 Acta Chir Orthop Traumatol Cech., 91, 2024, No. 5, p. 289–295
DOI: 10.55095/ACHOT2024/054

ORIGINAL PAPER
PŮVODNÍ PRÁCE

Risk Factors for Early Implant Failure in Geriatric Intertrochanteric Fractures Treated with Twin Interlocking Derotation and Compression Screw Cephalomedullary Nail (InterTAN)

Rizikové faktory časného selhání implantátu u geriatických intertrochanterických zlomenin léčených krátkým zajištěným nitrodřeňovým hřebem se zdvojeným kompresním a derotačním krčkovým šroubem (InterTAN)

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ABSTRACT

PURPOSE OF THE STUDY

Intertrochanteric hip fractures in elderly patients are a significant cause of morbidity and mortality, with increasing incidence due to the aging population. Despite advancements in intramedullary nailing (IMN) technology, fixation failure remains a concern. This study aims to evaluate pre-and postoperative radiographic risk factors for varus collapse in geriatric intertrochanteric fractures treated with twin interlocking derotation and compression screw cephalomedullary nail (InterTAN, Smith & Nephew).

MATERIAL AND METHODS

This retrospective study included patients over 60 years with AO 31A1 and 31A2 intertrochanteric femur fractures treated with InterTAN at a tertiary referral center from August 2012 to August 2017. Patients with high-energy fractures, AO 31A3 fractures, or those requiring open reduction were excluded. Data on demographics, fracture classification, implant sizes, imaging studies, and follow-up were collected. Radiographic assessments included Chang's medial cortical support concept, tip-apex distance (TAD), calcar-referenced TAD (CalTAD), neck-shaft angles (NSA), and screw placement according to Cleveland zones. Varus collapse was defined as a >5° change in NSA within three months postoperatively. Multivariate logistic regression analysis was used to identify risk factors for varus collapse.

RESULTS

The study included 136 patients with a mean age of 79.8 years, of whom 38.2% were male. The early postoperative tip-apex distance (TAD) averaged 21.9 mm, with 30.1% of patients experiencing varus collapse greater than 5°. Positive medial cortical support (PMCS) or neutral position (NP) type reduction was highly protective against varus collapse ($p < 0.001$), as well as TAD less than 25 mm ($p < 0.001$). Additionally, the placement of screws in the central-central or central-inferior zones provided a protective effect against varus collapse ($p = 0.031$). Conversely, having an OTA/AO type A2.2 or A2.3 fracture significantly increased the risk of varus collapse ($p = 0.030$). Other factors, such as CalTAD and the nail width to medullary canal ratio, did not significantly predict varus collapse ($p = 0.831$ and $p = 0.952$, respectively).

DISCUSSION

Our findings align with previous studies highlighting TAD and screw placement as critical factors in preventing fixation failure. The protective effect of PMCS or NP reduction and the increased risk associated with OTA/AO type A2.2 and A2.3 fractures are noteworthy. Unlike previous studies, CalTAD was not significantly associated with varus collapse in our cohort. The study underscores the importance of surgical technique and radiographic parameters in optimizing outcomes for elderly patients with intertrochanteric fractures.

CONCLUSIONS

In elderly patients treated with InterTAN nails, varus collapse is influenced by fracture type, TAD, reduction quality, and screw placement. Ensuring a TAD <25 mm, achieving PMCS or NP reduction, and placing screws in central-central or central-inferior zones are crucial for minimizing varus collapse. These findings highlight the importance of meticulous surgical technique and radiographic assessment in managing intertrochanteric fractures in the elderly.

Key words: hip fractures, intertrochanteric fractures, internal Fixation, geriatrics, cephalomedullary nail.

INTRODUCTION

Intertrochanteric hip fractures are prevalent low-energy fractures in elderly patients and are a significant cause of morbidity and mortality within this population (1). As the elderly demographic grows globally, the incidence of hip fractures and related surgeries is projected to increase (13, 16, 18). Despite advancements in intramedullary nailing technology, failure of fixation due to both patient and surgeon-related factors remains a concern (11) and risk factors for fixation failure is still debated (14, 24, 27, 29).

Various classification systems exist for intertrochanteric hip fractures, with the Evans classification and the AO/ASIF classification being the most frequently utilized (10). The Evans classification categorizes these fractures according to fracture line and mechanical stability, whereas the AO/ASIF classification(21) divides proximal femur fractures (AO 31) into groups A, B, or C with increasing severity, further sub-classified into subgroups 1, 2, or 3. Both of these classification systems indicate that instability and risk of complications increase with fracture severity.

Elderly patients often present with multiple comorbidities and fragile osteoporotic bone, making early mobilization a critical treatment goal. Consequently, traditional methods like spica casting or prolonged bed rest are reserved for high-risk patients and rarely employed. Operative treatment of these fractures is typically achieved through internal fixation or arthroplasty. Among internal fixation methods, dynamic hip screws (DHS) and intramedullary nailing (IMN), are the most common techniques (25). Evidence suggests that IMN may have lower complications and reoperation rates than DHS, at least for unstable fractures (4, 12, 20). In our institution, most patients with intertrochanteric fractures are treated with IMN, specifically InterTAN (Smith & Nephew, Memphis, Tennessee, USA).

Complications of IM nailing include cut-out, implant breakage, periprosthetic fractures, nonunion, superficial wound infection, hematoma, hip pain, femoral neck shortening, deep venous thrombosis, and pulmonary embolism (30). Failed osteosynthesis leads to increased morbidity and mortality; therefore, identifying the risk factors that may lead to failure are of main concern to surgeons (28). Research has shown that fracture type, the position of the screws, and tip-apex distance (TAD), as defined by Baumgartner (2), are important surgeon-related factors that may increase the risk of varus collapse and cut-out (23). High body-mass index and basicervical type of fracture are also associated with higher complications rates (24).

Cut-out occurs in the early postoperative period, before union, as the screws in the osteoporotic neck lose their purchase and cut through the superior cortex of the femoral neck with load-bearing. The most common mechanism for this fixation failure is the collapse of the femoral head and neck into a varus position relative to the femoral shaft (9). The objective of this study is to evaluate pre-and postoperative radiographic risk factors for varus collapse in geriatric intertrochanteric fractures treated with twin interlocking derotation and compression screw cephalomedullary nail (InterTAN, (Smith & Nephew, Memphis, Tennessee, USA)

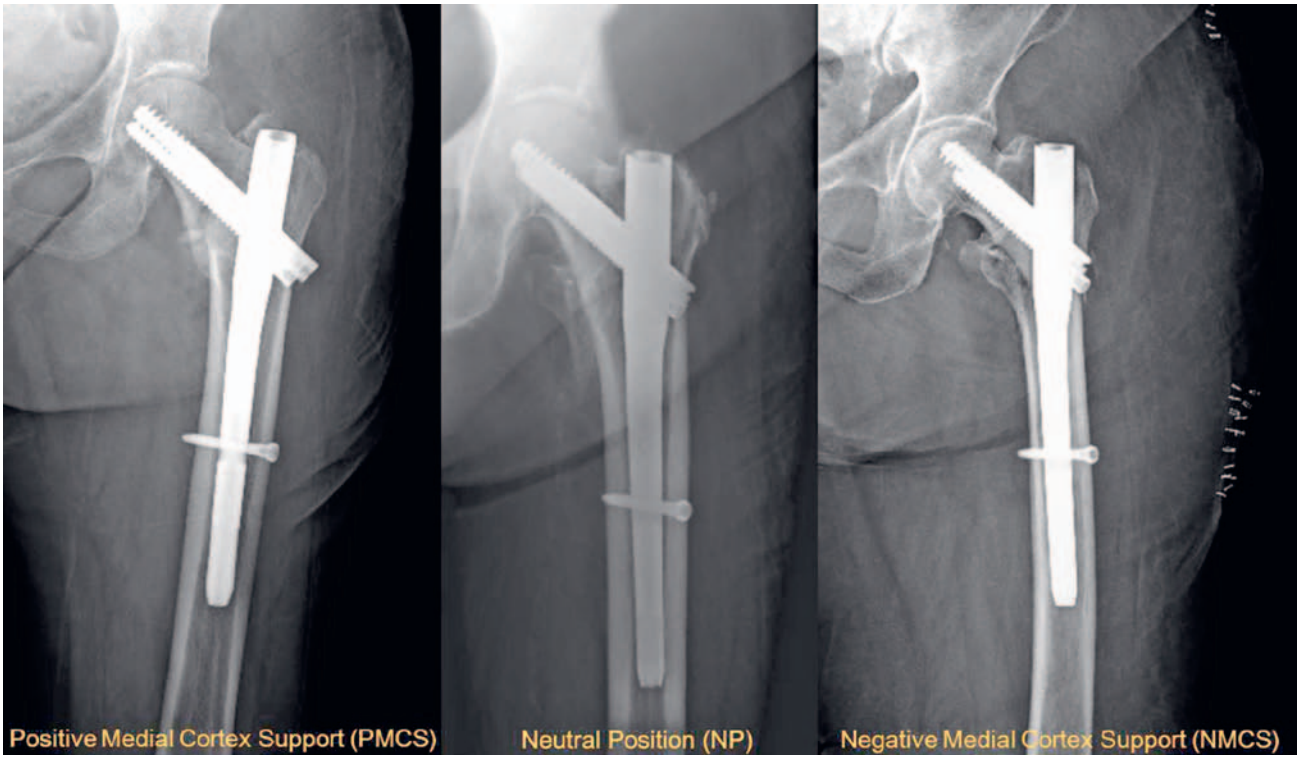

Fig. 1. Type of reduction according to Chang classification.

MATERIAL AND METHODS

This study is an IRB-approved retrospective review of all patients operated with AO 31A1 and 31A2 type intertrochanteric femur fractures in patients older than 60 at a single tertiary referral center from August 2012 to August 2017. Informed consent was obtained from all patients or legal guardians. Patients younger than 60, those with fractures secondary to high-energy injuries, those treated with modalities other than InterTAN, those with AO 31A3 (reverse oblique type) fractures, or those requiring open reduction were excluded. Data on age, sex, implant sizes, imaging studies, and follow-up notes were retrieved from electronic archives.

Pre-operative pelvic hip x-rays and traction x-ray radiographs were present for all patients. Fractures were classified based on AO/ASIF classification. All cases were operated using the same surgical technique. Patients were prepared supine under spinal anesthesia on a traction table. Before prepping the patient, the C-arm and traction table position were confirmed to allow perfect AP and lateral views. An acceptable closed reduction was achieved in all patients before proceeding, usually with moderate traction and rotation as dictated by fracture configuration. The incision was made starting from 2 cm proximal to the tip of the trochanter, curving slightly posteriorly. After incising the fascia, the tip of the trochanter major was reached with blunt dissection. A guide wire was inserted from the tip under C-arm control and sufficiently advanced. The medullary canal was reamed until the level of the lesser trochanter. No further reaming was done. A 10 or 11.5 mm nail was then selected and gently inserted. The reduction was controlled with a C-arm. Appropriate proximal and distal locking was performed. Short InterTAN (Smith & Nephew, Memphis, TN) was used in all patients without locking the set screw.

All patients were ordered bed rest on the day of the operation and were mobilized on postoperative day 1 using walkers. Patients were put on partial weight-bearing for six weeks. No particular physical therapy or strengthening regimen was used. Following discharge, patients were followed up at three weeks, six weeks, three months, six months, one year, and two years. The minimum follow-up was two years.

Quality of reduction (QoR) was assessed using Chang's positive/negative medial cortical support concept (6) (Fig. 1). Quality of fixation (QoF) was assessed using the tip-apex distance (Fig. 2) (2), calcar referenced tip-adex distance (CalTAD) (17), immediate post-operative neck-shaft angles (NSA) and placement of screws according to Cleveland et al. (8). Dorr types of the proximal femora and nail width to medullary canal ratio (Fig. 3) at the level of the distal screw were recorded as additional variables in the analysis. All size measurements were adjusted to compensate for 120% magnification (22). NSA measurements were repeated at a 3-month follow-up. Five degrees in the neck-shaft angle between the early postoperative period and the three months following was recorded as varus collapse (7). Cut-out was defined as a protrusion of the screw past the subchondral part of the femoral neck on either projection. The time to cut-out was recorded.

The data were analyzed by descriptive statistical methods (mean, standard deviation, median, frequency, percentage, minimum, maximum). The fit of quantitative data to the normal distribution was tested using the Shapiro-Wilk test. Multivariate logistic regression were used to assess the risk factors influencing the varus collapse. Statistical analyses were performed using SPSS version 20.0 (SPSS, Chicago, IL). A p-value of < 0.05 was considered statistically significant.

RESULTS

The average age of the patients was 79.8 (range, 60–97). Of the patients, 52 (38.2%) were male and 84 (61.8%) were female. The left side was affected in 73

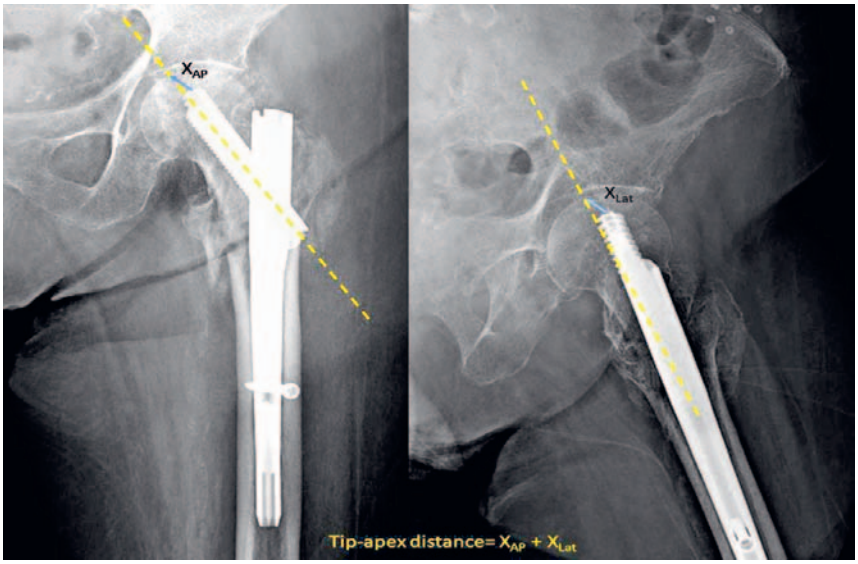

Fig. 2. Tip-apex distance according to Baumgaertner et al. (2).

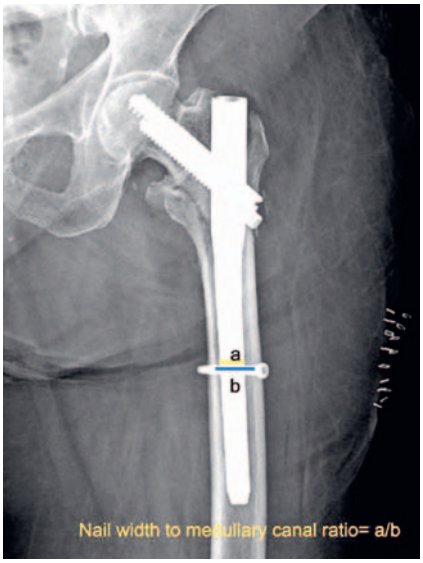

Fig. 3. Nail width to medullary canal ratio.

Table 1. Baseline demographic and fracture characteristics of the patients

	N=136
Age (range)	79.8 (60–97)
Sex	52 M (38.2%), 84 F (61.8%)
Side	73 L (53.6%), 63 R (46.4%)
Fracture pattern	
AO 31A1	120 (88.2%)
A1.1	8 (5.8%)
A1.2	45 (33.1%)
A1.3	67 (49.2%)
AO31A2	16 (11.8%)
A2.2	6 (4.4%)
A2.3	10 (7.3%)
Dorr type	
A	3 (2.2%)
B	79 (58.0%)
C	54 (39.7%)

cases (53.6%), and in 63 (46.4%) right side. Three patients (2.2%) had Dorr type A proximal femur, 79 (58%) had Dorr type B and 54 (39.7%) had Dorr type C. 120 of the 136 patients (88.2%) had AO type 31A1 fractures and 16 (11.8%) had AO type 31A2 fractures. Baseline patient demographics and fracture characteristics are summarized in Table 1.

Early postoperative tip-apex distance was 11.7 mm (range, 5.8–24.0) in the AP plane and 10.3 mm (range, 4.7–22.4) in the lateral plane. The total TAD was, on average, 21.9 mm (range, 11.8–46.4). Thirty-seven hips (27.2%) had a TAD of more than 25 mm. Early postoperative neck-shaft angles averaged 129.7 degrees (115–142). On average, late postoperative neck-shaft angles were 126 degrees (110–142). The average difference between early and late postoperative neck-shaft angles was 3.8 degrees (0–27). Forty-one patients (30.1%) had a varus collapse of more than 5 degrees.

46 (33.7%) patients had PMCS type reduction, 58 (42.6%) had Neutral MCS and 32 (23.5%) had Negative MCS type reduction. PMCS group had an early post-operative NSA of 129.8 degrees, Neutral had 130.4 degrees, and Negative MCS had 128.1 degrees. The mean NSA was not statistically significant between these groups. The nail width to medullary canal ratio at the level of the distal interlocking screw was, on average, 71.5% (43.6–100). Postoperative measurements and quality of reduction are summarized in Table 2.

Table 2. Postoperative measurements and reduction types

	N=136
Tip-apex distance (TAD)	
AP (range)	11.7 mm (5.8–24.0)
Lateral (range)	10.3 mm (4.7–22.4)
Total (range)	21.9 mm (11.8–46.4)
TAD>25 mm	37 (27.2%)
Nail	
Nail width to medullary canal ratio (range)	71,5% (43.6–100)
Nail width to medullary canal ratio >80%	23 (16.9%)
Reduction according to Chang et al. (17)	
Positive Medial Cortical Support	46 (33.7%)
Neutral	58 (42.6%)
Negative Medial Cortical Support	32 (23.%)
Position of lag screw (Cleveland index)	
1/2/3	2 (%1) /36 (%26) /0 (%0)
4/5/6	1 (%1) /60 (%44) /0 (%0)
7/8/9	7 (%5) /22 (%16) /8 (%6)

The multivariate logistic regression analysis (Table 3) for varus collapse identified several significant risk factors. Age was not a significant predictor (OR = -0.0129, 95% CI: -0.074 to 0.048, p = 0.681) as well as sex (OR = 0.6986, 95% CI: -0.249 to 1.646, p = 0.148). Having an OTA/AO types A2.2 and A2.3 fracture was found to be significant, with an OR of 0.3250 (95% CI: 0.031 to 0.619, p = 0.030), indicating a potential risk factor. Having the lag screw at Cleveland zones 5 or 8 (central-central or central-inferior) was associated with a protective effect (OR = -0.3461, 95% CI: -1.411 to -0.072, p = 0.031). Similarly, a PMCS or NP reduction showed a strong protective effect (OR = -5.8485, 95% CI: -8.042 to -3.655, p < 0.001). A tip-apex distance (TAD) less than 25 mm was also protective (OR = -3.2539, 95% CI: -5.059 to -1.449, p < 0.001). Other factors, including CalTAD > 25 mm (OR = -0.1639, 95% CI: -1.669 to 1.342, p = 0.831)

Table 3. Results of multiple logistic regression analysis for varus collapse

Risk factors	OR	Estimated 95% CI	p value (*:<0.05)
Age	-0.0129	-0.074–0.048	0.681
AO type A2.2 and A2.3 fracture	0.3250	0.031 to 0.619	0.030*
Cleveland 5 or 8	-0.3461	-1.411–-0.072	0.031*
PMCS or NP	-5.8485	-8.042–-3.655	0.000*
TAD > 25 mm	-3.2539	-5.059–-1.449	0.000*
CalTAD > 25 mm	-0.1639	-1.669–1.342	0.831
Nail ratio > 80 %	-0.0555	-1.877–1.766	0.952

OR: Odds ratio, CI: Confidence interval

and nail ratio > 80% (OR = -0.0555, 95% CI: -1.877 to 1.766, p = 0.952), were not significant predictors of varus collapse. The fill rate greater than 80% was not protective against varus collapse (OR = -0.0555, 95% CI: -1.877 to 1.766, p = 0.952). Finally, the Dorr type showed a positive association with varus collapse but was not statistically significant (OR = 0.8881, 95% CI: -0.232 to 2.008, p = 0.120). In the multivariate regression model for predicting varus collapse, the ROC curve demonstrated an area under the curve (AUC) of 0.84, indicating a high level of predictive accuracy (Fig. 4)

Our cohort included one patient with intramedullary nail breakage (Fig. 5) and one patient with screw cut-off due to improper screw placement (Fig. 6) who had to be revised with bipolar hemiarthroplasty in the early postoperative period (Fig. 7).

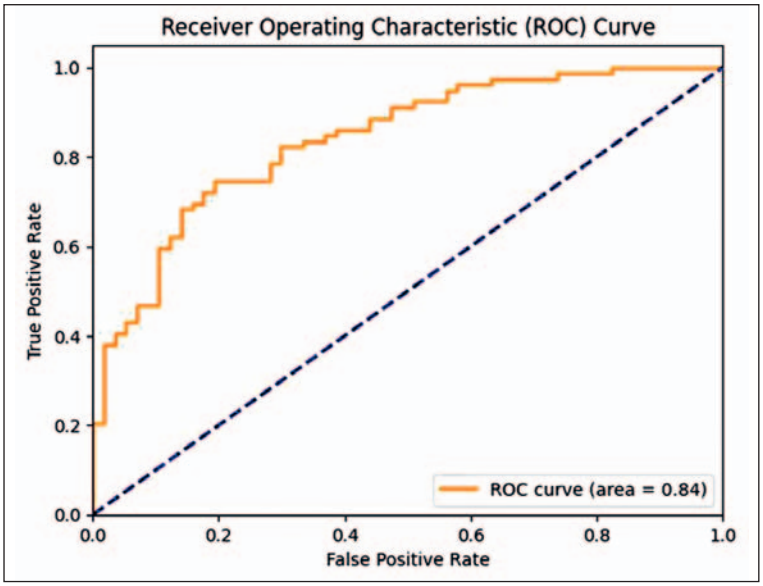

Fig. 4. ROC curve of the multivariate regression model for predicting varus collapse. Area under the curve 0.84.

DISCUSSION

The primary goal in treating geriatric intertrochanteric hip fractures is early mobilization and weight bearing. Therefore, the quality of initial fixation significantly affects the post-operative outcomes through complications related to fixation failures. The risk factors for such failures are still debated in the literature (12, 24, 29), although significant evidence has accumulated over the years regarding certain technical factors.

One of the most commonly cited risk factors is the Tip-Apex Distance (TAD). Baumgartner et al. have reported that a tip-apex distance of more than 25 mm is associated with an increased risk of screw cut-out(2). However, it is essential to note that Baumgartner's study was done on sliding hip screw devices. Regardless, a tip-apex distance of less than 25 mm is conventionally targeted with cephalomedullary nails. Other authors suggested different cut-off values for the TAD. For instance, in their study evaluating different risk factors for cut-out, Fujii et al. reported that a TAD of more than 20 mm was significantly associated with an increased cut-out (11). On the other hand, Caruso et al. (6) found a TAD cut-off of 30.7 mm for increased risk of cut-off and commented on the discrepancy between the literature and their findings. The authors suggested that the difference may be due to anthropometric characteristics.

In the last decade, some authors suggested improving on the TAD to better assess the quality of fixation

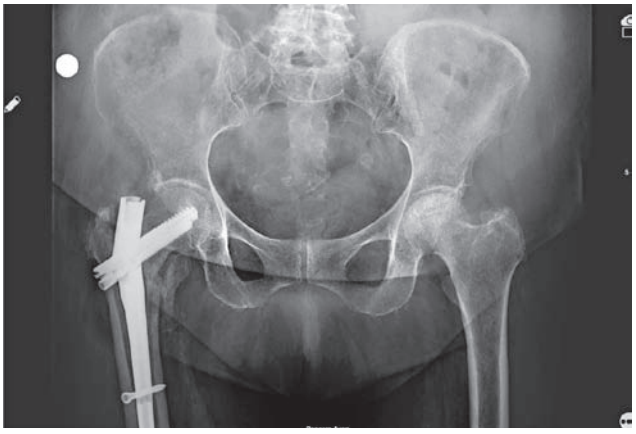

Fig. 5. Implant failure 2 months after the index operation.

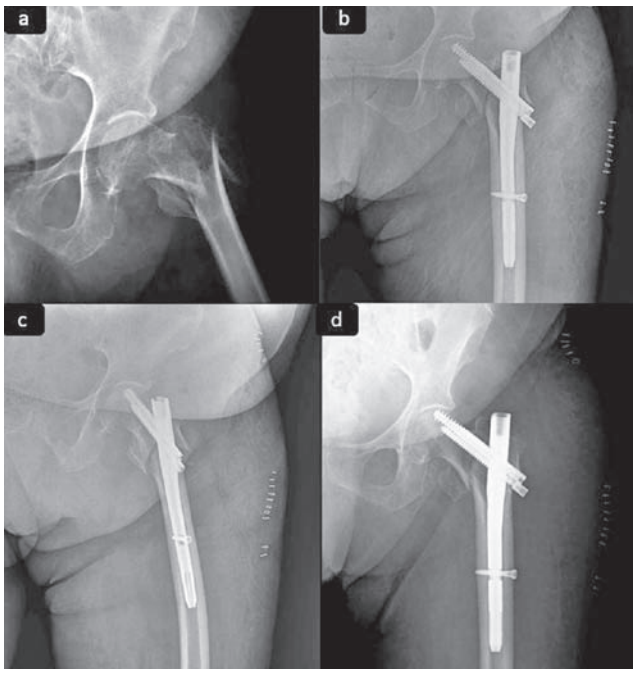

Fig. 6. Varus Cut-off (a). Pre-operative X-rays (b and c). The fracture was fixed with negative medial cortical support, and the screws were placed high in the neck, both of which are risk factors for cut-out (b). AP view (c). Lateral view (d). Varus cut-off was seen at 2 weeks.

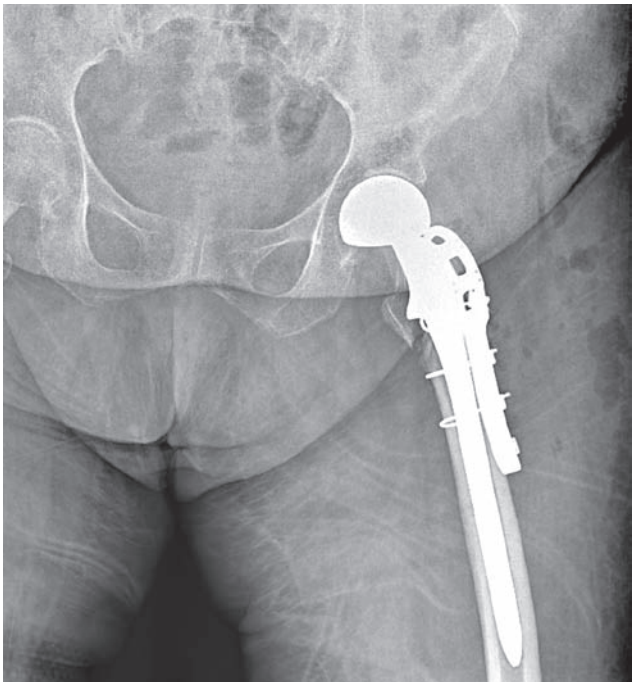

Fig. 7. Revision with bipolar hemiarthroplasty.

in the newer IMN designs. One such attempt was the CalTAD by Kashigar et al. in 2014 (17), which employs the same technique as the traditional TAD for the lateral view but differs for the anteroposterior (AP) view. In the AP view, the CalTAD-AP is measured by moving this guideline that runs through the middle of the femoral neck (Fig. 2) to be adjacent to the medial cortex of the femoral neck. The intersection of the new guideline with the femoral head is taken as the apex, and the distance between the tip of the screw and the "modified" apex is measured.

It should be noted that CalTAD was suggested for single lag screw designs, such as the proximal femur nail antirotation system (PFNA; Synthes, Solothurn, Switzerland). However, it is authors' opinion that the concept can be applied to dual screw designs such as the InterTAN as well. In the recent years, there are two notable studies that measured CalTAD for dual screw designs(5, 19) with smaller cohorts. To the best of authors' knowledge, the current study is the largest series in the literature investigation CalTAD for InterTAN and our results indicate that unlike the original TAD, it is not significantly associated with varus collapse.

Another modification of the TAD measurement was proposed by Selim et al. in 2023, and authors report than the modified TAD had the highest reliability of predicting lag screw cut-out compared to classical TAD, CalTAD and several other parameters including Cleveland zones(26). However, these results have not been validated by other authors so far.

The quality of reduction was assessed according to Chang et al., who reported that in the positive medial cortical support position, the cortex contact between the two main fragments was achieved, and the medial cortex of the femoral shaft can resist the femoral head-neck fragment from further sliding laterally. They also claimed that obtaining both medial and anterior cortical buttress would be the best option for reducing pertrochanteric fragments. Our results align with his findings that positive medial cortical support (medial reduction) or neutral position is associated with less varus collapse compared to negative medial cortical support.

The placement of the screws is also cited to be an essential factor in decreasing mechanical complications (2). It is suggested that the screws should be placed central-inferiorly or central-central to achieve the most stable construct (3). Multivariate analysis in this study was consistent with these suggestions with central-central or central-inferior placement being protective against varus collapse ($p<0.05$).

It is also important to note that our postoperative protocol included partial weight-bearing in all cases. This protocol may have affected varus collapse degrees and cut-out rates as well. This study focused on radiological and demographic risk factors for complications, and as such, the bone mineral density of the patients was not considered. It is, however, likely that the degree of osteoporosis may have affected the rate of complications.

This study has limitations primarily due to its retrospective design; clinical and radiographic data were incomplete in some cases due to inconsistent documentation or lost hard-copy films before adopting a digital PACS system. In rare cases, radiographs were not appropriate for measurements. Additionally, it has been clearly shown that NSA measurements can vary widely due to femoral neck anteversion in AP views and this may have affected the measured varus angles (15). The study period was limited with the selected time period because the brands and designed used in our institution changed over time. A decision was made to include only a single type and brand to eliminate confounding factors due to design and brand differences. The current study is one of the larger studies in the literature looking at risk factors for fixation in a single type and brand of IMN.

CONCLUSIONS

In our study of elderly patients with intertrochanteric hip fractures treated with InterTAN nails, we found that varus collapse was influenced by several factors. While age and sex were not significant predictors, having an OTA/AO type 31A2.2 or 31A2.3 fracture increased the risk of varus collapse. Conversely, a tip-apex distance (TAD) less than 25 mm, PMCS or NP reduction, and lag screw placement in Cleveland zones 5 or 8 (central-central or central-inferior) were protective against varus collapse. Other factors, such as CalTAD, nail ratio, and Dorr type, did not significantly predict varus collapse. The high predictive accuracy of our multivariate regression model underscores the importance of the surgeon related factors in preventing complications.

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