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Postoperative Safety of Proximal Femoral Nail Anti-Rotation for Treating Intertrochanteric Fractures in Elderly Patients with Different Coronary Positions

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Abstract

Objective: Closed reduction and proximal femoral nail anti-rotation (PFNA) fixation are the primary surgical treatments for elderly intertrochanteric fractures. However, PFNA often requires a reliable lateral wall for secondary stability, which is compromised when coronal fracture lines are present. In previous studies, the impact of variations in coronal fracture lines on PFNA fixation has not been clearly defined. This study retrospectively analysed the clinical efficacy of PFNA for intertrochanteric fractures with different coronal fracture lines by dividing the enrolled patients into groups based on the location of the coronal fracture blocks using three-dimensional computed tomography.

Methods: This retrospective study enrolled 392 patients from June 2018 to January 2023, with 22 patients lost to follow-up because of death or other reasons. Patients with confirmed coronal fracture blocks, intact lateral walls and PFNA history were included. Relevant data, including surgical techniques and imaging findings, were obtained from the medical record management system of Ningxia Medical University General Hospital. The patients were confirmed to have intertrochanteric fractures, with coronal fracture blocks and intact lateral walls, and were divided into three groups based on the location of the coronal fracture blocks: anterior lateral (Group A), posterior lateral (Group B) and anterior plus posterior lateral (Group C). The inner boundary of the coronal fracture block on the anterior lateral aspect did not exceed the anterior intertrochanteric line, and the outer boundary did not exceed the anterior limit of the lateral wall. The inner boundary of the coronal fracture block on the posterior lateral aspect did not exceed the posterior intertrochanteric line, and the outer boundary was the posterior limit of the lateral wall. The duration of operation (DoO), incision length (IL), intraoperative blood loss (IBL) and lateral wall rupture (LWR) were assessed for each group. The patients were followed up 1 day, 6 months and 12 months after surgery to evaluate the impact of different coronary fracture lines on healing and functionality based on intraoperative and postoperative imaging findings and healing and functional scoring.

Results: All three groups were successfully followed up, with no significant differences in the follow-up time (Group A: 12.8 ± 2.7 months; Group B: 12.6 ± 2.4 months; Group C: 12.3 ± 3.1 months; all $p > 0.05$). No significant differences in age, body mass index or IL were observed among the groups (all $p > 0.05$). However, statistically significant differences in DoO, IBL and LWR were found. Specifically, DoO was longest in Group C compared with Groups A and B; IBL was highest in Group C and lowest in Group A (C > B > A); and LWR occurred more frequently in Group C than in Groups B and A (C > B > A). At the final follow-up, Lower Extremity Functional Scale scores were higher in Group A than in Groups B and C, and Visual Analogue Scale scores were higher in Group C than in Groups B and A. Harris scores were higher in Group A than in Groups B and C.

Conclusion: When anterior and posterior lateral coronal fracture lines are present, LWR is more likely to occur during surgery, leading to changes in the neck–shaft angle and calcar-referenced tip–apex distance and corresponding postoperative complications.

Keywords: Coronal Fracture; Lateral Wall; Neck–Shaft Angle; Intramedullary Nail

Introduction

Amidst the accelerating demographic shift towards an older population in China, the frequency of osteoporotic fractures has been on an uptrend. Hip fractures, the second most prevalent osteoporotic fracture, are expected to affect as many as 4.5 million individuals by 2050 [1].Notably, intertrochanteric fractures stand out as a common occurrence among the oldest age groups [2]. These fractures stem from a variety of incidents, most notably falls and vehicular collisions, and carry a mortality rate between 10%-30% [3]. For elderly patients, suffering from intertrochanteric fractures typically results in extended periods of bed rest, leading to grave complications like pressure sores, lower limb deep vein thrombosis, lung infections, and urinary tract infections[4]. Timely surgical management has been shown to mitigate these complications and enhance overall patient survival rates [5].

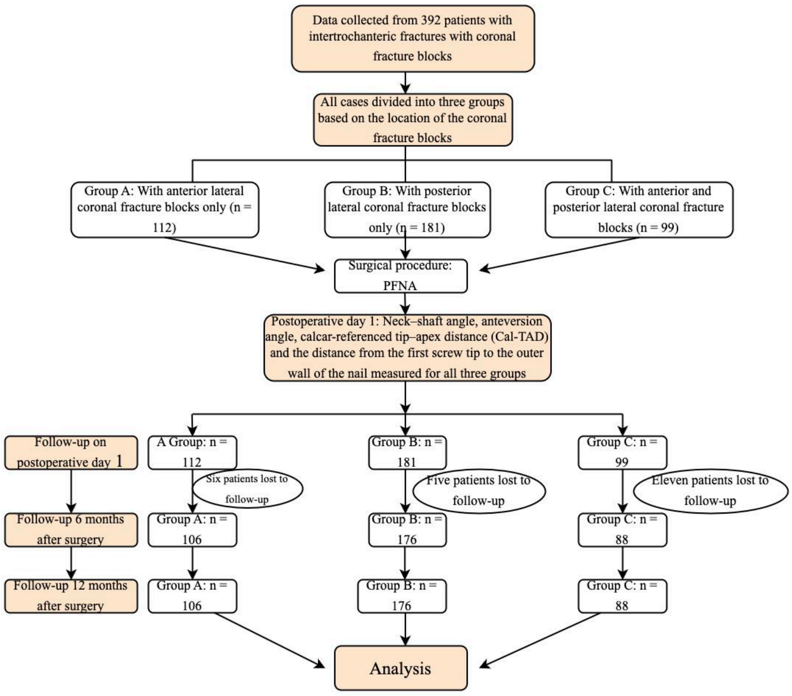
Fixation techniques for intertrochanteric fractures can be broadly categorised into intramedullary and extramedullary fixations. Gamma nails, proximal femoral nail anti-rotation (PFNA) and Intertan nails are commonly used for intramedullary fixation, whereas proximal femoral plates and dynamic hip screws are frequently used for extramedullary fixation. Although extramedullary fixation is preferred for stable intertrochanteric fractures, the failure rate of extramedullary fixation can be as high as 41.4% for unstable fractures[6] . Compared with extramedullary fixation, intramedullary nailing has several advantages, such as shorter duration of operation (DoO), faster resumption of full weight bearing, lower implant failure and reoperation rates and better postoperative functional recovery [6]. Specifically, PFNA is an intramedullary fixation technique superior to Intertan nails in terms of DoO, intraoperative blood loss (IBL), radiation exposure and simplicity of operation [7]. Therefore, PFNA is preferred for the treatment of intertrochanteric fractures in elderly patients. However, as clinical research progresses, it has been observed that PFNA is not a universal solution for intertrochanteric fractures. Literature reports indicate complication rates as high as 20.5%–24.2%, with a strong correlation between lateral wall damage and high failure rates[8]. Consequently, a large body of literature has reported favourable clinical outcomes using lateral wall protection plates and PFNA for the treatment of intertrochanteric fractures with lateral wall rupture (LWR). However, studies on the use of PFNA alone in cases of intertrochanteric fractures with intact lateral walls but coronal fracture lines and its potential impact on clinical efficacy are scarce.

This study analysed the clinical efficacy of PFNA as a single modality treatment for intertrochanteric fractures with different coronal fracture lines.

Patients and Methods

Study subjects: The inclusion criteria were as follows: (1) fresh unilateral intertrochanteric fracture, (2) presence of coronal fracture lines, (3) history of PFNA fixation, (4) intact lateral walls and (5) a follow-up period of at least 12 months. The exclusion criteria were as follows: (1) Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association 31-A3 intertrochanteric femoral fractures, (2) fractures accompanied by vascular or neural injuries, (3) pre-existing functional impairment of the hip joint and/or (4) patients lost to follow-up. The patients were divided into three groups based on the locations of the coronal fracture blocks relative to the intertrochanteric line on preoperative 3D-CT: Group A, anterior lateral; Group B,

The experimentation roadmap is as follows:



Posterior lateral; and Group C, anteroposterior lateral. All coronal fracture lines did not involve the lateral wall. This study was approved by the Ethics Committee of Ningxia Medical University General Hospital.

Surgical Procedures

All patients were positioned in supine traction on the operating table to receive epidural or general anaesthesia preoperatively, and traction reduction was performed under fluoroscopy. After satisfactory reduction, the affected limb was routinely sterilised, and draping was performed. The incision started from the apex of the greater trochanter and extended approximately 5 cm proximally longitudinally. A guide pin was inserted through the opening at the apex of the greater trochanter, and under fluoroscopic guidance (anteroposterior and lateral views), the guide pin was positioned within the medullary canal. Using a hollow drill, the medullary canal was then expanded. The size and length of the intramedullary nail were determined based on preoperative measurements of the medullary canal. Using an aiming device at the proximal end, a helical blade guide pin was drilled into the medullary canal. The anteversion was adjusted to achieve a calcar-referenced tip–apex distance (Cal-TAD) of <30 mm. Once in position, an appropriate helical blade was inserted. As long as the distal end was secured, the helical blade was locked. The end cap was then installed. Fracture reduction and internal fixation were assessed under a fluoroscope, and the incision was irrigated before closing layer by layer.

Senior surgeons with comparable levels of expertise performed all surgical procedures, and the patients followed similar rehabilitation protocols. One week after surgery, the patients were assisted in ambulation using a walking aid. X-rays were taken 1 day, 6 - months and 12 months after surgery for recovery assessment based on hip joint function and radiographic parameters.

Clinical Observation: Basic patient data, including age, sex and body mass index (BMI), were collected from all three groups. Perioperative data included incision length (IL), IBL, DoO and LWR occurrence on postoperative day 1. Measurements were taken on X-rays 1 day, 6 months and 12 months after surgery, including the neck–shaft angle, anteversion angle and Cal-TAD. Lower extremity function, hip joint function and pain levels were evaluated using the Lower Extremity Functional Scale (LEFS), Harris Hip Scale (HHS) and Visual Analogue Scale (VAS) 6 and 12 months after surgery. The neck–shaft angle, anteversion angle and Cal--TAD were measured on standard anteroposterior and lateral X-ray images. The neck–shaft angle was measured as shown in Figure 1, where the AO line represents the femoral neck axis, the AOC line denotes the femoral shaft axis, and the AOC is defined as the neck–shaft angle. Loss of the neck–shaft angle greater than 10° was defined as reduction loss. Cal-TAD, which is an important prognostic parameter, was measured as proposed by Kuzyk [6]. As shown in Figure 2, the AT segment of the TAD is expressed by the BT value in the anteroposterior view, whereas the TAD is measured using the lateral view. The Harris Hip Score is classified as excellent (90–100), good (80–89), fair (70–79) and poor (<70). The LEFS is scored on a scale of 0 to 80, with scores of 70–80, 60–69 and 50–59 indicating excellent, good and poor lower extremity function, respectively. Regarding the postoperative evaluation criteria, the neck–shaft angle, anteversion angle and Cal-TAD were measured for postoperative evaluation, with the values at postoperative day 1 as baseline values. A neck–shaft angle < 3° was defined as normal, 3–5° as acceptable and >5° as poor. An anteversion angle < 3° was defined as normal, 3–5° as acceptable and >5° as poor. A Cal-TAD < 30 mm was defined as normal, 31–35 mm as acceptable and >35 mm as poor. Considering that screw back-out is unlikely during the early postoperative stage, measurements were taken 6 and 12 months after surgery by measuring the vertical distance between the upper and lower edges of the head screw to the nail (i.e. EF + GH) and averaging the results to reduce errors (Fig. 3). A screw back-out distance < 5 mm was defined as normal, 5–10 mm as acceptable and >10 mm as poor.

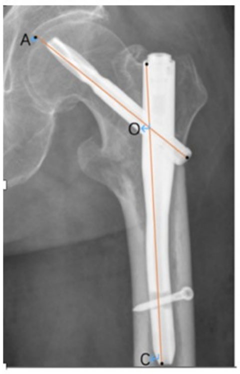


Figure 1

Figure 2

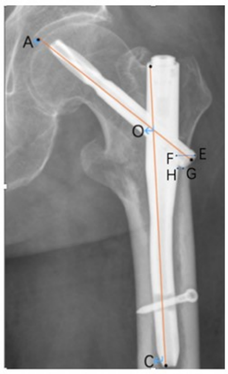


Figure 3

Statistical Analysis: Data analyses were performed using Statistical Package for the Social Sciences, version 26.0. Measurement data are expressed as means ± standard deviations (x ± s), and comparisons were made using one-way analysis of variance. Categorical data are presented as percentages or ratios (%), and comparisons were performed using the chi-square test or Fisher's exact probability test. P-values < 0.05 were used to denote statistical significance.

Results

No statistically significant differences in age, BMI and IL were observed between the three groups (all p > 0.05). For Groups A, B and C, ILs were 5.58 ± 0.86 cm, 5.29 ± 0.96 cm and 5.63 ± 0.96 cm, respectively; DoO was 76.26 ± 13.31b min, 71.51 ± 9.11b min and 86.94 ± 19.56a min, respectively; IBL was 105.60 ± 19.94c mL, 117.79 ± 13.95b mL and 128.89 ± 11.72a mL, respectively. These perioperative data significantly differed among the three groups. Pairwise comparisons showed that Group C had a longer DoO than Groups A and B; Group C had higher IBL than Group B, and Group B displayed higher IBL than Group C; LWR was more prevalent in Group C than in Group B and was least prevalent in Group A.

Table 1: Comparative analysis among the three groups

Group	Age	BMI (kg/m²)	Incision length (cm)	DoO (min)	IBL (mL)	LWR
Group A	72.82 ± 5.49	21.14 ± 1.65	5.58 ± 0.86	76.26 ± 13.31[b]	105.60 ± 19.94[c]	1.02 ± 0.14[c]
Group B	73.50 ± 6.69	21.11 ± 1.71	5.29 ± 0.96	71.51 ± 9.11[b]	117.79 ± 13.95[b]	1.23 ± 0.43[b]
Group C	72.70 ± 5.19	21.29 ± 2.12	5.63 ± 0.96	86.94 ± 19.56[a]	128.89 ± 11.72[a]	1.46 ± 0.50[a]
F	0.364	0.164	2.725	20.659	30.41	16.052
P-value	0.695	0.848	0.068	0.000**	0.000**	0.000**

*$p < 0.05$, **$p < 0.01$; BMI, body mass index; DoO, duration of operation; IBL, intraoperative blood loss; LWR, lateral wall rupture.

On postoperative day 1, no statistically significant differences in the neck–shaft angles were observed between Groups A, B and C (p > 0.05). At 6 and 12 months postoperatively, the neck–shaft angle showed statistically significant differences among the three groups (p < 0.05). Specifically, Group C had a lower neck–shaft angle than Groups A and B. In Group C, significant differences in the neck–shaft angle were observed at different time points (p < 0.05). Notably, the neck–shaft angles at 6 and 12 months were lower than those at 1 day postoperatively (p < 0.05). Although the neck–shaft angles in Groups A and B decreased over time, no statistically significant differences were observed between the two groups (p > 0.05).

Table 2: Comparison of neck–shaft angles among the three groups

Group n	1 day	6 months	12 months	P-value
Group A 106	128.66 ± 6.34	127.21 ± 6.51	125.78 ± 6.93	0.096
Group B 106	128.86 ± 6.69	127.39 ± 6.38	126.44 ± 6.50	0.051
Group C 106	128.72 ± 6.67	125.14 ± 6.77	122.93±6.53	0.000**
P	0.984	0.116		0.009**

*p < 0.05, **p < 0.01.

On postoperative day 1, no statistically significant differences in anteversion angles were observed between the three groups (p > 0.05). Intragroup comparison results showed no statistically significant difference in the anteversion angles at different time points (all $p > 0.05$).

Table 3: Comparison of the anteversion angles among the three groups

Group	1day	6 months	12 months	*P-value*
Group A	12.35 ± 1.29	12.47 ± 1.53	12.58 ± 1.54	0.729
Group B	12.42 ± 1.22	12.67 ± 2.12	12.76 ± 1.91	0.442
Group C	12.28 ± 1.36	12.69 ± 2.32	13.10 ± 2.06	0.099
p-value	0.822	0.828	0.351	

*$p < 0.05$, **$p < 0.01$.

On postoperative day 1, no statistically significant differences in Cal-TAD were observed between Groups A, B and C ($p > 0.05$). At 6 months postoperatively, no statistically significant differences in Cal-TAD were observed among the three groups ($p > 0.05$). At 12 months postoperatively, statistically significant differences in Cal-TAD were found among the three groups ($p < 0.05$). The LSD test results showed that Group C had a greater Cal-TAD than Groups B and A (C > B > A). For Group A, no statistically significant differences in Cal-TAD were observed at different time points ($p > 0.05$). For Groups B and C, statistically significant differences in Cal-TAD were observed at different time points ($p < 0.05$).

Table 4: Comparison of Cal-TAD among the three groups

Group	1 day	6 months	12 months	P-value
Group A	23.90 ± 1.87	24.34 ± 1.62	24.72 ± 1.68	0.062
Group B	23.98 ± 3.26	24.64 ± 2.97	25.99 ± 3.27	0.000**
Group C	23.54 ± 2.40	24.94 ± 2.30	27.11 ± 2.47	0.000**
p-value	0.634	0.466	0.000**	

*$p < 0.05$, **$p < 0.01$.

Because screw back-out typically occurs during postoperative weight-bearing activities, severe screw back-out events were reported in 1 patient in Group A, 2 patients in Group B and 13 patients in Group C at 6 and 12 months postoperatively. The pairwise comparison results showed no statistically significant differences between Groups A and B (p > 0.05). In contrast, statistically significant differences were observed between Groups B and C and between Groups C and A (p < 0.05, respectively).

Table 5: Comparison of screw back-out rates among the three groups

Group	N	Normal	Acceptable	Poor	Overall response rate	Comparison	*P*-value
Group A	106	101 (95.3)	4 (3.8)	1 (0.9)	105 (99.1)	I	>0.05
Group B	176	169 (96.0)	5 (2.8)	2 (1.2)	174 (98.8)	II	>0.01
Group C	88	70 (79.5)	5 (5.6)	13 (14.9)	75 (85.1)	III	>0.01

Note: I: Comparison between Groups A and B. II: Comparison between Groups B and C. III: Comparison between Groups C and A.

At 6 months postoperatively, Group A had a higher LEFS score than Groups B and C; Group C had a higher VAS score than Groups B and A (C > B > A); and Group A had a higher HHS score than Groups B and C. At 12 months postoperatively, the LEFS score was higher in Group A than in Groups B and C; the VAS score was higher in Group C than in Groups B and A; and the HHS score was higher in Group A than in Groups B and C. The LEFS and HHS scores at 12 months were higher than those at 6 months in Groups A, B and C. The VAS scores at 6 months were higher than those at 12 months in the three groups.

Table 6: Comparison of LEFS, VAS and HHS scores among the three groups at different time points

Group	LEFS score			VAS score			HHS score		
	6 months	12 months	*P-value*	6 months	12 months	*P*-value	6 months	12 months	*P*-value
Group A	70.38 ± 3.00a	74.62 ± 2.77a	0.000**	1.74 ± 0.66c	0.94 ± 0.47c	0.000**	79.22 ± 6.31a	87.06 ± 5.89a	0.000**
Group B	68.84 ±3.56b	73.44 ± 2.70b	0.000**	2.35 ± 0.87b	1.28 ± 0.66b	0.000**	73.14 ± 3.81b	80.26 ± 4.50b	0.000**
Group C	67.85 ± 3.09b	72.48 ± 2.20c	0.000**	2.89 ± 0.79a	1.52 ± 0.64a	0.000**	72.82 ± 2.36b	80.04 ± 3.31b	0.000**
P-value	0.001**	0.000**		0.000**	0.000**		0.000**	0.000**	

Discussion

PFNA has become an extensively used surgical treatment for intertrochanteric fractures [7]. Compared with extramedullary fixation, PFNA is characterised by reduced DoO, IBL, implant failure and reoperation rates and better postoperative functional recovery [10]. Furthermore, PFNA aligns more closely with human biomechanics because its helical blade provides a broad surface area, which ensures maximum bone compression and anchoring force, making it particularly suitable for elderly patients with osteoporosis[11].

However, PFNA is a sliding compression intramedullary fixation system in which, upon weight bearing, compression applies between the fracture blocks towards the first nail, thereby achieving secondary stability of the fracture[12]and promoting fracture healing. Complete support on the anterior and posterior aspects of the intertrochanteric region provides excellent secondary stability. When support is simultaneously lacking on the anterior and posterior aspects, as seen in the presence of anterior and posterior coronal fracture lines, the risk of internal fixation failure increases. As shown in Figure 5 the patient had an intertrochanteric fracture with an intact lateral wall and anterior and posterior coronal fracture lines. Although satisfactory reduction and PFNA fixation were achieved during surgery, gradual nail loosening and limb shortening occurred after 3 months of postoperative weight-bearing activities, suggesting that the formation of secondary stability is delayed because of the presence of anterior and posterior coronal fracture lines. In this study, all patients in Group C had anterior and posterior coronal fracture lines, and the internal fixation failure rate in this group was significantly higher than that in Groups A and B.

Moreover, coronal fracture lines weaken the lateral wall[13].which provides lateral support for the femoral head–neck block and the intramedullary nail, representing a crucial factor in the 'three-point stability theory' of PFNA [14]. When the weakened lateral wall experiences iatrogenic or postoperative weight-bearing-induced rupture, the pendulum effect occurs[15], which increases the risk of internal fixation failure [10]. Studies have confirmed that the complication rate of PFNA is significantly higher (20.5%–24.2%) when the lateral wall becomes weak or ruptured [8]. As shown in Figure 4, the lateral wall is weakened by the fracture. Although the reduction achieved a satisfactory neck–shaft angle, iatrogenic or postoperative LWR eventually resulted in internal fixation failure and fracture displacement[14] .The 2018 classification system[16] for intertrochanteric fractures has redefined fractures that involve the lesser trochanter. What was previously categorized as A2.1 is now designated as the simpler A1.3 type. This amendment, which considers the lateral wall's role, underscores the critical importance of maintaining the lateral wall's integrity[17] .

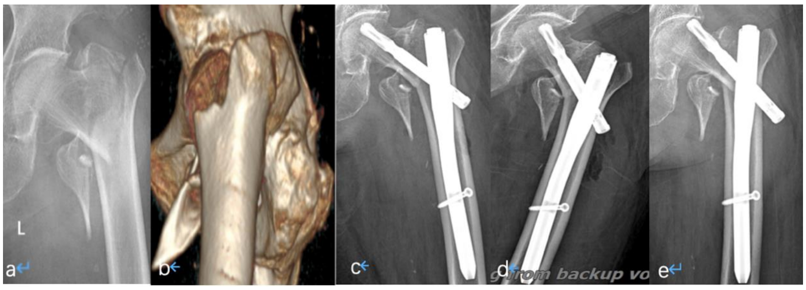


Figure 4: A 73-year-old male diagnosed with an intertrochanteric fracture. (a–b) Preoperative imaging showing intertrochanteric fracture with coronal fracture. (c) X-ray at 1 day postoperatively; (d–e) X-rays at 6 and 12 months postoperatively, showing screw cut-out and back--out.

In this study, the Cal-TAD, instead of the TAD, was selected as an outcome measure because the TAD is measured based on the centre vertex of the femoral head without considering the screw's lower position in three-dimensional space. This cannot sufficiently explain the better stability with TAD > 25 mm, which is attributed to the slightly lower screw placement [18]. Kashigar et al. [14]retrospectively analysed 170 patients with intertrochanteric fractures and found that Cal-TAD was the only parameter that could predict screw cut-out, which exhibited the best consistency among different observers.

One limitation of this study is that all patients were from a single trauma centre. More extensive multi-centre samples are required to validate our findings. Furthermore, retrospective studies are more susceptible to the influence of missing data, bias and confounding factors. Furthermore, some patients in this study did not undergo postoperative computed tomography scans, leading to the evaluation of the femoral lateral wall relying solely on X-rays, introducing a certain degree of deviation. [15-18].

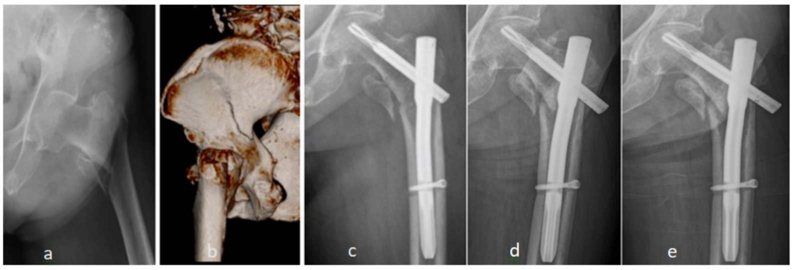


Figure 5: An 81-year-old female diagnosed with an intertrochanteric fracture accompanied by a coronal fracture block. (a–b) Preoperative imaging showing intertrochanteric fracture with coronal fracture. (c) X-ray at 1 day postoperatively; (d–e) X-rays at 6 and 12 months postoperatively, showing neck–shaft angle shortening and nail back-out.

When the lateral wall is intact, the dynamic hip screw (DHS) continues to be recognized as the "gold standard" for surgical intervention in intertrochanteric fractures[19] . Nonetheless, DHS is associated with an increased rate of failure in cases where the lateral wall is compromised, as it is less capable of withstanding rotational forces and due to its design, which involves eccentric fixation. The proximal femoral nail antirotation (PFNA), a form of intramedullary fixation, has been shown to deliver positive outcomes in the clinical management of intertrochanteric fractures [20]. Instances of successful lateral wall reconstruction have been documented following the application of PFNA in scenarios where the lateral wall has been breached, leading to enhanced stability. Despite this progress, there remains a lack of consensus both nationally and internationally on the appropriate intervention for intertrochanteric fractures characterized by an intact but thinned lateral wall due to coronal fractures affecting both the anterior and posterior aspects. Further research is required to validate the efficacy of proactively affixing a steel plate to the anterolateral aspect as a means to augment the lateral wall's thickness and strength during PFNA procedures.

In conclusion, intramedullary nailing is the preferred treatment for intertrochanteric fractures. However, when accompanied by a coronal fracture block, the lateral wall is prone to rupture during or after surgery, leading to a higher incidence of complications. In this case, preoperative three-dimensional computed tomography should be performed to identify the position and shape of the coronal fracture block and to achieve lateral wall protection during surgery. Alternatively, further studies are required to investigate the fixation of the coronal fracture block before implanting the intramedullary nail.

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