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Comparative outcomes of in-situ fixation and fixation after reduction in geriatric patients with severe valgus-impacted femoral neck fractures: a retrospective multicenter (TRON group) study

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ABSTRACT

The objective of this study was to evaluate and compare the clinical and radiographic outcomes between in situ fixation and fixation after reduction of severe valgus-impacted femoral neck fractures in patients aged 65 years or older. This was a multicenter retrospective study of 561 patients who underwent open reduction and internal fixation for femoral neck fracture. From this population, we selected patients aged 65 years and older with severe valgus-impacted femoral neck fractures characterized by a Garden alignment index greater than 15 degrees compared to that on the non-injury side. After exclusion criteria were applied, the study included 92 patients who were categorized into two groups: in situ fixation group (n = 56) and fixation after reduction group (n = 36). Our analysis covered patient demographics, surgical details, postoperative complications, radiographic evaluations, Numeric Rating Scale for pain, and Parker's Mobility Score for clinical outcomes. Bone union was achieved in all patients. The incidence of avascular necrosis was consistent between the groups. Patients in the reduction group reported lower Numeric Rating Scale scores (mean: 0 vs 2, p = 0.003) and higher Parker's Mobility Score scores (mean: 7 vs 6, p = 0.009) compared with the in situ group. Radiographically, the reduction group showed significantly lower femoral neck shortening (mean: 4.75 mm vs 5.75 mm, p = 0.049) and a reduced length of cannulated cancellous screw backout (mean: 3.4 mm vs 5.4 mm, p = 0.007) at the final follow-up. Fixation after reduction for severe valgus-impacted femoral neck fractures in patients aged 65 and above appears to be a safe and effective approach.

Keywords: femoral neck fracture, femoral neck shortening, severe valgus impaction

Abbreviations:
AVN: avascular necrosis of the femoral head
FNS: femoral neck shortening
CCS: cannulated cancellous screw
NRS: Numeric Rating Scale

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PMS: Parker's Mobility Score
GAI: Garden alignment index

INTRODUCTION

Femoral neck fractures are a common injury for orthopedic surgeons to treat and are one of the major causes of worsening of daily activities in elderly patients.[1] Typically, internal fixation is recommended for non-displacement femoral neck fractures. Nonetheless, some studies have reported that even non-displacement fractures, characterized by valgus impaction and a pronounced posterior tilt angle, heighten the likelihood of complications and diminish hip functionality.[2,3] Avascular necrosis of the femoral head (AVN) is frequently reported after treatment of femoral neck fractures with severe valgus deformity and posterior tilt fracture.[3,4] There is ongoing debate regarding the necessity of reduction for the valgus and posterior tilt fracture sites during internal fixation of a femoral neck fracture. Historical data from the 1980s shows a hesitancy to reduce valgus impaction due to concerns of precipitating avascular necrosis.[5] Recently, in patients aged 65 years or younger who presented with fractures featuring posterior tilt and a severe valgus impaction, it has been observed that internal fixation following reduction for severe valgus-impacted femoral neck fractures is both safe and effective.[6] However, few studies have specifically examined the effects of reduction for severe valgus-impacted femoral neck fractures in the older population.

Femoral neck length after fracture site reduction is important after internal fixation for femoral neck fracture. Such complications as femoral neck shortening (FNS) and protrusion of screws can lead to deterioration in hip function.[7] Additionally, preservation of the femoral neck length during fracture treatment is desirable in patients whose abductor lever arm has already been decreased by valgus impaction.[8] The reduction procedure not only ensures successful bone union but also aids in the restoration of femoral neck length.[6]

Therefore, we hypothesized that in older patients who have sustained a femoral neck fracture, as in younger patients, it might be better to perform reduction of the valgus and then fixation. We conducted a retrospective multicenter analysis to evaluate femoral neck length and gait function and the incidence of complications following reduction for severe valgus-impacted femoral neck fractures in geriatric patients.

PATIENTS AND METHODS

The ethics committee of each participating hospital approved this multicenter retrospective study. All eligible patients were registered using an opt-out consent process. Patients were provided with a letter and a brochure informing them that they had been registered, the purpose of the registration, and the procedure to remove themselves from the registry. The registry received ethical approval from all participating institutions, and this study received institutional ethical approval (Ref no. 2020-564). Hospitals of the Trauma research of Nagoya group (named TRON) have registered orthopedic trauma surgery cases. The participating hospitals in the database are all hospitals associated with the Department of Orthopedic Surgery of our university. Orthopedic surgeons perform the surgery at these hospitals. We collected cases of femoral neck fractures from the TRON database that were treated surgically.

Subjects

From April 2016 to March 2020, 561 patients who underwent open reduction and internal fixation and those who were followed up for more than 12 months were identified. We excluded the following patients: 135 patients under 65 years old, 95 patients treated without cannulated cancellous screw (CCS), 40 patients with a history of surgery on the unaffected side, and 199 patients with femoral neck fractures with valgus impaction ≤15°. Finally, 92 patients with an average follow-up time of 25 (range 13–78) months were included in this retrospective study (Fig. 1).

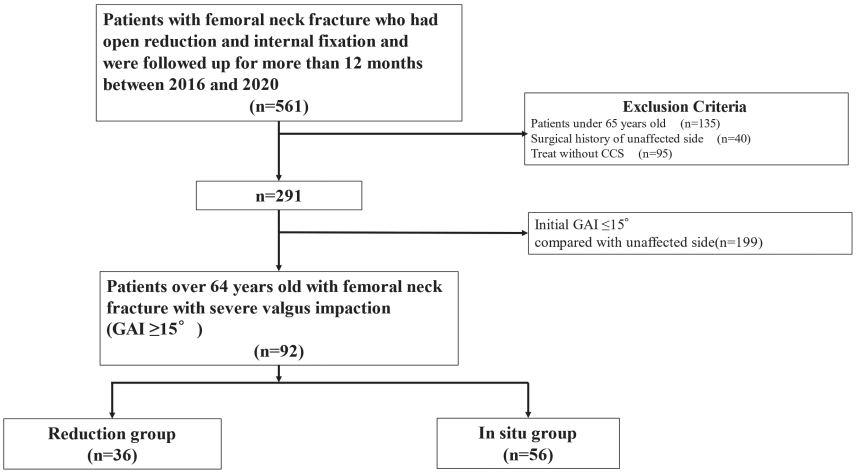

Fig. 1 Flowchart illustrating patient selection
CCS: cannulated cancellous screw
GAI: Garden alignment index

Clinical assessments

The data we collected from the medical records were age, sex, affected side, body mass index, fracture type, type of injury (high energy: falling from a high space, traffic accident; low energy: falling on flat ground and from a low space), smoking status, and time from trauma to surgery. We also obtained operative time and blood loss. Dementia was determined based on a Hasegawa Dementia Scale score of less than 20 at the time of admission or a history of dementia in the patient's medical records.

Complications, such as non-union, re-fracture, and AVN, were identified when all medical records and radiographs up to the final follow-up visit were reviewed. Non-union was defined when there was no evidence of bone healing along with significant hip pain after six months.[9] AVN was diagnosed in patients who complained of pain and had simple radiographs showing cystic changes and focal bone radiolucency with more than 2 mm of femoral head collapse.[10,11]

We also assessed the Numeric Rating Scale (NRS) for pain[12] at the last follow-up postoperatively, and Parker's Mobility Score (PMS) for clinical outcomes before injury and at the last follow-up postoperatively.[13]

Radiological assessments

Severe valgus impaction was defined as a Garden alignment index (GAI) >15° on the non-injury side on preoperative radiographs.[14] The initial valgus angle was measured on the

preoperative anteroposterior radiograph using angulation of the principal trabecular system of the femoral head, as described for measuring the GAI (Fig. 2). It was also used to assess the corrective loss. Anteroposterior radiographs of the pelvis were obtained with the patient in the supine position with both femurs internally rotated at 15°. The size of both lesser trochanters was matched to make a valid comparison of measured values. The posterior tilt angle, screw backout, and the amount of FNS were measured on radiographs preoperatively, immediately postoperatively, and at the last follow-up. The degree of posterior tilt was measured in the lateral view using the method described by Palm et al,[15] and the amount of FNS was measured on anteroposterior radiographs using the method described by Yuan et al (Fig. 3).[16] The amount of

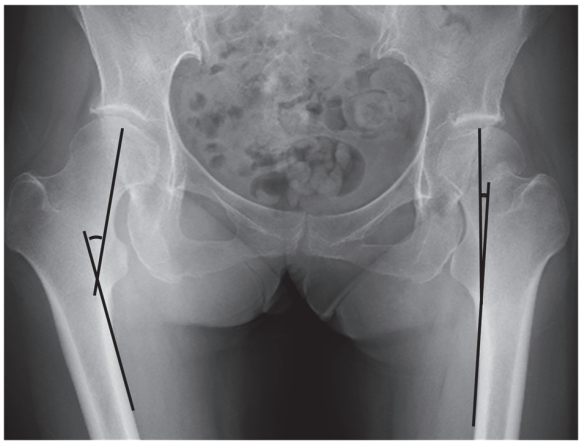

Fig. 2 Measurement of the Garden alignment index
On the anteroposterior radiograph, the Garden alignment index is defined as the angle between two lines: the trabecular line in the femoral head and a line drawn through the long axis of the medial cortex of the femoral shaft.

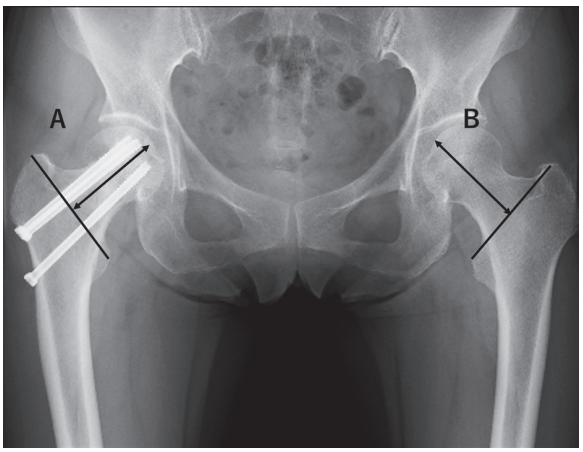

Fig. 3 Measurement of femoral neck shortening
On the anteroposterior radiograph, a line is made through the center of the femoral head on the long axis of the femoral neck on both sides. The distance between the tip of the femoral head and this intertrochanteric line is measured. The length of femoral neck shortening is determined as the distance on the uninjured side (B) minus the distance on the injured side (A).

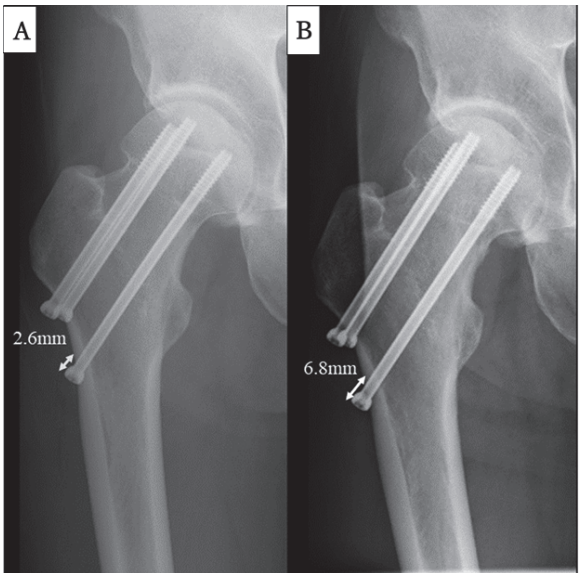

Fig. 4 The amount of cannulated cancellous screw backout
Fig. 4A: Anteroposterior radiograph obtained immediately postoperatively.
Fig. 4B: Anteroposterior radiograph obtained at the last follow up.
The amount of cannulated cancellous screw backout is determined by measuring the length of screw head protuberance. Screw head protuberance is measured from the lateral femoral cortex to the most prominent point of the cannulated head along the axis of the screw and compared between the immediate postoperative radiograph and that obtained at the last follow up.

screw backout was measured on the anteroposterior radiograph along the long axis of the femoral neck by comparing the position of the most distal fixation implant between the intraoperative or immediate postoperative film with that on the last available follow-up radiograph (Fig. 4). Also, we measured the actual length of the CCS. Radiological measurements were performed by two orthopedic surgeons.

To assess consistency between the two observers, Fleiss' kappa value and the Interclass Coefficient Correlation (ICC) of GAI, FNS, and CCS length were calculated. The interobserver reliability was determined to be robust, with a Fleiss' kappa value of 0.83 (95% confidence interval [CI]: 0.79–0.88) and ICCs of 0.88 (95% CI: 0.84–0.93), 0.80 (95% CI: 0.76–0.94), and 0.89 (95% CI: 0.86–0.93), respectively.

Surgical management

When performing reduction of severe valgus impaction, each surgeon followed the same protocol as below:

1. The posterior tilt of the capital fragment (apex anterior angulation) was rectified by internally rotating the leg and exerting anterior pressure.

2. Subsequently, valgus impaction was reduced by applying traction to the leg and adducting it. If this approach was ineffective, towels were positioned between the table and the groin of the affected side. If these measures still did not achieve the desired reduction, the methodology reported by Mahajan et al was used.[17,18]

Following these steps, patients underwent fixation of their femoral neck fractures using cancellous screws.

Postoperative treatment

Patients started rehabilitation from the day after surgery that included transfer to wheelchair, active and passive range of motion exercises, and gait training. Weight bearing as tolerated was allowed immediately postoperatively.

Statistical analyses

The patients were divided into two groups based on their treatment approach: the in situ fixation group or reduction of valgus impaction group. Data are described as the mean with standard deviation or frequency with percentage. Between-group differences were evaluated by Mann-Whitney U test, as appropriate for the data type. All statistical analyses were performed using EZR software, version 1.63 (Jichi Medical School, Tochigi, Japan), with $p < 0.05$ considered to be significant for all analyses.

RESULTS

Of the 92 patients, 56 were in the in situ fixation group, and 36 were in the fixation after reduction group. There were no significant differences in background characteristics between the two groups (Table 1).

Table 1 Patient demographics

	In situ group	Reduction group	p value
Number of patients	56	36	
Average age, y, (SD)	80.62 (7.02)	78.94 (7.88)	0.28
Sex, n (%)			
Male	13 (23.2)	5 (13.9)	0.29
Female	43 (76.8)	31 (86.1)	
Average BMI, kg/m^2 (SD)	20.00 (3.81)	19.80 (3.10)	0.79
Smoker, n (%)			
No	53 (94.6)	35 (97.2)	0.58
Yes	3 (5.4)	1 (2.8)	
Alcohol, n (%)			
No	51 (91.1)	35 (97.2)	0.034
Yes	5 (8.9)	1 (2.8)	
Dementia, n (%)			
No	41 (73.2)	27 (75.0)	1
Yes	15 (26.8)	9 (25.0)	
Diabetes mellitus, n (%)			
No	47 (83.9)	32 (88.9)	0.55
Yes	9 (16.1)	4 (11.1)	
Initial GAI, mean, ° (range)	176 (155, 202)	181 (170, 201)	<0.001
Initial posterior tilt angle, mean, ° (range)	6.77 (0, 20)	7.99 (0, 20)	0.43
PMS before injury, mean (range)	7.00 (0, 9.00)	8.00 (0, 9.0)	0.12

SD: standard deviation
BMI: body mass index
GAI: Garden alignment index
PMS: Parker's Mobility Score

Bone union was achieved in all cases. AVN was observed in 3 cases in the in situ group and 5 cases in the reduction group, but the difference was not statistically significant (p = 0.161). All eight of these patients with AVN underwent re-operation for conversion to hemiarthroplasty. There were no significant differences in operative time and blood loss between the patients in the two groups.

The median NRS score in the reduction group was lower than that in the in situ group (0 [range: 0–1] vs 2 [range: 0–4], p = 0.003) at the last follow-up. Conversely, the median PMS in the reduction group was higher than that in the in situ group (7 [range: 0–9] vs 6 [range: 0–9], p = 0.009) at the last follow-up.

From the radiographic evaluation, FNS at the final follow-up was significantly less in the reduction group versus the in situ group (4.75 mm [range: 1–19.3 mm] vs 5.75 mm [range: 2–25 mm], p = 0.049). Furthermore, the amount of CCS backout was notably lower in the reduction group versus the in situ group at the last follow-up (3.4 mm [range: 0.7–9.4 mm] vs 5.4 mm [range: 0–11.4 mm], p = 0.007). The average length of the CCS used in the reduction group was longer than that in the in situ group (79.2 ± 4.9 mm vs 71.7 ± 5.1 mm, p = 0.02). Postoperative GAI values were 172° (range: 160–202°) and 164° (range: 152–183°) (p <0.001), and posterior tilt angles were 5° (range: 0–22°) and 3° (range: 0–15°) (p = 0.13) in the in situ and reduction groups, respectively. GAI values at last follow-up were 174° (range: 162–200°) and 163° (range: 155–180°) (p <0.001), respectively (Table 2).

Table 2 Outcomes in the two groups

	In situ group	Reduction group	p value
Number of patients	56	36	
Operative time, min (range)	35 (19, 77)	37 (17, 80)	0.16
Blood loss, mL (range)	10 (0, 30)	7 (0, 20)	0.92
FNS, mm (range)	5.75 (2.0, 25.0)	4.75 (1.0, 19.3)	0.049
CCS backout, mm (range)	5.4 (0, 11.4)	3.4 (0.7, 9.40)	0.007
CCS length, mm (range)	71.7 (70, 80)	79.2 (70, 90)	0.02
NRS, mean (range)	2.00 (0, 5.00)	0.00 (0, 8.00)	0.003
PMS, mean (range)	6.00 (0, 9.00)	7.00 (0, 9.0)	0.009
GAI, mean, ° (range)	172 (160, 202)	164 (152, 183)	<0.001
GAI at last follow-up, mean, ° (range)	174 (162, 202)	163 (155, 180)	<0.001
Posterior tilt angle, mean, ° (range)	5 (0, 22)	3 (0, 15)	0.13

FNS: femoral neck shortening
CCS: cannulated cancellous screw
NRS: Numeric Rating Scale
PMS: Parker's Mobility Score
GAI: Garden alignment index

DISCUSSION

This study investigated the clinical and radiographic outcomes after reduction in patients aged 65 years or older with severe valgus-impacted femoral neck fractures. The results showed that reduction followed by screw fixation does not increase complications and significantly reduces FNS, with significantly lower NRS scores and higher PMS shown in the reduction group than the in situ group in these older patients. In addition, there were no significant differences in

operative time and blood loss between the two groups.

The most important concern when reducing valgus deformity is whether it increases the risk of complications such as AVN. The occurrence of AVN was not statistically significant (3/56 cases in the in situ group, 5/36 cases in the reduction group) in our cohort. Several prior studies recommended that surgeons should avoid the reduction of valgus deformity due to concerns about fixation stability and AVN.[5,19] However, these reports did not describe the specific techniques used for the reduction procedure, nor did they provide an assessment of the resulting quality of reduction achieved. Song et al reported that valgus deformity >15° was predictive of the risk of failure of internal fixation, in addition to a posterior tilt >15°.[3] It is also thought that reduction of valgus deformity leads to healing via blood circulation from the superior retinacular artery,[20] so the risk of AVN might not increase.

The present study showed that in cases in which valgus deformity was reduced, the amount of CCS backout and FNS were significantly lower than those in cases in the in situ group. Also, the average length of the CCS used in the reduction group was longer than that in the in situ group. Some studies suggest that longer screws provide greater primary stability compared to shorter screws in fragility fractures in older patients.[21,22] In our study, we were able to use longer screws in the realignment group. This may have contributed to the prevention of screw backout and FNS. We showed significant improvements in PMS in the reduction group compared to the in situ group. Zlowodzki et al reported a gradient effect, showing that greater shortening is associated with lower functional scores.[2] Weil et al also reported a negative correlation between overall FNS of more than 5 mm and the physical component score of the Short Form 12 Health Survey.[23] Similarly, Park et al found a negative correlation between FNS of more than 5 mm and the Harris Hip Score.[6] The NRS score in the reduction group was significantly lower than that in the in situ group. A prior study showed that shortening of the femoral neck is associated with the degree of pain experienced.[24] Despite previous reports identifying posterior tilt as a potential risk factor for AVN, it is noteworthy that in the present study no discernible difference in pre- and postoperative posterior tilt was observed between the two groups. Consequently, the present evaluation focused primarily on the influence of severe valgus impaction.[25]

This study was associated with several limitations. First, in older patients with femoral neck fractures and severe valgus impaction, some surgeons choose hemiarthroplasty. However, it is important to recognize that therein lie specific problems associated with the use of artificial heads, including infection, screw loosening, periprosthetic fractures, and acetabular wear. Second, this was a retrospective study using a clinical database, and because the subjects were not randomly assigned, selection bias could exist. The decision to perform reduction maneuvers was made at the discretion of the surgeons, and it is possible that factors related to patient background that were not fully addressed in this study may have influenced this decision. In addition, the decision to use CCS despite the availability of implants with greater angular stability may have been based on an assessment of bone quality. Third, the sample size was relatively small. Based on the calculation of the required sample size from a previous study that reported the incidence of AVN associated with valgus impaction,[26] 84 cases are required in each group. Therefore, the current sample size may be insufficient when considering AVN as an outcome. However, this study reports the largest number of cases among studies that performed radiographic evaluation after reduction. Fourth, this study collected data on fractures treated by CCS. Although other implants were not considered, recent studies have reported on the strength of implants other than CCS.[27,28] Fifth, it is not known whether it is advisable to reduce the initial GAI to ≤15°. Sixth, we did not assess the short-term cases as these were excluded, and only cases followed up for over 12 months were analyzed. Finally, it was not possible to mention the consequences of a high degree of posterior tilt. This study did not include posterior tilt in the exclusion criteria,

although a retrospective look at the cohort resulted in a posterior tilt of less than 20°. However, prosthetic replacement is a reasonable indication for femoral neck fractures with a high degree of posterior tilt,[25] and we considered this study to be in accordance with clinical practice.

CONCLUSION

Fixation after reduction of severe valgus-impacted femoral neck fractures was effective in preserving the length of the femoral neck, even in patients over 65 years of age. Accordingly, PMS and NRS scores in the reduction group were also better than those in the in situ group. It may be preferable to perform repair and fixation of severe valgus-impacted femoral neck fractures regardless of the patient's age.

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CONFLICT OF INTEREST

None.

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