



# Factors Associated with Mechanical Complications in Intertrochanteric Fracture Treated with Proximal Femoral Nail Antirotation

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**Purpose:** Although proximal femoral nail antirotation (PFNA; Synthes, Switzerland) has demonstrated satisfactory results when used for the treatment of intertrochanteric fractures, mechanical complications may occur. To better quantify the risk of mechanical complications when proximal femoral nail antirotation is used to treat intertrochanteric fractures, this study aimed to: (1) characterize the frequency of mechanical complications and extent of blade sliding and their correlation with reduction quality and (2) identify factors associated with mechanical complications.

**Materials and Methods:** A review of medical records from 93 patients treated for intertrochanteric fractures with a minimum of 6-months of follow-up between February 2014 and February 2019 was conducted. Blade position was evaluated using Tip-apex distance (TAD) and Cleveland index. The extent of blade sliding was evaluated using the adjusted Doppelt's method for intramedullary nailing. Individuals were classified as having or not having mechanical complications, and reduction quality and radiologic outcomes were compared between the two groups.

**Results:** Mechanical complications occurred in 12 of 94 hips (12.8%), with 11 out of 12 being from the intramedullary reduction group. There was no significant difference in TAD between groups; however, there were significant differences were noted in Cleveland index, AO/OTA classification, reduction quality and extent of blade sliding. The mean blade sliding distance was 1.17 mm (anatomical group), 3.28 mm (extramedullary group), and 6.11 mm (intramedullary group), respectively ( $P < 0.001$ ). Data revealed that blade sliding was an associated factor for mechanical complications (odds ratio 1.25, 95% confidence interval 1.03-1.51).

**Conclusion:** The extent of blade sliding determined using the adjusted Doppelt's method was significantly associated with mechanical complications suggesting that prevention of excessive sliding through proper intraoperative reduction is important to help achieve satisfactory treatment outcomes.

**Key Words:** Blade sliding, Femur, Hip fractures, Intramedullary reduction

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## INTRODUCTION

The number of osteoporotic hip fracture increases in the elderly population as life expectancy increases. Additionally, the incidence of osteoporotic hip fractures has also increased over the years<sup>1,2</sup>. The 1-year mortality rate following hip fractures in previous studies ranges from 8.4% to 36%<sup>3</sup>. The goal of treatment for hip fractures is to lower mortality rate through early recovery of ambulatory function<sup>4,5</sup>.

Patients with intertrochanteric fractures tend to be older and have more severe osteoporosis compared with patients with femoral neck fractures<sup>6,7</sup>. Although some studies report that arthroplasty is better for early rehabilitation, internal fixation using various devices is currently the treatment of choice for intertrochanteric fractures<sup>8</sup>. Cephalomedullary nailing has several advantages (e.g., shorter operating time, biomechanical stability) for the treatment of intertrochanteric fractures<sup>9,10</sup>. Among several types of cephalomedullary nails, proximal femoral nail antirotation (PFNA; Synthes, Solothurn, Switzerland) is characterized by the anti-rotation helical blade which is more resistant to rotational deformity compared with lag screws<sup>11,12</sup>.

Although the PFNA system has demonstrated satisfactory results, the rate of mechanical failure including nonunion, cut-through or cut-out, excessive migration of blade, peri-implant fracture and implant breakage ranges from 2.6% to 13%<sup>13,14</sup>. For the prevention of mechanical complications, appropriate fracture reduction and blade position are essential<sup>15,16</sup>. Anatomical reduction or extramedullary reduction with medial cortical overlap known as the Wayne-County technique are associated with biomechanical stability compared with intramedullary reduction<sup>17</sup>. Intramedullary reduction in comminuted intertrochanteric fractures without posteromedial cortical support is prone to excessive sliding and varus malposition of proximal fragment leading to mechanical failures. We hypothesized that the extent of blade sliding is different according to the reduction quality. In addition, we consider that excessive blade migration is a factor associated with mechanical complications.

Therefore, the purpose of this study was to: (1) determine the proportion of mechanical complications according to reduction quality and (2) to identify factors associated with mechanical complications in patients with intertrochanteric fracture treated by PFNA.

## MATERIALS AND METHODS

This study was approved by the Institutional Review Board (IRB) of Yeungnam University Medical Center, and the informed consent was waived by the IRB (YUMC 2020-03-012). A retrospective study was conducted at a tertiary referral hospital. Medical records and radiographs of patients who were surgically treated with PFNA for intertrochanteric fractures between February 2014 and February 2019 were evaluated. During the study period, all patients with intertrochanteric fractures who visited our institution underwent osteosynthesis surgery. Only patients treated with implants using a helical blade were included in this study. The inclusion criteria were: (1) over 55 years of age with osteoporotic intertrochanteric fracture due to low energy trauma like simple fall<sup>18</sup> and (2) minimum of 6-month post-surgical follow-up. Patients with high energy trauma, reoperation, subtrochanteric or atypical femoral fractures were excluded. During the study period, 491 patients (492 hips) underwent intramedullary nailing at our institution for treatment of intertrochanteric fractures; all surgeries were conducted by a single surgeon. Among these patients, 62 were excluded (62 hips) because they were not treated by implants with a helical blade. Of the remaining 429 patients (430 hips) who underwent surgery using PFNA, only 93 patients (94 hips) had at least 6 months of post-surgical follow-up and were thus included in the final analysis (Fig. 1). Of the 93 patients included, 22 and 71 were male and female, respectively; mean age at time of surgery was  $77.6 \pm 7.8$  years (range, 55.0-95.0 years). Mean body mass index was  $22.2 \pm 4.0$  kg/m<sup>2</sup> (range, 13.6-32.4 kg/m<sup>2</sup>) and the mean duration from admission to operation was  $1.11 \pm 1.5$  days (range, 0-6 days). Operations were not delayed beyond 48 hours as except in the rare case that patients were not able to undergo surgery because of poor general condition. The medical status of patients was evaluated according to the American Society of Anesthesiologists (ASA) classification and Charlson comorbidity index (CCI). The median preoperative ASA classification and CCI were 2.5 (range, 2-4) and 4.5 (range, 2-8), respectively.

All fractures were classified according to AO/OTA guidelines based on preoperative computed tomography scans; 31A2.2 was the most common classification (n=34 hips). The percentages of stable and unstable fractures were 40.4% and 59.6%, respectively according to the AO classification (31A1=stable; 31A2=unstable).

The mean postoperative follow-up period was 18.1 months (range, 6-56 months). PFNA nails with a centrum-collum-

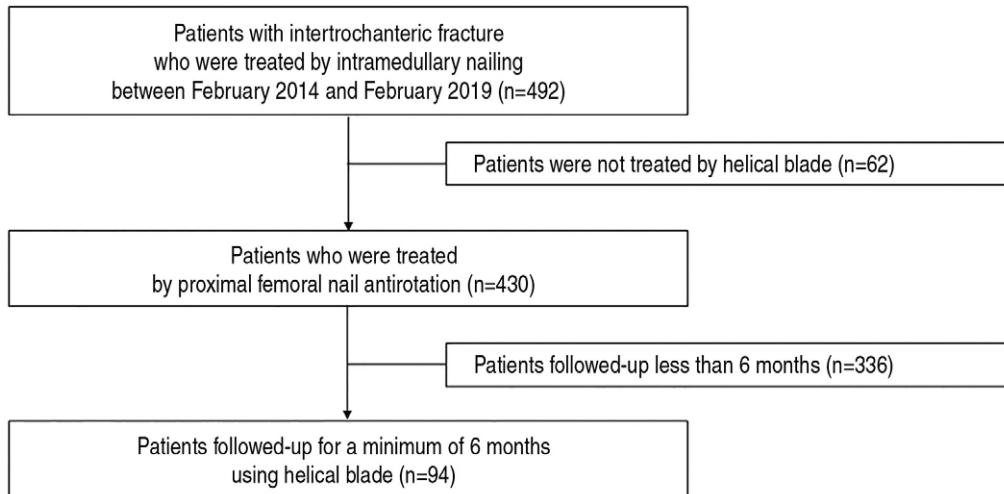


Fig. 1. Study flow chart.

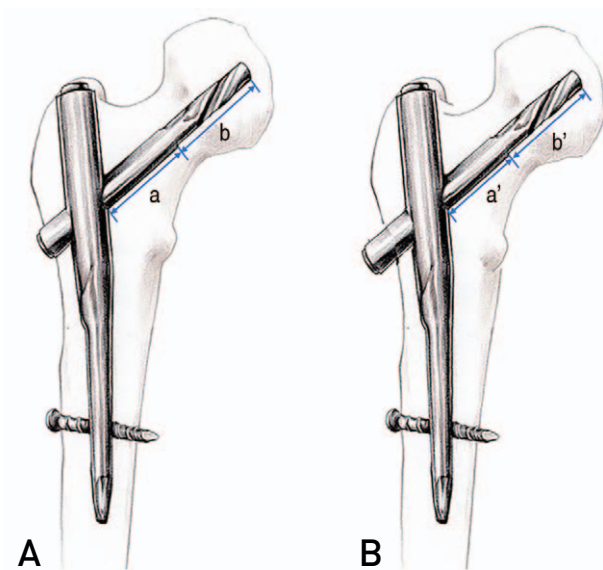


Fig. 2. Adjusted Doppelt's method for intramedullary nailing (A) immediate postoperative radiograph (B) subsequent radiograph after sliding. Correction factor= $b/b'$ , the extent of blade sliding= $a-(a' \times b/b')$ .

diaphyseal (CCD) angle of  $125^\circ$  or  $130^\circ$  were selected based on the CCD angle of the contralateral side. Nails with  $125^\circ$  and  $130^\circ$  CCD angles were used in 81 hips (86.2%) and 13 hips (13.8%), respectively.

Using radiographs gathered immediately after surgery, two independent orthopedic surgeons evaluated tip-apex distance (TAD)<sup>16)</sup>, blade position in the femoral head (using the Cleveland index)<sup>19)</sup> and classified fracture reduction quality into one of three categories (anatomical, extramedullary, and intramedullary) as described by Ito et al.<sup>15)</sup>. Intramedullary reduction classification required observation in at least one

of the anteroposterior and lateral radiographs. If the radiologic outcome was not in agreement, results were confirmed after discussion. The quality of reduction was anatomical reduction (n=23 hips), extramedullary reduction (n=25 hips), and intramedullary reduction (n=46 hips). Blade sliding was evaluated using the Doppelt's method adjusted suitably for intramedullary nailing comparing initial postoperative radiograph with the last follow-up (Fig. 2)<sup>20)</sup>. To minimize measurement error, femur rotation was confirmed by comparing the size of the lesser trochanter immediately after surgery to the radiograph captured at final follow-up. Mechanical complications included non-union, cut-out or cut-through, excessive migration of blade, peri-implant fracture, and implant breakage<sup>14)</sup>. Demographic data of patients according to reduction quality are summarized in Table 1.

Statistical analyses were performed with univariate comparisons using independent *t*-test or ANOVA test for continuous variables and chi-square test for categorized data. Then, multivariable logistic regression analyses were performed to identify potential factors associated with mechanical complications. Differences were considered significant if *P*-values were  $<0.05$ . All analyses were performed using IBM SPSS Statistics for Windows (ver. 20.0; IBM, Armonk, NY, USA).

## RESULTS

During the follow-up period, mechanical complications occurred in 12 of 94 hips (12.8%). Although TAD was measured as the mean  $20.1 \pm 5.07$  mm (range, 11-34 mm) in all patients, TAD exceeded 25 mm in 22 hips (23.4%). There was no significant difference in TAD between those with

and without mechanical complications. Blades were inserted into a safe zone (Cleveland zones 5, 6, 8, and 9) in 82 hips (87.2%). The proportion of AO/OTA classification and Cleveland index was significantly different between those with and without mechanical complications (Table 2).

Among the 12 hips with mechanical complications, bony union was achieved in 4 hips through a revision osteosynthesis operation within 6 months following the initial oper-

ation; treatment failure occurred in 8 hips (8.5%). Conversion to hip arthroplasty was performed in 5 patients due to cut-out or cut through and osteonecrosis of femoral head. An additional 3 patients refused to undergo additional operations. All patients achieved bony union at a mean of 7.2 months post operation except for those patients with treatment failure.

The mean distance of blade sliding was 1.17 mm, 3.28 mm,

**Table 1.** Patients Demographics

Characteristic	Anatomical (n=23)	Extramedullary (n=25)	Intramedullary (n=46)	P-value
Age (yr)	76.5±8.6	78.4±7.8	78.3±7.5	0.626
Sex				0.593
Male	6 (26.1)	4 (16.0)	12 (26.1)	
Female	17 (73.9)	21 (84.0)	34 (73.9)	
Laterality				0.261
Right	10 (43.5)	8 (32.0)	24 (52.2)	
Left	13 (56.5)	17 (68.0)	22 (47.8)	
BMI (kg/m <sup>2</sup> )	21.5±3.9	21.5±4.1	22.9±4.0	0.237
ASA classification	2.3±0.5	2.3±0.6	2.2±0.4	0.653
CCI	4.6±1.6	5.0±1.6	4.5±1.3	0.391
Anesthesia				0.959
General	19 (82.6)	20 (80.0)	38 (82.6)	
Regional	4 (17.4)	5 (20.0)	8 (17.4)	
Duration from admission to operation (day)	0.9±1.4	1.3±1.7	1.05±1.4	0.639
PFNA diameter				0.242
9 mm	0 (0)	1 (4.0)	2 (4.3)	
10 mm	5 (21.7)	12 (48.0)	17 (37.0)	
11 mm	11 (47.8)	7 (28.0)	16 (34.8)	
12 mm	7 (30.4)	5 (20.0)	11 (23.9)	
PFNA length				0.417
170 mm	4 (17.4)	2 (8.0)	7 (15.2)	
200 mm	19 (82.6)	20 (80.0)	36 (78.3)	
340 mm	0 (0)	3 (12.0)	2 (4.3)	
380 mm	0 (0)	0 (0)	1 (2.2)	
PFNA CCD angle				0.061
125°	18 (78.3)	20 (80.0)	43 (93.5)	
130°	5 (21.7)	5 (20.0)	3 (6.5)	
AO/OTA classification				0.001
31A1.2	20 (87.0)	1 (4.0)	8 (17.4)	
31A1.3	0 (0)	1 (4.0)	8 (17.4)	
31A2.2	3 (13.0)	12 (48.0)	19 (41.3)	
31A2.3	0 (0)	8 (32.0)	11 (23.9)	
31A3.3	0 (0)	3 (12.0)	0 (0)	
Stability of fracture				0.001
Stable	20 (87.0)	2 (8.0)	16 (34.8)	
Unstable	3 (13.0)	23 (92.0)	30 (65.2)	
Follow-up period (mo)	22.7±15.3	17.9±12.7	15.9±8.4	0.071

Values are presented as mean±standard deviation or number (%).

BMI: body mass index, ASA classification: American Society of Anesthesiologists classification, CCI: Charlson comorbidity index, PFNA: proximal femoral nail antirotation, CCD: centrum-collum-diaphyseal.

**Table 2.** Radiologic Outcomes between Groups with or without Mechanical Complications

Characteristic	Normal (n=82)	Mechanical complications (n=12)	P-value
TAD: tip-apex distance (mm)	20.9±4.9	21.6±6.5	0.708
Reduction quality			0.003
Anatomical	23 (28.0)	0 (0)	
Extramedullary	24 (29.3)	1 (8.3)	
Intramedullary	35 (42.7)	11 (91.7)	
Cleveland index			0.004
4	7 (8.5)	2 (16.7)	
5	43 (52.4)	1 (8.3)	
6	5 (6.1)	3 (25.0)	
7	1 (1.2)	2 (16.7)	
8	19 (23.2)	3 (25.0)	
9	7 (8.5)	1 (8.3)	
AO/OTA classification			0.001
31A1.2	23 (28.0)	0 (0)	
31A1.3	12 (14.6)	3 (25.0)	
31A2.2	31 (37.8)	3 (25.0)	
31A2.3	13 (15.9)	6 (50.0)	
31A3.3	3 (3.7)	0 (0)	
Stability of fracture			0.395
Stable	35 (42.7)	3 (25.0)	
Unstable	47 (57.3)	9 (75.0)	
The extent of blade sliding (mm)	3.5±2.9	8.1±5.7	0.018

Values are presented as mean±standard deviation or number (%).

TAD: tip-apex index.

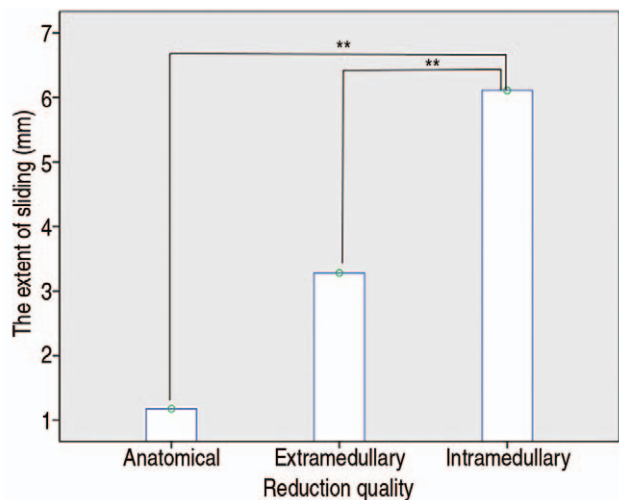
and 6.11 mm in the anatomical reduction, extramedullary reduction, and intramedullary reduction groups, respectively ( $P<0.001$ ) (Fig. 3).

There were no cases of mechanical complications in the anatomical reduction group. Although excessive blade sliding (>5 mm) occurred in 1 hip in the extramedullary reduction group, bony union was achieved after blade exchange to a shorter one was performed. Most mechanical complications occurred in the 11 hips in the intramedullary reduction group.

When patients were classified into two groups (i.e., those with and those without mechanical complications), a univariable analysis revealed significant differences in among the groups. Multivariable logistic regression analysis including these three factors (i.e., reduction quality, AO/OTA classification, extent of blade sliding), only the extent of blade sliding was associated with a mechanical complication after adjustment (odds ratio 1.25, 95% confidence interval 1.03-1.51) (Fig. 4).

## DISCUSSION

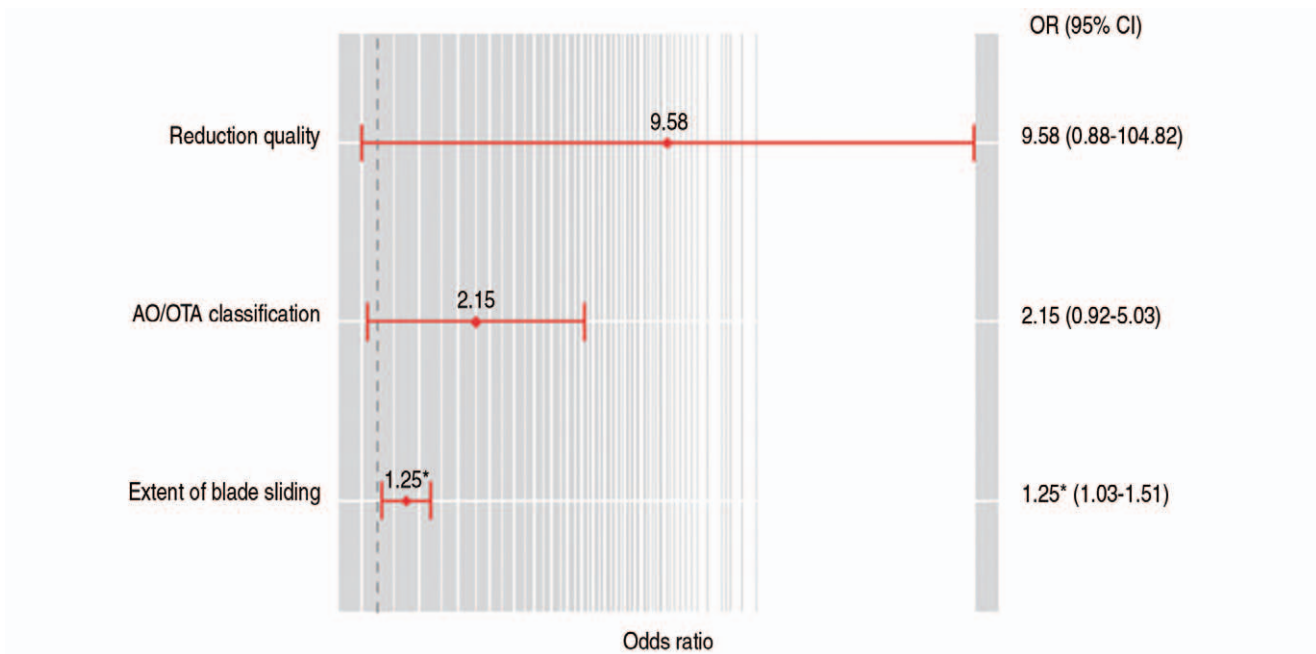
Internal fixation remains the treatment of choice for



**Fig. 3.** The extent of blade sliding according to reduction quality.

\*\*  $P<0.001$ .

intertrochanteric fractures, however some arthroplasty studies have demonstrated satisfactory results (e.g., mortality, risk of complications)<sup>21</sup>). Reduction quality is important during internal fixation, intramedullary reduction in commin-



**Fig. 4.** Odds ratio (OR) plot for mechanical complications.

CI: confidence interval.

\*  $P < 0.05$ .

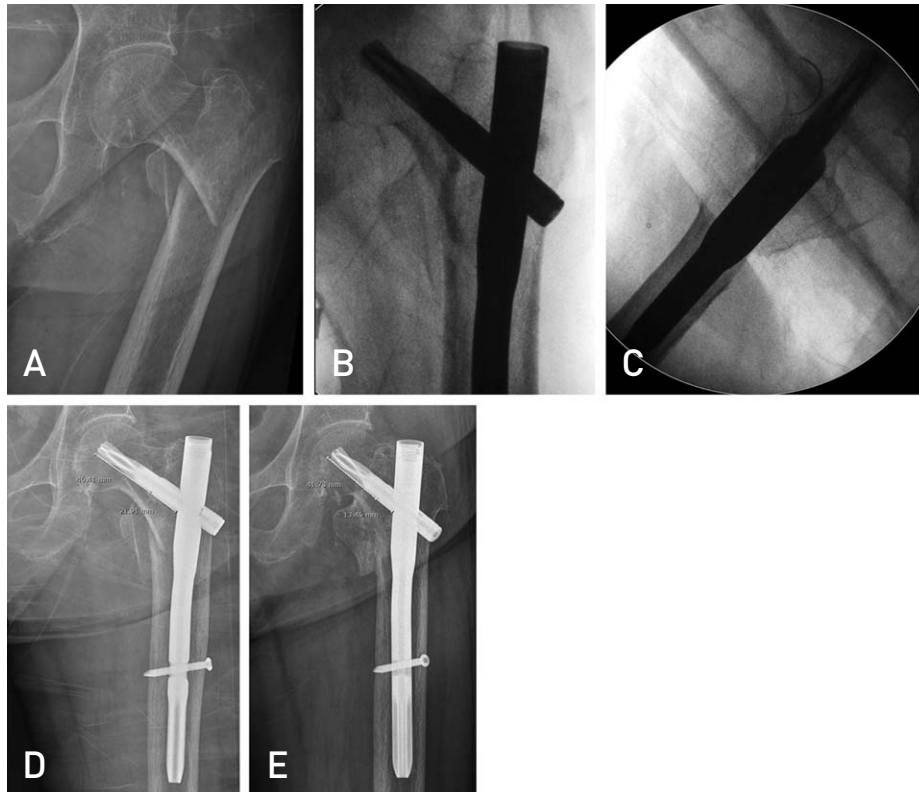
uted intertrochanteric fracture without posteromedial cortical support may lead to varus malposition of the proximal fragment. Excessive blade sliding—defined as sliding more than 5 mm—may eventually cause treatment failure<sup>22</sup>. In the present study, the extent of blade sliding occurred more frequently in the intramedullary reduction group compared with the two other groups. In addition, blade slides was identified as a factor associated with mechanical complications. To prevent excessive blade sliding, reduction quality is essential. In elderly patients with severe osteoporosis specifically, it is exceedingly difficult to achieve appropriate reduction of comminuted fragments in posteromedial cortex. Therefore, if anteromedial cortex is not reduced properly, treatment failure is likely<sup>23,24</sup>. Yoon et al.<sup>22</sup> emphasized the importance of achieving continuity of the medial and anterior cortical line in anteroposterior and axial images intraoperatively (Fig. 5).

Although the number of conversion arthroplasties included in this study was too small to identify statistical significance, all conversion arthroplasty occurred in the intramedullary group because cut-out eventually occurred due to excessive sliding in this group. On the other hand, blade exchange alone did not cause further sliding and bone union was achieved in the anatomical and extramedullary reduction groups; if blade sliding did occur in these groups, the blade was not able to slide excessively after the cortical apposi-

tion. However, blade sliding was not blocked by cortical apposition in the intramedullary reduction group, and after that, cut-out occurred following varus malposition and rotation of proximal fragment. A previous biomechanical study demonstrated results similar to those in the extramedullary reduction group which had better resistance against axial loading compared with the intramedullary reduction group<sup>17</sup>.

Implant design has been developing to prevent excessive sliding—namely sliding that adversely affects clinical results. Although this study only determined the results associated with blade-type cephalomedullary nails, Gamma nail (Stryker Trauma, Schoenkirchen, Germany), which is the lag-type screw cephalomedullary nail, early versions were associated with higher rates of cut-out compared with dynamic hip screw<sup>25</sup>. Gamma-3 nails, a third-generation version, employ a U-blade to withstand varus and rotational deforming force. Comparing the Gamma 3 nail without U-blade, U-blade significantly prevented lag screw sliding<sup>26</sup>. After all, surgeons must try to reduce sliding through appropriate reduction and implant design because the extent of blade or lag screw sliding is a risk factor for treatment failure in this study.

The present study had several limitations. First, the number of cases was small because the rate of follow-up loss and mortality in elderly patients with hip fractures were relatively high. Second, there might be selection bias because only patients followed-up for a minimum of 6 months were



**Fig. 5.** (A) A 75-year-old woman sustained a 31A2.2 intertrochanteric fracture. (B) Intramedullary reduction visual in an intraoperative anteroposterior radiograph. (C) Anterior cortical line was well reduced as noted in an intraoperative axial radiograph. (D, E) Bone union was achieved after 6.75 mm sliding of blade as noted by a comparison of a radiograph captured immediately after surgery to a radiograph collected 1-year postoperatively.

included. For this reason, the rate of treatment failure and mechanical complication was overestimated and higher than previous studies. Third, the reliability of radiologic and clinical outcomes as related to blade sliding (e.g., trochanter pain, limping) were not evaluated.

Nevertheless, the extent of blade sliding was more accurately assessed using the adjusted Doppelt's method for intramedullary nailing. In addition, the extent of sliding was deemed an important factor impacting treatment outcomes.

## CONCLUSION

The extent of sliding was significantly different depending on reduction quality, a factor associated with mechanical complications. Preventing excessive sliding through proper intraoperative reduction is important to achieve satisfactory treatment outcomes.

## CONFLICT OF INTEREST

The authors declare that there is no potential conflict

of interest relevant to this article.

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