortical bones using the imaging system's measurement tool. The ratio of the actual diameter of the cannulated screws to the measured diameter was used for correction of the measured JSW.

The participants were divided into two groups according to the degree of postoperative valgus deformity, and no demographic or radiologic differences in terms of initial posterior tilt, alpha angle, and LCEA on plain images that could potentially contribute to the early development of degenerative osteoarthritis were observed. Although no significant difference in the JSW of the operated and contralateral sides was observed between the two groups immediately after surgery, a significantly higher degree of JSW narrowing was observed for both the operated and contralateral sides in the high valgus group. Greater annual narrowing of the JSW on the operated side was observed in the high valgus group, although the difference was not significant. In contrast, statistically higher narrowing of the joint space was observed for the contralateral hip in the high valgus group. Thus, as we have hypothesized, relatively sizeable narrowing of the JSW was observed in patients with a valgus angle of more than 15° at the time of fixation compared to those with a small valgus angle even during a mean follow-up period of 41 months. The mean differences in annual narrowing of the JSW between the two groups were 0.12 mm (0.21-0.09 mm/yr) and 0.24 mm (0.26-0.02 mm/yr) in operated and contralateral hips, which appears both modest and minute (Table 1). Nevertheless, consistent with the current study, previous studies of joint space narrowing in patients with arthritis of the hip have reported an annual decrement of 0.10 to 0.15 mm per year[23-25].

Of particular interest, no significant difference in narrowing of the JSW between the operated and contralateral sides was observed in either group, suggesting that performing *in situ* fixation in the case of a large valgus deformity may contribute to narrowing of the operated side as well as the contralateral hip, which may be a cause of alteration of biomechanics and gait in asymmetric hip joints in the high valgus group. A total of eight cases (three cases in the high valgus group and five cases in the low valgus group) showed greater narrowing of the JSW on the side contralateral to the operated side, indicating greater difference in JSW in the contralateral hip, which may suggest overuse of the contralateral side by patients as an attempt to protect the operated side after surgery.

The limitations of this study include potential bias as well as a small number of cases, a relatively short follow-up period for evaluating the progression of osteoarthritis, bias due to the retrospective design, and potential error associated with measurement of JSW, as detection of a subtle increment of JSW narrowing less than 1.0 mm is difficult without careful measurement and proper calibration. However, because the values were corrected using the diameter of the cannulated screws documented in the medical records, it can be expected that such errors will be minimized. In addition, as mentioned above, a previous study reported a small annual decrease in JSW in the arthritic hip, which is consistent with the findings of this study.

Subgroup analysis should be performed to eliminate the confounding effect of posterior tilt; however, a posterior tilt $\geq 15°$ was detected in only two of the 38 patients, thus an analysis was not possible. Instead, calculation of the correlation coefficient between posterior tilt and JSW narrowing showed no significant correlation. Considering the relatively small posterior tilt detected within the study population, which was on mean 6.8° and 8.0° in each group, higher valgus deformity may contribute to narrowing of the JSW in the high valgus group, using the available numbers. Even though the posterior tilt had no significant impact on the development of early osteoarthritic changes in the current study, it should be noted that some authors have reported that the risk of a suboptimal outcome is higher for retrotorsion of the femoral head after a femoral neck fracture when compared with the valgus deformity[2]. Thus, conduct of a more sophisticated study including a larger population will be required for evaluation and comparison of the clinical implications of posterior tilt and valgus deformity in support of the surgeon's effort toward reduction of the fracture, which should be emphasized.

Finally, although functional assessment at the final follow-up for examination of differences in the level of activity, satisfaction, and joint function between the two groups would have provided important clinical implications, this was not possible due to the retrospective design. Conduct of additional research will be required in order to determine whether greater narrowing of the joint space in patients with high valgus deformity can be attributed to changes in biomechanics or impingement itself or both, and further development can be achieved with use of more sophisticated and accurate measurements of JSW, such as computerized methods for measurement of JSW, as proposed by other research[23-25].

CONCLUSION

Performing internal fixation without correction of severe valgus deformity in non-displaced femoral fractures of the neck may cause accelerated narrowing of the hip joint space compared to patients whose valgus angle was smaller at the time of fixation.

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CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ORCID

Hyungtae Kim (https://orcid.org/0000-0002-1857-6644)
Ji Su Kim (https://orcid.org/0000-0002-4316-4676)
Yerl Bo Sung (https://orcid.org/0000-0002-6628-0530)

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