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Does Hip Abduction during Intramedullary Nail Fixation Help Correct Residual Varus Alignment in Subtrochanteric Fractures? A Retrospective Cohort Study

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Background: Varus malalignment is a risk factor for nonunion and mechanical complications in subtrochanteric femoral fractures (SFFs). Although various reduction techniques have been reported to avoid varus malalignment in SFFs, achieving anatomic reduction remains challenging, often resulting in residual varus alignment (RVA) after reduction. This study aimed to investigate the radiographic and clinical outcomes of a novel method resolving RVA by abducting the ipsilateral hip after cephalomedullary fixation with an intramedullary nail and subsequently inserting distal interlocking screws.

Methods: This retrospective study, conducted between March 2016 and March 2022, included patients who underwent hip abduction during intramedullary nailing due to RVA. Demographics and fracture patterns (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association [AO/OTA]) and types (typical or atypical) were analyzed. Radiographic outcomes included Baumgaertner reduction quality criteria (BRQC), tip-apex distance (TAD), neck-shaft angle (NSA), lateral cortex residual gap, union, and time to union. Clinical outcomes included ambulatory level using the Palmer-Parker Mobility Score (PPM), complications, and reoperation.

Results: This study included 45 patients (mean age, 65.8 years; mean follow-up period, 18.4 months). The most common fracture pattern was 32A2 in 15 patients and 29 were typical and 16 were atypical fractures. The BRQC was good in 36 patients, and TAD was < 25 mm in 43 patients. Pre-abduction NSA (126.0° ± 3.8°) was significantly smaller than post-abduction NSA (129.9° ± 3.4°, $p < 0.001$). Post-abduction NSA was comparable to contralateral NSA of 128.9° ± 2.8° ($p = 0.155$). Residual gap was significantly reduced from 6.1 ± 2.9 mm pre-abduction to 1.7 ± 1.0 mm post-abduction ($p < 0.001$). Union was achieved in 44 patients (97.8%; mean duration, 5.9 months). PPM decreased from 7.8 ± 2.0 pre-injury to 7.0 ± 2.1 1-year postoperatively. One nonunion case required reoperation. Radiographic outcomes did not significantly differ by fracture pattern ($p = 0.470$ for NSA and $p = 0.334$ for residual gap).

Conclusions: Hip abduction during intramedullary nailing corrects alignment and reduces the gap in SFFs with residual varus alignment. This method can be applied to various fracture patterns in a straightforward manner and considered valuable for managing SFFs.

Keywords: *Subtrochanteric fracture, Varus deformity, Intramedullary nail, Hip abduction*

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Subtrochanteric femoral fractures (SFFs) have high nonunion and reoperation rates and are considered challenging fractures.[1,2] The high physiological stress on the subtrochanteric area, combined with the strong varus and flexion deforming forces exerted by the surrounding muscles, makes the reduction of SFFs difficult and predisposes patients to suboptimal reduction and residual fracture gaps.[3,4] Recently, intramedullary (IM) nailing has been widely utilized as a standard treatment for SFFs owing to its biomechanical and biological advantages.[5] Varus malreduction and residual gap at the fracture site after IM nail fixation in SFFs increase the risk of nonunion and mechanical complications.[6-9] Various reduction techniques have been reported to avoid varus malalignment and achieve anatomical reduction in SFFs.[10-13] Nevertheless, achieving anatomic reduction in SFFs remains challenging, often leaving varus alignment and fracture gaps even after reduction techniques are performed.[14-16] The authors have also experienced cases of residual varus alignment in the surgical treatment of SFFs despite the use of reduction techniques. Therefore, we attempted to address the residual varus alignment and found that proximal fixation of the IM nail followed by abduction of the affected hip and insertion of distal interlocking screws could correct the residual varus alignment and minimize the residual gap in a simple and effective manner.

This study aimed to investigate the radiographic and clinical results of a novel method of correcting residual varus alignment and minimizing the residual gap by abducting the affected hip and inserting distal interlocking screws after cephalomedullary fixation using IM nails in SFFs.

METHODS

Study Design and Participants

After obtaining Institutional Review Board approval (Hanyang University Hospital; IRB No. 2023-08-032-001), this retrospective study was conducted at a single university hospital from March 2016 to March 2022 in patients who underwent IM nailing for SFFs. Informed consent was waived due to the retrospective nature of this study. SFFs were defined as fractures occurring in an area extending 5 cm inferior to the lesser trochanter of the femur.[7] The inclusion criteria for this study were as follows: patients with residual varus alignment who underwent hip abduction at the time of IM nailing, were aged ≥18 years, and had a follow-up period of ≥ 1 year. The exclusion criteria were as follows: patients aged < 18 years, had < 1 year of follow-up, open fractures, bilateral fractures, neoplastic pathological fractures, or femoral fractures involving regions other than the subtrochanteric region, undergoing concurrent surgery for other injuries, had a history of hip surgery, undergoing fixation using short IM nails, and had neurovascular injury at the initial visit. Initially, 61 patients were included in this study. Of these, 5 patients were excluded owing to a follow-up period of < 1 year, 8 owing to concomitant fractures in other regions of the femur, and 3 owing to a history of hip surgery, resulting in 45 patients being finally enrolled in this study.

Data Collection and Outcome Measures

Patient age, sex, body mass index (BMI), diabetes mellitus, smoking status, chronic kidney disease, American Society of Anesthesiologists (ASA) classification, bone mineral density (BMD), injury mechanism, and follow-up period were examined using a medical record analysis. BMD was measured in patients aged ≥ 60 years or with a history of osteoporosis. Injury mechanism was categorized as high- or low-energy. High-energy injury was defined as a fall from a height > 1 m or a traffic accident, whereas low-energy injury was defined as a fall from a height < 1 m. The study cohort had a mean age of 65.8 ± 16.5 years (range, 20–92 years), comprising 21 men and 24 women. The mean BMI was 23.2 ± 3.0 kg/m^2 (range, 15.2–33.0 kg/m^2), 15 patients had diabetes, 9 were smokers, and 3 were diagnosed with chronic kidney disease. ASA classification 2 was the most common, observed in 22 patients (48.9%), followed by classification 3 in 17 (37.8%), classification 1 in 5 (11.1%), and classification 4 in 1 (2.2%). BMD was measured in 33 patients (mean, –2.4 ± 1.0) and T-score ranged from –0.5 to –4.5. Osteoporosis was diagnosed in 20 of the 33 patients. Twenty-seven patients (60.0%) had low-energy injuries. The average follow-up was 18.4 months (range, 12–46 months) (Table 1).

Fracture pattern was classified according to the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association (AO/OTA) classification,[17] and fracture type was classified as typical or atypical. Atypical fractures were defined as fractures that met the American Society for Bone and Mineral Research criteria.[18] The primary objective of this study was to determine the changes in intraoperative radiographic parameters after hip abduction and to determine whether alignment could be consistently corrected across different fracture patterns. Therefore, atypical fractures with predominantly transverse and short oblique patterns were included to cover a wide range of fracture patterns. According to the AO/OTA classification, the fracture pattern 32A2 was the most common (15 patients [33.3%]), followed by 32B2 (10 patients [22.2%]),

Table 1. Patient Demographics

Variable	Value (n = 45)
Age (yr)	65.8 ± 16.5
Sex (male : female)	21 : 24
BMI (kg/m^2)	23.2 ± 3.0
DM	15 (33.3)
Smoking	9 (20.0)
CKD	3 (6.7)
ASA classification	
1	5 (11.1)
2	22 (48.9)
3	17 (37.8)
4	1 (2.2)
BMD* (T-score)	–2.4 ± 1.0
Osteoporosis*	20/33 (60.6)
Injury mechanism	
Low	27 (60.0)
High	18 (40.0)
Follow-up (mo)	18.4 ± 9.3

Values are presented as mean ± standard deviation or number (%).
BMI: body mass index, DM: diabetes mellitus, CKD: chronic kidney disease, ASA: American Society of Anesthesiologists, BMD: bone mineral density.
*Measured in patients aged ≥ 60 years.

Table 2. Fracture Classification and Operative Data

Variable	Value (n = 45)
AO/OTA classification	
32A1	6 (13.3)
32A2	15 (33.3)
32A3	9 (20.0)
32B2	10 (22.2)
32B3	5 (11.1)
Atypical fracture	16 (35.6)
Operative time (min)	96.9 ± 22.7
EBL (mL)	374.3 ± 156.8
Nail diameter (mm)	
10	37 (82.2)
11	6 (13.3)
12	2 (4.4)
Nail length (mm)	
300	13 (28.9)
320	1 (2.2)
340	19 (42.2)
360	3 (6.7)
380	7 (15.6)
400	2 (4.4)

Values are presented as number (%) or mean ± standard deviation.
AO/OTA: Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association, EBL: estimated blood loss.

32A3 (9 patients [20.0%]), 23A1 (6 patients [13.3%]), and 32B3 (5 patients [11.1%]). Atypical fractures were diagnosed in 16 patients (35.6%) (Table 2).

Operative data included operative time, estimated blood loss (EBL), canal diameter of the femur isthmus, and diameter and length of the IM nail. EBL was calculated using the preoperative and 24–48 hours postoperative hemoglobin levels using Brecher's formula.[19] Intraoperative blood transfusion was calculated as 200 mL per packed red blood cells and included in the EBL. The canal diameter of the femoral isthmus was measured on the preoperative femur anteroposterior (AP) plain radiograph.

Radiographic outcomes included the Baumgaertner reduction quality criteria (BRQC), tip-apex distance (TAD), neck-shaft angle (NSA), residual gap, union, and time to union. The BRQC was categorized as good, acceptable, or poor based on the alignment and displacement on AP and lateral plain radiographs.[20] The TAD was standardized by multiplying the ratio of the actual helical blade width to the measured width on AP and lateral radiographs by the measured TAD value.[20] The TAD was categorized based on 25 mm by summing the values from the AP and lateral plain radiographs.[21] The NSA was measured using intraoperative C-arm AP images before (pre-abduction) and after (post-abduction) hip abduction, following cephalomedullary fixation of the IM nail. The NSA of the contralateral femur was measured using a preoperative AP plain radiograph of the hip as a reference. The residual gap was defined as the interfragmentary distance between the lateral cortex of the fracture site based on reports that the gap in the lateral cortical bone is one of the main factors affecting union in SFFs.[9] The residual gap was also measured for the pre- and post-abduction values from the intraoperative C-arm AP images. Union was defined as the disappearance of the fracture line and the presence of bridging callus in at least 3 of the 4 cortices on AP and lateral plain radiographs.[22] Nonunion was defined as failure to achieve union by 9 months postoperatively and no progression of union on consecutive radiographs for 3 months.[23]

Clinical outcomes were measured using the Palmer-Parker Mobility Score (PPM).[24] The PPM ranges from 0 (severe impairment of ambulation) to 9 (no limitation of ambulation) by summing the scores of 3 items on ambulation. The PPM was examined for pre-injury status at the time of admission and 1-year postoperative status at outpatient follow-up.

Complications and reoperations were also examined. Complications were defined as problems related to bone union or soft tissue that occurred during inpatient or outpatient follow-up, and reoperation was defined as a second surgery to address them. The primary outcomes were NSA and residual gap after abduction, and the secondary outcomes were union, time to union, 1-year postoperative PPM, complications, and reoperation.

Surgical Technique

The patient was placed in the supine position on the fracture table, and the affected limb was adducted and internally rotated while applying a longitudinal traction force. The contralateral limb was abducted by minimizing the hip and knee flexion.[25] The C-arm was used to verify the proper length, alignment, and rotation of the femur. If unsatisfactory reduction was noted, various additional minimally invasive reduction (MIR) techniques were used to achieve anatomical reduction. MIR techniques included making a lateral stab incision at the lesser trochanter level and pressing the anterior cortex of the proximal fragment with long Kelly forceps to correct flexion and external rotation deformities,[26] making an incision on the lateral side of the fracture site and inserting a clamp for temporary reduction,[10] or passing a cerclage wire passer through the lateral incision site and applying a cerclage wire or cable.[12,13] After the appropriate reduction techniques were utilized, the alignment of the affected femur on the intraoperative C-arm AP image was compared with that of the contralateral femur on the plain preoperative hip AP plain radiograph. To minimize distortion, the C-arm image was obtained with the fracture site in the subtrochanteric region centered. Residual varus alignment was determined to be present if the affected femur, after reduction, was aligned more varus than the contralateral femur. After confirming the quality of reduction, an entry portal was created just medial to the tip of the greater trochanter, a reamed long IM nail (PFNA-II or TFNA; DePuy-Synthes) was inserted, and cephalomedullary fixation was performed using a helical blade. The diameter of the IM nail was determined based on the canal diameter of the isthmus measured on the preoperative femur plain radiograph and the tactile sensation of bone chatter during reaming. Over-reaming by 1.5 mm was performed relative to the predetermined IM nail diameter. In cases in which residual varus alignment was observed, the hip socket of the fracture table was released to abduct the affected limb

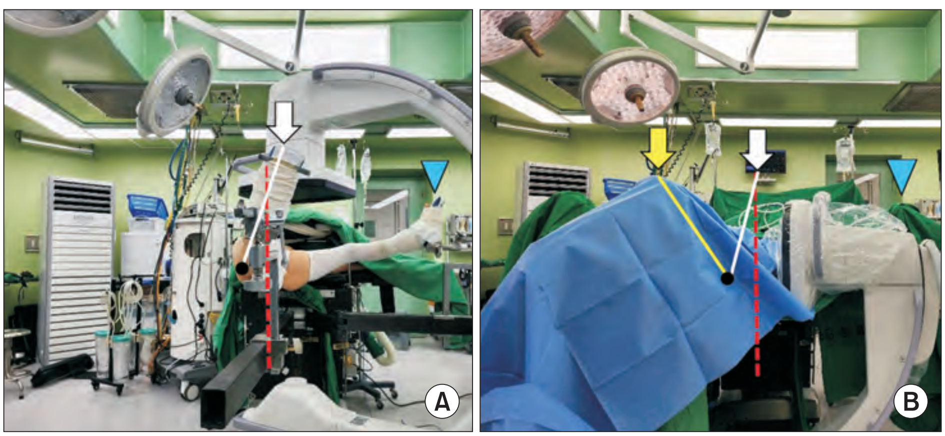

Fig. 1. (A) Fracture table setup for a patient with a right subtrochanteric femoral fracture. The patient was placed on the fracture table; the affected limb was adducted and internally rotated, and longitudinal traction was applied. The alignment of the right lower extremity (white solid line) through the right hip joint center (black circle) and the right traction boot (white arrow) was adducted across the midline of the body (red dashed line). Position of the left traction boot (blue arrowhead). (B) Intraoperative hip abduction was performed by releasing the hip socket of the affected limb and abducting it by approximately 30°, while the contralateral limb (blue arrowhead) remained intact. After abduction, the right traction boot (white arrow) was shifted to the right (yellow arrow), and the alignment of the right lower extremity (yellow solid line) from the right hip joint center (black circle) to the traction boot (yellow arrow) was in abduction compared with the initial alignment (white solid line).

25°–40° after cephalomedullary fixation (Fig. 1). The traction boot worn on the affected limb was left unchanged to maintain the rotation of the distal fragment. The quality of reduction was assessed with a C-arm after abduction, and 2 or 3 distal interlocking screws were inserted with the hip abducted. Hip abduction was not performed if residual varus alignment was not present and neutral alignment had been achieved.

At the beginning of IM nailing, the affected limb was placed in adduction on the fracture table to ensure an optimal entry point and facilitate IM nail insertion. The proximal fragment tends to abduct owing to stretching of the hip abductor muscles, whereas the distal fragment is adducted owing to the alignment of the limb during adduction, resulting in varus alignment at the fracture site.[3] After inserting the IM nail and performing cephalomedullary fixation, maintaining the limb in adduction is no longer necessary. If the affected limb is abducted at this point, the mobile distal fragment that is not fixed to the IM nail will abduct, using the IM nail as a fulcrum. Once the distal fragment is abducted, the residual varus alignment is corrected, achieving the desired alignment (Fig. 2). In addition, as the limb was abducted, the stretched hip abductor muscles became lax, and the abduction force on the proximal fragments diminished. The decreased abduction force on the proximal fragment also contributed to correcting varus malalignment and reducing the lateral cortical gap (Fig. 3).

Rehabilitation Protocol and Follow-up

Active range of motion exercises were started the day after surgery. Partial weight-bearing with crutches was implemented within 1 week after surgery, and progressive weight-bearing was performed for pain tolerance. Patients unsuitable for crutches were mobilized using a wheelchair or walker. Once the patient was deemed capable of walking independently, the walking aid was discontinued, and full weight-bearing was initiated. Outpatient follow-up

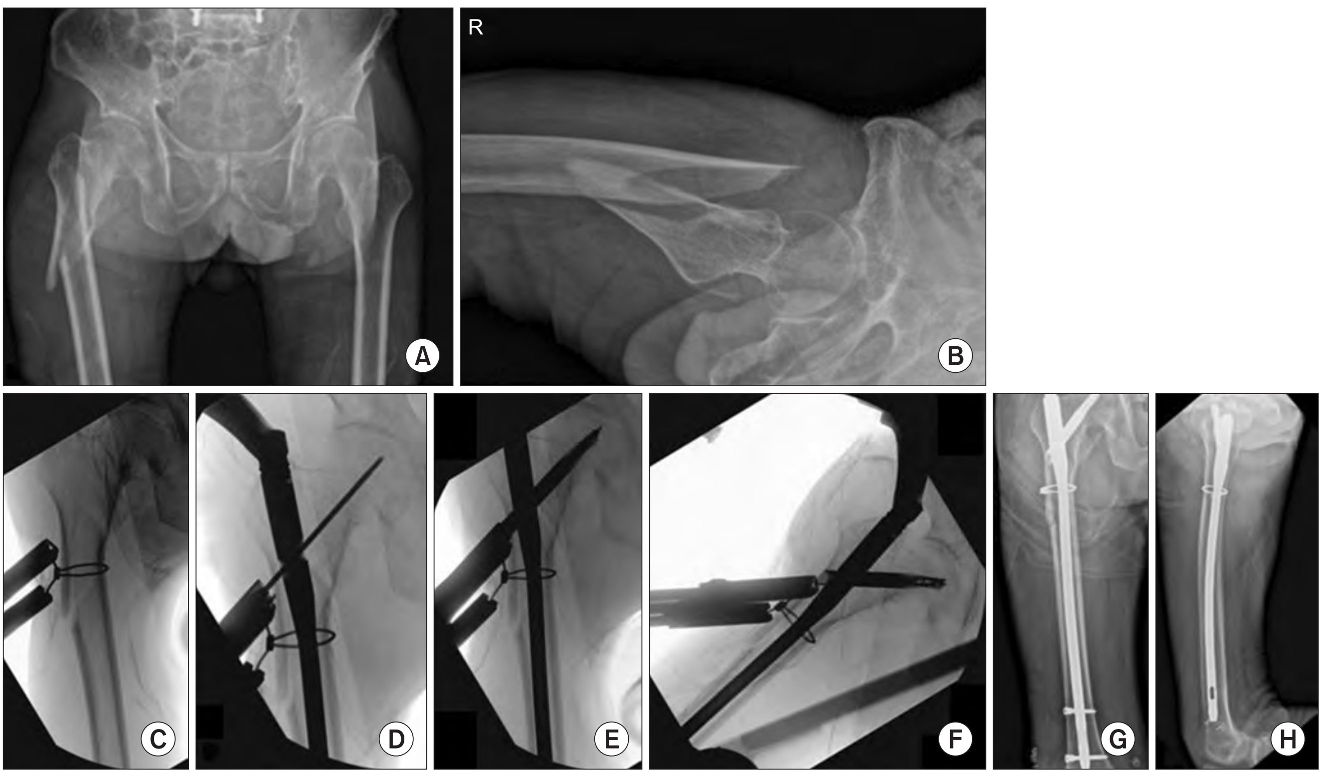

Fig. 2. An 85-year-old male patient sustained a right subtrochanteric fracture after a slip down. Preoperative hip anteroposterior (A) and lateral (B) plain radiographs revealed a fracture with an oblique pattern corresponding to 32A2 according to the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association (AO/OTA) classification. (C) Reduction was attempted with a minimally invasive reduction technique using a cable, but residual varus alignment was observed even after reduction. (D, E) An intramedullary nail was inserted, and cephalomedullary fixation was performed with 1 helical blade. (F) Intraoperative C-arm anteroposterior image after hip abduction. After abduction, the varus alignment was corrected and the residual gap was minimized. The greater trochanter tip of the femur and the superior acetabular rim were adjacent owing to the abduction. (G, H) Postoperative femur anteroposterior and lateral plain radiographs. Good alignment and high reduction quality were noted.

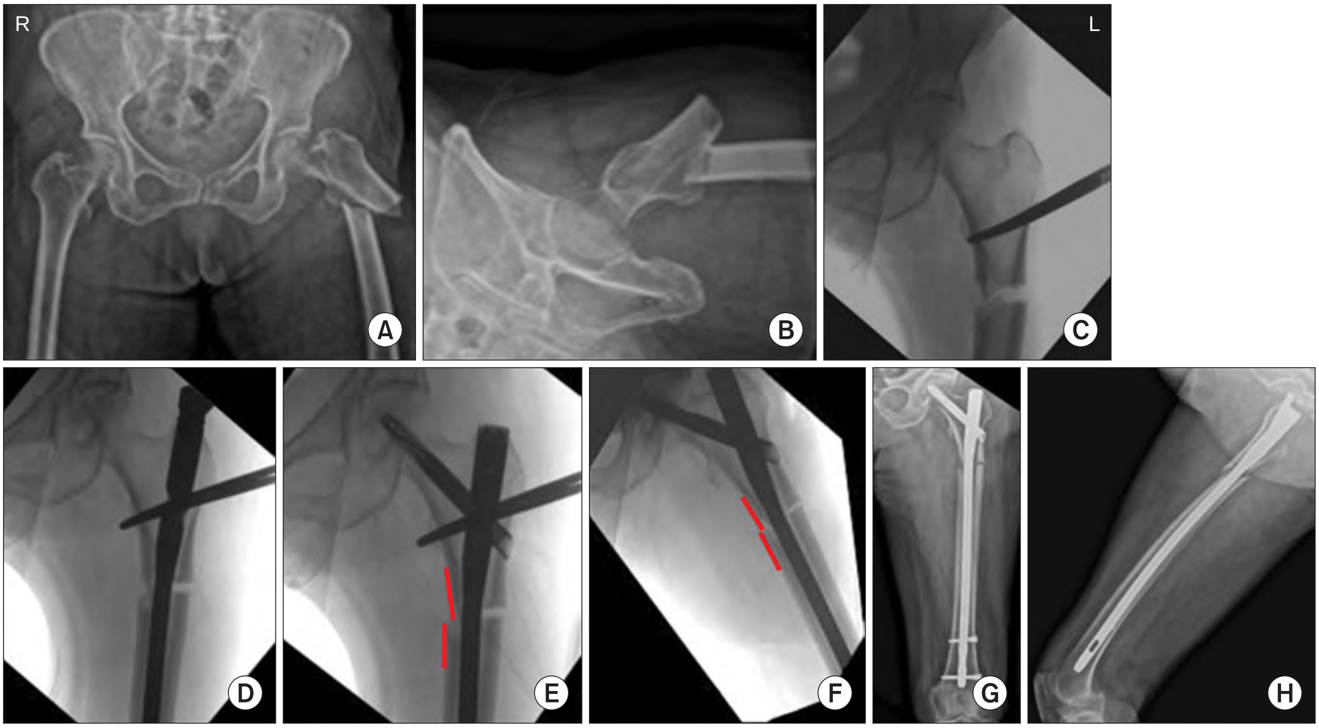

Fig. 3. A 92-year-old female patient sustained a left atypical subtrochanteric fracture following a ground level fall. Preoperative hip anteroposterior (A) and lateral (B) plain radiographs revealed a transverse pattern of fracture corresponding to 32A3 in the AO/OTA classification. (C) A minimally invasive reduction technique using long Kelly forceps was performed to correct the flexion and external rotation deformity of the proximal fragment and restore alignment, but residual varus alignment was observed after reduction. (D) An intramedullary nail was inserted and cephalomedullary fixation was performed with 1 helical blade. (E, F) Intraoperative C-arm anteroposterior image before and after hip abduction showed correction of the varus alignment and reduction of the residual gap. The medial cortex (red lines) of the proximal and distal fragments changed from varus to near-neutral alignment. (G, H) Postoperative femur anteroposterior and lateral plain radiographs. Alignment was well restored and high reduction quality was achieved.

was performed at 1, 2, 3, 6, 9, and 12 months postoperatively and at 6-month intervals thereafter.

Statistical Analyses

The NSA and residual gaps of pre- and post-abduction and pre- and 1-year postoperative PPM were compared. The Shapiro-Wilk test was used to assess for normality, and a paired *t*-test was used if normality was satisfied. Otherwise, the Wilcoxon signed-rank test was used. The post-abduction NSA was compared with the NSA of the contralateral femur. If normality was satisfied, independent *t*-tests were performed. Otherwise, the Mann-Whitney *U*-test was used. Comparative analyses were performed to determine differences in the amount of change in the NSA and residual gap after hip abduction according to the fracture pattern. One-way analysis of variance was performed if normality was met using the Shapiro-Wilk test, and the Kruskal-Wallis test was performed if normality was not satisfied. All statistical analyses were performed using SPSS version 27.0 (IBM Corp.). Statistical significance was set at $p < 0.05$.

RESULTS

The final cohort of 45 patients included in the study had a mean operative time of 96.9 ± 22.7 minutes and a mean EBL of 374.3 ± 156.8 mL (Table 2). In all patients, MIR techniques were used in addition to reduction with longitudinal traction on the fracture table. The mean preoperative canal diameter of the femur isthmus was 10.0 ± 0.9 mm, and the mean diameter of the IM nail used was 10.2 ± 0.5 mm. The most common diameter and length of IM nails used were 10 mm (37 patients [82.2%]) and 340 mm (19 patients [42.2%]), respectively (Table 2).

Radiographic outcomes showed that according to the BRQC, 36 patients (80.0%) were identified as good and 9 (20.0%) as acceptable. The mean TAD value was 19.5 ± 4.2 mm, with 43 patients (95.6%) having a TAD < 25 mm. The mean pre-abduction NSA was 126.0° ± 3.8°, which was significantly smaller than the post-abduction NSA of

129.9° ± 3.4° ($p < 0.001$). The mean NSA of the contralateral femur was 128.9° ± 2.8° and was not significantly different from the post-abduction NSA ($p = 0.155$). The mean pre-abduction residual gap was 6.1 ± 2.9 mm, which was significantly larger than the post-abduction gap of 1.7 ± 1.0 mm ($p < 0.001$). Union was achieved in 44 of 45 patients (97.8%), with a mean time to union of 5.9 ± 1.7 months (Table 3). For clinical outcomes, the mean 1-year postoperative PPM was 7.0 ± 2.1, which was significantly lower than the pre-injury PPM of 7.8 ± 2.1 ($p < 0.001$), but did not reach the minimum clinically important difference of 1.0.[27] Complications included 1 case of nonunion, which required reoperation (Table 3).

Of the patients with osteoporosis or treated for atypical fractures, the use of teriparatide was considered, with 9 of 23 patients receiving teriparatide for a mean of 5.4 ± 4.0 months. In this subgroup, there was no difference in the rate of union ($p = 1.000$) or time to union ($p = 0.873$) with or without the use of teriparatide. The increments in NSA after hip abduction were 2.6° ± 2.5° in 32A1, 4.2° ± 2.8° in 32A2, 4.8° ± 1.1° in 32A3, 3.3° ± 2.8° in 32B2, and 4.1° ± 3.1° in 32B3, and there was no significant difference according to fracture pattern ($p = 0.470$) (Table 4). The decrements in residual gap also showed no significant difference according to fracture pattern ($p = 0.334$): 3.9 ± 2.7 mm in 32A1, 4.8 ± 2.9 mm in 32A2, 5.1 ± 1.9 mm in 32A3, 3.4 ± 1.3 mm in 32B2, and 4.9 ± 4.1 mm in 32B3 (Table 4).

Table 3. Radiographic and Clinical Outcomes

Variable	Value (n = 45)
BRQC	
Good	36 (80.0)
Acceptable	9 (20.0)
Poor	0
TAD (mm)	19.5 ± 4.2
TAD < 25 mm (%)	43 (95.6)
Neck-shaft angle (°)	
Before abduction*	126.0 ± 3.8
After abduction*,†	129.9 ± 3.4
Contralateral†	128.9 ± 2.8
Residual gap (mm)	
Before abduction‡	6.1 ± 2.9
After abduction‡	1.7 ± 1.0
Union	44 (97.8)
Time to union (mo)	5.9 ± 1.7
PPM	
Pre-injury§	7.8 ± 2.0
1-Year postoperative§	7.0 ± 2.1
Complication (%)	1 (2.2)
Reoperation (%)	1 (2.2)

Values are presented as number (%) or mean ± standard deviation.
BRQC: Baumgaertner reduction quality criteria, TAD: tip-apex distance, PPM: Palmer-Parker Mobility Score.
*Paired *t*-test, $p < 0.001$. †Independent *t*-test, $p = 0.155$. ‡Wilcoxon signed-rank test, $p < 0.001$. §Wilcoxon signed-rank test, $p < 0.001$.

DISCUSSION

This study found that the method of abducting the hip and inserting distal interlocking screws after proximal fixation of the IM nail could restore the mean NSA by 3.9° and reduce the mean lateral cortical gap by 4.4 mm in SFFs with residual valgus alignment, with high union rates and good clinical outcomes. Hip abduction during IM nailing corrected the varus malalignment and restored the NSA sufficiently. Varus malalignment has been reported to increase the risk of nonunion and mechanical complications in SFFs.[6-9] Various reduction techniques have been suggested to address varus malalignment; however, varus persists even with the use of these techniques.[14-16] A study comparing the outcomes of closed reduction and MIR with clamp or cerclage wiring in 402 cases of SFFs found that varus > 5° and a lateral cortical gap > 5 mm were observed in 23% and 45% of cases in the MIR group, respectively.[14] Furthermore, Hoskins et al.[15] reported that only 60% of patients using the cerclage wire in SFFs had a good reduction in BRQC, and another study on MIR using a clamp revealed that only 58.5% patients achieved a good reduction.[16] The authors performed hip abduction with distal interlocking screw insertion after proximal fixation of the IM nail to address residual varus alignment and observed good reduction in 80% of patients. These favorable results were attributed to the IM nail acting as an internal splint during abduction, the altered direction of the traction force, the relaxed lateral thigh muscles generating a strong valgus compressive force on the distal fragment, and the effective transmission of the reduction force to the fracture site due to the dense cortical bone in the subtrochanteric area.

The residual gap was substantially reduced through hip abduction. The distal fragment is abducted along the

Table 4. Radiographic Outcomes and Changes Based on the AO/OTA Fracture Classification

Variable	32A1 (n = 6)	32A2 (n = 15)	32A3 (n = 9)	32B2 (n = 10)	32B3 (n = 5)
Neck-shaft angle (°)					
Before abduction	125.7 ± 2.5	125.9 ± 4.1	125.9 ± 3.0	127.6 ± 5.0	123.8 ± 3.0
After abduction	128.2 ± 2.6	130.1 ± 3.9	130.7 ± 2.8	130.9 ± 4.1	127.9 ± 0.4
Amount of change*	2.6 ± 2.5	4.2 ± 2.8	4.8 ± 1.1	3.3 ± 2.8	4.1 ± 3.1
Contralateral	128.0 ± 2.0	129.3 ± 3.0	128.3 ± 2.5	130.8 ± 2.9	126.4 ± 1.7
Residual gap (mm)					
Before abduction	5.4 ± 2.9	6.9 ± 3.6	6.5 ± 2.3	5.4 ± 2.1	5.9 ± 4.0
After abduction	1.5 ± 0.9	2.1 ± 1.3	1.4 ± 0.8	2.0 ± 1.2	1.0 ± 0.4
Amount of change†	3.9 ± 2.7	4.8 ± 2.9	5.1 ± 1.9	3.4 ± 1.3	4.9 ± 4.1

Values are presented as mean ± standard deviation.
AO/OTA: Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association, ANOVA: analysis of variance.
*One-way ANOVA, $p = 0.470$. †One-way ANOVA, $p = 0.334$.

IM nail during hip abduction, as the IM nail acts as an internal splint, and the proximal fragment exerts less abduction force as the attached hip abductor relaxes, resulting in a minimized lateral cortical gap. In this study, the lateral cortical gap decreased from 6.1 mm pre-abduction to 1.7 mm post-abduction. A recent study reported that a lateral cortical gap > 5 mm was one of the major risk factors for nonunion in SFFs, and another study reported that fracture site displacement in SFFs affected bone union.[9,28) Our study showed a high union rate of 97.8%, which may have been influenced by the minimal residual gap at the fracture site due to hip abduction. The gap-minimizing effect of hip abduction may be due to the increased tension of the adductor muscles attached to the medial side of the distal fragment as they are stretched and the resulting pulling force applied to the distal fragment; however, this requires further anatomical studies.

The advantages of this method are that it is simple and straightforward and can be applied to a wide range of fracture patterns. Previous techniques reported managing SFFs requires additional incisions and manipulation and a learning curve to safely and effectively perform the technique.[29)] The present method does not require an additional incision and requires only intraoperative hip abduction, which has a small learning curve and can be performed in a short time. Reduction with cerclage wires or cables may be difficult to apply to transverse fractures, and clamps may be difficult to apply to wedge-shaped fractures.[10,30)] SFFs occur as high-energy injuries in younger patients and low-energy injuries in older patients, resulting in various fracture patterns.[3)] The present study showed similar NSA increments and residual gap decrements for different SFF fracture patterns. Therefore, this method is expected to be widely and effectively used in SFFs.

Based on the authors' experience, a hip abduction of 25°–40° is necessary for successful application of this technique. If the abduction is insufficient, the abduction force on the proximal fragment generated by the stretched hip abductors will not diminish, which can lead to varus malalignment and a lateral cortical gap. In this study, we aimed to achieve maximum abduction based on the patient's hip laxity. Further studies are needed to validate the 25°–40° abduction range based on our observations. This technique mainly corrects varus malalignment in the coronal plane. Other MIR methods should be used in conjunction, as in this study, to correct flexion and external rotation deformities in the sagittal plane. It is also important to note that this technique is not intended as a primary solution for varus malalignment, but rather as a method to correct residual varus malalignment after other reduction techniques have been applied. While hip abduction technique may not be a definitive solution for all varus malalignment cases, it has been shown in practice to effectively reduce the lateral gap and correct residual varus malalignment. As the distal fragment of the SFF moves proximally during abduction, an IM nail of appropriate length should be used to consider the migration of the distal fragment. A lateral view of the femoral condyle area should be taken with the C-arm prior to abduction to ensure adequate bone stock distal to the nail tip because IM nails that are significantly long can cause cortical perforation of the nail tip after abduction. The method of forward or backward striking may be a good option for reducing the fracture site gap, and it is thought to be useful when used in combination with hip abduction, but further research is needed.

The limitations of this study include its retrospective design, small sample size, and the lack of a control group. SFFs are rare fractures, and although the patients were recruited over a 6-year period, the final cohort was relatively small. Subgroup comparisons based on the fracture patterns showed similar radiographic outcomes, which may have been underpowered by the small sample size. Although we did not have a direct control group using a different technique, we measured the alignment of the contralateral femur and used it as a reference for comparison, and we attempted to ensure objectivity of the results by measuring and presenting reduction quality using the same criteria as previous studies that performed MIR alone without hip abduction. The diameter of the IM nail and the canal may influence the correction of residual varus alignment during abduction. In this study, an IM nail with a diameter similar to the canal was inserted after 1.5 mm of over-reaming. Further studies should investigate whether the degree of varus alignment correction varies with the difference between the canal and IM nail diameters. The strengths of this study include the fact that a single surgeon used the same surgical technique and rehabilitation protocol, which minimized surgical bias and increased the homogeneity of the study cohort. Future prospective comparative studies involving a larger patient population and comparing to a group that did not perform the abduction method are warranted.

In conclusion, cephalomedullary fixation of the IM nail followed by hip abduction and insertion of distal interlocking screws in SFFs corrects the residual varus alignment and reduces the residual gap. This technique can be applied to various fracture patterns in a straightforward manner and may be useful for the reduction of SFFs.

CONFLICT OF INTEREST

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

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