Complications of fixation of unstable trochanteric fractures with gamma nail. How to avoid it?

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Background
The incidence of intertrochanteric fractures is increasing worldwide due to the aging of the population. These fractures are common among osteoporotic people who may suffer from multiple comorbidities. Early surgical intervention is a must. Trochanteric fractures may be stable or unstable. Unstable fractures always tend to cause more complications during or after surgery such as femoral shaft medialization, varus collapse, malunion, delayed union, nonunion, and implant failure. Intertrochanteric fractures can be fixed by extramedullary devices such as DHS or intramedullary devices such as intramedullary gamma nail. Gamma nail has a locked fixed junction between the lag screw and the nail preventing femoral shaft medialization that decreases the bone-to-bone contact and increases the incidence of mechanical complications. Other theoretical advantages are that the technique is percutaneous with reduced blood loss, reduced sepsis, minimal tissue damage, and a shorter operating time.
Patients and methods
This is a retrospective study of 77 patients with recent unstable intertrochanteric fractures between December 2021 and June 2022. 70 patients of them continued till the last follow-up. All of them were fixed by intramedullary gamma nails. The age of the patients ranged from 61 to 99 years with a mean value of 71.64. This study included 19 (27.1%) males and 51 (72.9%) females. 50 (71.4%) patients had a history of associated comorbidities such as diabetes mellitus, hypertension, cardiac,….) and 20 (28.6%) patients were free. All fractures were classified according to Evan's classification to be unstable (Evan's type III, IV, V, and VI).
Results
At the end of the follow-up period, 58 (82.9%) patients achieved full radiological union, and 12 (17.1%) cases found to be failed of total 70 cases: 6 cases with screw cut out, 4 cases with broken nails and 2 cases with lag screw back out. According to Harris hip score, 11 (15.7%) patients did excellently, 35 (50%) patients did good, 12 (17.1%) patients did fair and 12 (17.1%) patients did poorly. There was a significant correlation between Evan's type V and failure rate, failure rate and quality of reduction failure rate and tip apex distance, failure rate and lag position, and failure rate and postoperative neck-shaft angle. But, no significant correlation between failure rate and length of gamma nail, or failure rate and lateral wall thickness was found.
Conclusion
It is concluded that this study supported the previous series in the literature, which proved that intramedullary gamma nails give good results when used to fix unstable intertrochanteric fractures. They have a lower complication rate when compared with other type of implants. Ideal fracture reduction, ideal implant choice, and application can lessen the rate of complications.

Keywords:
complications, gamma nail, trochanteric fractures, unstable

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Introduction

The incidence of intertrochanteric fractures is increasing worldwide due to the aging of the population [1,2]. These fractures are common among osteoporotic people who may suffer from multiple comorbidities that make the preparation for surgery, the surgical procedure, and postoperative complications and immobilization more difficult and hazardous [3–5]. Early surgical intervention is a must. It is very important to determine the fracture pattern regarding the concept of stability to assess the best implant to be used for the fixation of the fracture. Trochanteric fractures may be stable or unstable. Fractures are considered to be unstable in the

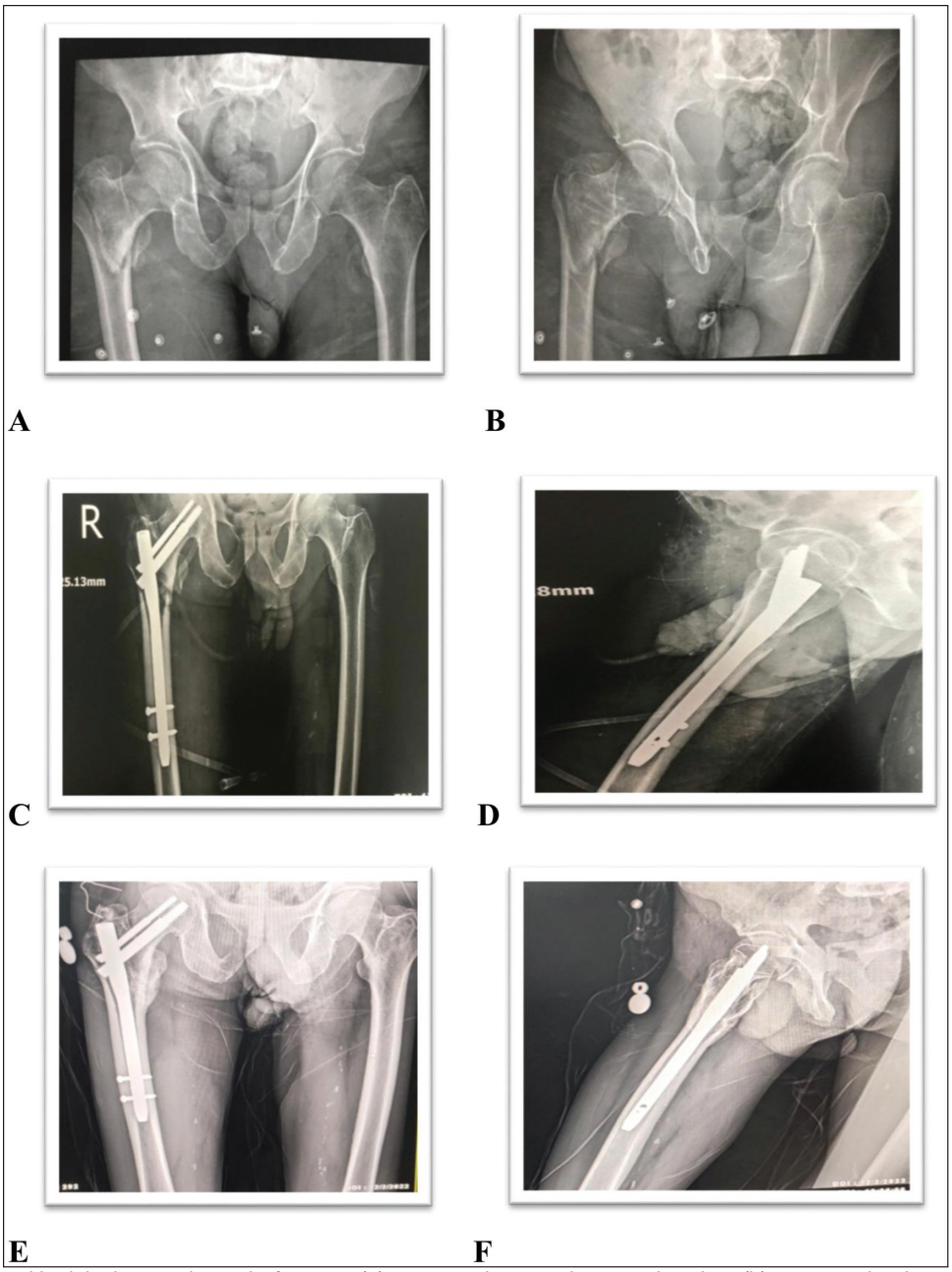
presence of comminution of the posteromedial cortical bone, reverse obliquity, and subtrochanteric extension [6]. Unstable fractures always tend to cause more complications during or after surgery such as femoral shaft medialization, varus collapse and malunion, delayed union, nonunion, and implant failure. All of these complications can occur in case of unstable fractures due to loss of calcar support. Intertrochanteric fractures can be fixed by extramedullary devices such as DHS or intramedullary devices such as intramedullary gamma nail. Extramedullary devices mostly cannot control shaft medialization occurring due to loss of calcar support in case of unstable fractures [7,8]. The gamma nail is designed for the treatment of trochanteric fractures either being stable or unstable. The nail consists of a dynamic lag screw passing through the intramedullary nail. It has many mechanical advantages when compared with extramedullary devices. Using a gamma nail, the distance between the hip joint and the nail is reduced, reducing the deforming forces across the implant. Using an intramedullary implant with a locked fixed junction between the lag screw and the nail prevents femoral shaft medialization that decreases the bone-to-bone contact and increases the incidence of mechanical complications. Other theoretical advantages are that the technique is percutaneous with reduced blood loss, reduced sepsis, minimal tissue damage, and a shorter operating time. It may also allow early weight bearing after fracture stabilization reducing the complications occurring with prolonged immobilization [9]. Mechanical complications are also reported with the application of gamma nails which can be avoided. Such as improper insertion of the nail and improper placement of the lag screw, which may lead to malalignment of the fracture and the lag screw cut-out of the femoral head. Also, the improper implant dimension, its geometric mismatch, and the fatigue failure of the implant either at the lag screw hole or at the distal locking screw hole. Fracture of the femur after nailing is mainly due to the geometric mismatch between the implant and the femoral shaft. It can be prevented by modification of the implant design, avoidance of excessive intramedullary reaming, and using a nail with a diameter less than the reamed diameter by 2 mm [10,11]. Our study aimed to conclude if the gamma nail is an effective implant when used to fix unstable trochanteric fractures, the complications types occurring with this method of fixation the rate of occurrence of these complications, and the best methods to avoid or lessen the incidence of these complications.

Patients and methods

This retrospective study was approved by the local ethical committee of our institution and has therefore been performed following the pertinent ethical guidelines (i.e. Declaration of Helsinki, as laid down in 1964 and revised in 2008). Written informed consent was obtained from all the patients. Between December 2021 and June 2022, 77 patients with unstable recent intertrochanteric fractures were enrolled in our study. 70 patients of them continued till the last follow-up of our study, all their data were available, and some data of the other 7 patients were lost. We excluded the patients with incomplete data from our study. The instability of the fractures was classified according to Evan's classification as Evan's type I and II are considered stable, but Evan's type III, IV, V, and VI are considered to be unstable fractures [12]. All Patients included in our study aged more than 60 years and had unstable trochanteric fractures. Patients who were unable to weight bear before fracture, patients with open fractures, proximal femoral deformities, poly traumatized, and pathological fractures other than osteoporosis were excluded from our study. The age of the patients ranged from 61 to 99 years with a mean value of 71.64. This study included 19 (27.1%) males and 51 (72.9%) females. 50 (71.4%) patients had a history of associated comorbidities such as diabetes mellitus, hypertension, cardiac,….) and 20 (28.6%) patients were free. Computed tomography was done for all patients included in our study to assess the degree of comminution of the fractures and the degree of instability. 15 (21.4%) patients were classified as Evan's type III, 26 (37.2%) patients were Evan's type IV, 18 (25.7%) patients Evan's type V, and 11 (15.7%) patients were classified as Evan's type VI. The time-lapse from the onset of trauma to the date of surgery ranged from 1 to 14 days with a mean of 4.24 days. All surgeries were operated on in El Hadra University Hospital. After stabilization of the general status of the patients by the anaesthesia specialist, third generation cephalosporin was given through an intravenous route to all patients as a prophylactic antibiotic 30 min preoperatively and continued for 3 days postoperatively. In addition, low molecular weight heparin (Clexane, 40 000 IU, administered subcutaneously) as thromboembolism prophylaxis was administered after the admission of the patients in our hospital, continued as a daily dose, stopped 12 h preoperatively. The anesthesia specialist was responsible for the decision on the appropriate anesthesia according to the general status of the patients. All the patients were operated on in a supine position on a traction table with the assistance of C-arm fluoroscopy guidance. The anatomic reduction was obtained. To reduce the fracture, closed reduction was applied first by holding the leg and doing an internal rotation in abduction with longitudinal traction of the affected

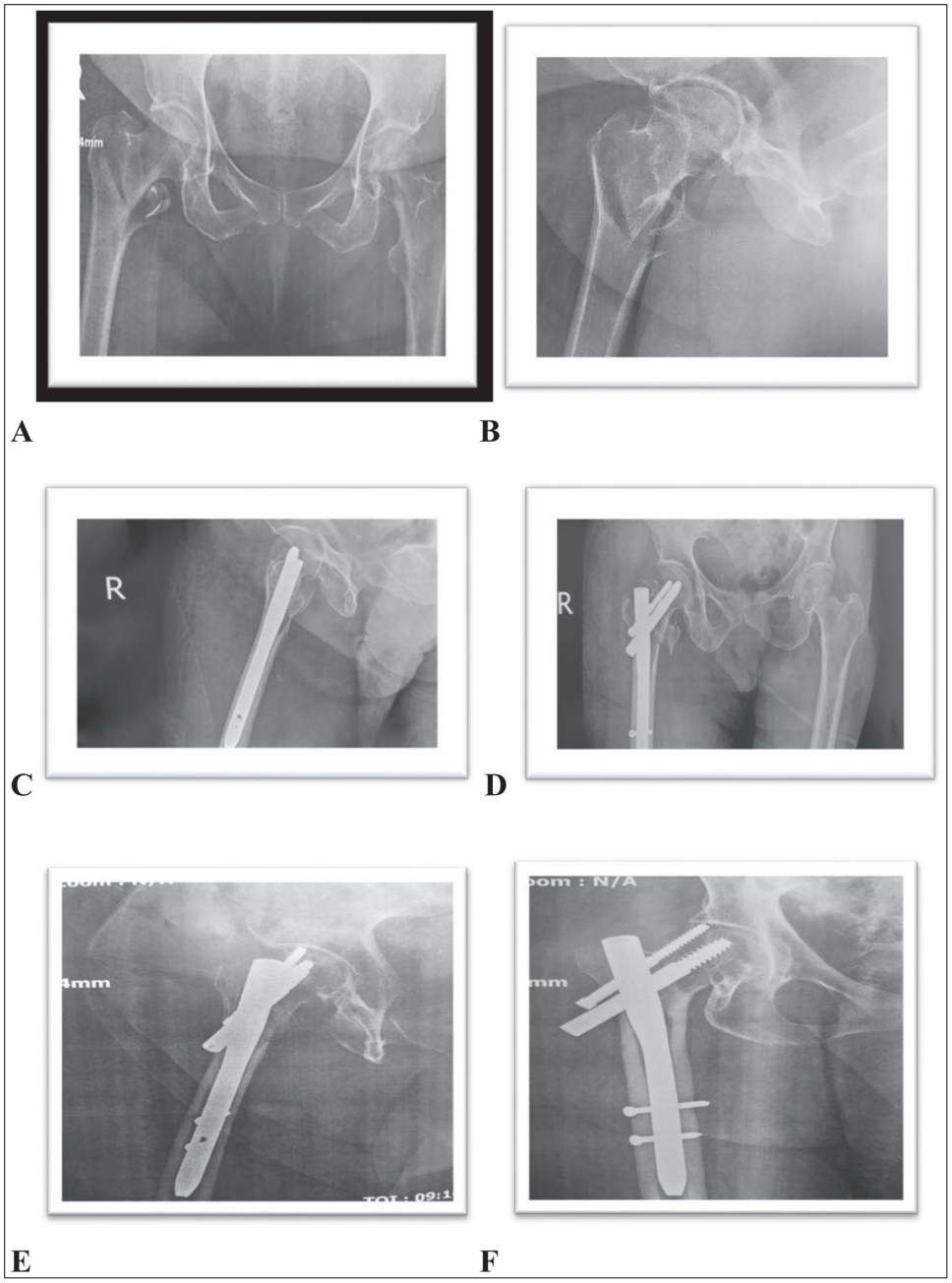
limb. Overreduction with excess internal rotation will lead to malrotation. Each step was checked with the image intensifier (Anteroposterior and true lateral images). All the fractures were reduced by closed reduction with no need for open reduction. Gamma nail was used to fix all of our fractured patients (Figs 1 and 2). Postoperatively, all the patients started a progressive physiotherapy program. Clexane was readministered 12 h postoperatively, and it was administered as a daily dose till the patients were discharged from our hospital. They continued oral anticoagulation therapy at home till 2 months postoperatively. Immediate postoperative exercises strengthen quadriceps muscles and improve the range of motion of the hip and knee joints. Full weight-bearing was allowed only when a callus was observed on follow-up radiography. Clinical and radiological follow-up was made in the 2nd and 8th weeks, then at 3, and 6 months until radiographic and clinical healing. All patients included in our research were followed up for at least 6 months postoperatively. All complications were recorded. Union of the fracture is determined clinically by painless weight-bearing and hip movement in all directions, and radiologically

Figure 1



62 years old male with right intertrochanteric fracture: (a) preoperative anterior-posterior view (b) preoperative Lat view (c) immediate postoperative anterior-posterior view of the fracture fixed by gamma nail (d) immediate postoperative Lat view of the fracture (E) 6 months follow-up postoperative anterior-posterior view showing full union (f) 6 months follow-up postoperative Lat view.

Figure 2



74 years old female with right intertrochanteric fracture: (a) preoperative anterior-posterior view (b) preoperative Lat view (c) immediate postoperative Lat view of the fracture fixed by gamma nail (D) immediate postoperative anterior-posterior view of the fracture (e) 6 months follow-up postoperative Lat view (F) 6 months follow-up postoperative anterior-posterior view showing varus malunion with antirotatory screw cut out.

by the disappearance of the fracture line in 3 or 4 cortices on the lateral and anteroposterior radiograph and complete bone trabeculae crossing the fracture site. Functional outcome was done using Harris hip score every 3 months. Delayed union was considered if no radiological union occurred at the end of 3 months and nonunion was considered when no union occurred at the end of 6 months. Shortening in the femoral neck and the shaft neck angle were compared between the first postoperative radiographs and those at the 6-month follow-up and femoral shortening and varus were measured. Malunion was defined as greater than 20 mm femoral shortening compared with the contralateral side or varus collapse of greater than 15° [13]. In addition to femoral shortening and varus collapse, reduction loss or implant failure was also evaluated. The clinical outcome was evaluated using the Harris hip score [14].

Statistical analysis

Data were analyzed by using SPSSR software (Statistical package for social science for personal

computers, IBM, Armonk, New York) using the Pearson χ^2 test and comparing means, Qualitative data were described using numbers and percentages. Quantitative data were expressed as mean±SD and *P* less than 0.05 was considered significant.

Results

All cases were assessed clinically and radiologically after at least 6 months postoperatively. With a mean follow-up of 9.45±2.07 months.

At the end of the follow-up period, 58 (82.9%) patients achieved full radiological union, and 12 (17.1%) cases were found to be failed of total of 70 cases: 6 cases with screw cut out, 4 cases with broken nails and 2 cases with a lag screw back out. Two patients of the 4 ones with broken nail suffered from deep infection and died with septic shock. Two patients of the 6 ones with screw cut out had varus malunion, the other one patients with implant failure (Table 1).

At the end of follow-up period, 11 (15.7%) patients did excellent, 35 (50%) patients did good, 12 (17.1%) patients did fair and 12 (17.1%) patients did poor according to Harris hip score (Table 2).

At the end of follow-up period, we found that five patients died after more than 6 months of surgery. Two patients suffered from radiological failure with deep infection and septic shock. One patient had experienced DVT while treated by Vaxato as an anti-coagulant medication and complicated with pulmonary embolism. The other two patients died due to sudden cardiac arrest after being well. ICU specialist mentioned that one of the two patients who had sudden cardiac arrest had acute pulmonary edema and heart failure and the other one had ventricular arrhythmia.

Table 1 Distribution of the studied cases according to radiological failure: (*n*=70)

Radiological failure	Number (%)
Failure	
No	58 (82.9)
Yes	12 (17.1)
Causes of failure (*n*=12)	
Screw cut out	6 (50)
Brocken implant	4 (33.3)
The lag screw backed out	2 (16.7)

Table 2 Distribution of the studied cases according to Harris hip score

Harris hip score	Total (*N*=70) *n* (%)
Excellent	11 (15.7)
Good	35 (50.0)
Fair	12 (17.1)
Poor	12 (17.1)
Minimum–maximum	50.0–97.0
Mean±SD	80.24±10.18
Median (IQR)	82.0 (78.0–88.0)

At the end of the follow-up period, there was a significant correlation between Evan's type V intertrochanteric fracture and failure rate (*P*= 0.009). This means that the failure rate increased with high grades of fracture comminution (Table 3).

At the end of the follow-up period, there was a strong correlation between failure rate and quality of reduction (*P*=0.002). Only one patient who experienced radiological failure of 36 patients had a good quality of reduction. While six patients experienced radiological failure 16 patients had poor reduction (*P*=0.001) significant with failure (Table 4).

At the end of follow-up period, there was a significant correlation between failure rate and tip apex distance (TAD) (*P*<0.001) (Table 5).

At the end of the follow-up period, there was a significant correlation between failure rate and lag position. Two patients experienced radiological failure from 39 patients had a central lag position (*P*=0.003),

Table 3 Relation between failure rate and fracture type (*n*=70)

Fracture type	Failure rate		*P*
	No (*n*=58)	Yes (*n*=12)	
Evan's	*N* (%)	*N* (%)	
Type III	14 (24.1)	1 (8.3)	0.439
Type IV	23 (39.7)	3 (25.0)	0.514
Type V	11 (19.0)	7 (58.3)	0.009
Type VI	10 (17.2)	1 (8.3)	0.675

Table 4 Relation between failure rate and BRQC quality of reduction

BRQC quality of reduction	Total (*N*=70) *n* (%)	Failure rate		*P*
		No (*N*=58) *n* (%)	Yes (*N*=12) *n* (%)	
Good	35 (50.0)	34 (58.6)	1 (8.3)	0.002
Acceptable	25 (35.7)	20 (34.5)	5 (41.7)	0.744
Poor	10 (14.3)	4 (6.9)	6 (50.0)	0.001

Table 5 Relation between failure rate and tip apex distance (*n*=70)

TAD	Failure rate		*P*
	No (*n*=58)	Yes (*n*=12)	
Minimum–maximum	1.61–2.28	2.2–3.12	0.001
Median	1.8	2.89	

while nine patients experienced radiological failure from 15 patients (*P*=<0.001) (Table 6).

At the end of the follow-up period, no significant correlation between failure rate and length of gamma nail was found (Table 7).

At the end of the follow-up period, no significant correlation between failure rate and lateral wall thickness was found (Table 8).

At the end of the follow-up period, eight patients had varus malunion and six of them had implant failure, seven patients had valgus malunion and three of them had implant failure and 52 patients were neutral but only three of them got implant failure. There was a significant correlation between failure rate and postoperative neck shaft angle (NSA) (<0.001) (Table 9).

Table 6 Relation between failure rate and lag position

Lag position	Total (*N*=70) *n* (%)	Failure rate		χ^2	*P*
		No (*N*=58) *n* (%)	Yes (*N*=12) *n* (%)		
Central	39 (55.7)	37 (63.8)	2 (16.7)	8.950	0.003
Superior	15 (21.4)	6 (10.3)	9 (75.0)	24.687	<0.001
Inferior	16 (22.9)	15 (25.9)	1 (8.3)	1.733	0.272

Table 7 Relation between failure rate and length of Gamma nail (*n*=70)

Length of Gamma nail	Total (*N*=70) *n* (%)	Failure rate		χ^2	^{FE}P
		No (*N*=58) *n* (%)	Yes (*N*=12) *n* (%)		
Short	47 (67.1)	40 (69.0)	7 (58.3)	0.509	0.511
Long	23 (32.9)	18 (31.0)	5 (41.7)		

Table 8 Relation between failure rate and lat wall thickness (*n*=70)

Lat wall thickness	Total (*N*=70) *n* (%)	Failure rate		χ^2	^{FE}P
		No (*N*=58) *n* (%)	Yes (*N*=12) *n* (%)		
≥20 mm	52 (74.3)	43 (74.1)	9 (75.0)	0.004	1.000
10 – <20 mm	5 (7.1)	4 (6.9)	1 (8.3)	0.031	1.000
Destroyed	13 (18.6)	11 (19.0)	2 (16.7)	0.035	1.000

Table 9 Relation between failure rate and Neck Shaft Angle (NSA) (*n*=70).

NSA	Total (*N*=70) *n* (%)	Failure rate		χ^2	*P*
		No (*N*=58) *n* (%)	Yes (*N*=12) *n* (%)		
<120 (Varus)	8 (11.4)	2 (3.4)	6 (50.0)	21.286	<0.001
120–135 (Neutral)	52 (74.3)	49 (84.5)	3 (25.0)	18.417	<0.001
>135 (Valgus)	10 (14.3)	7 (12.1)	3 (25.0)	1.358	0.359

At the end of the follow-up period, four patients had deep hematoma formation, which were controlled by changing the postoperative anticoagulation therapy to aspirin and the introduction of Kapron injection. No one suffered from periprosthetic fracture, nerve injury or fat embolism.

Discussion

Intertrochanteric fractures represent one of the most common fractures in the elderly and are associated with increased morbidity and mortality. Multiple comorbidities, osteoporosis, bad selection of implants, and suboptimal surgery can all contribute to poor patient outcomes [15]. In our study, we tried to discuss the results of managing unstable trochanteric fractures by gamma nail. We tried to discover the nail efficacy to fix trochanteric fractures, the complications of fixation, and how to get the best results with the least complication rate. Gamma nails have several advantages over traditional implants such as shorter operating time, smaller wounds, less soft tissue damage, easier fracture reduction, less blood loss, fewer units of blood transfused, and a shorter hospital stay. In this study, we had good results in managing unstable intertrochanteric fractures by intramedullary gamma nail regarding radiological union (82.9%). Dymus *et al.* had (a 100%) union which is better than our results [13]. Better union with nails may be due to the preservation of the natural biomechanics and stresses over the trochanteric region better than traditional implants. In our study, implant-related complications were reported 12 (17.1%) cases with implant failure 6 cases of screw cut-out related mainly to varus malunion, 4 cases with a broken implants which results from fracture nonunion, and 2 cases with screw back out. Mohamed *et al.*, had reported in their research on 30 cases of unstable trochanteric fractures fixed with gamma 3 nail 7 (23.3%) cases developed implant failure divided into 3 cases with screw cut out, 3 cases with a broken implant, and 1 case with screw back out [15]. Fosca *et al.* mentioned that their global failure rate was 12.3% divided into lateral protrusion of the lag screw (7.67%), distal locking screw failure (0.67%), static screw migration (0.33%) and screw cut-out (3.67%) [16] In our study mortality rate after 6 months of follow-up represent 5 (7.1%) cases of total 70. Horner *et al.* reported that after receiving treatment with a gamma nail, the total death rate was 9.5% after 30 days and 27% after a year [17]. In this study there is a significant correlation between the comminution of the fracture and failure rate. Abram *et al.* that found an increase in failure rate with increasing grade of fracture [18]. Others noted no significant correlation between the type of fracture and their final results like Parker

and Handoll [19] All cases in our study were assessed postoperatively according to Baumgaertner reduction criteria [20]. 35 had been good, 25 had been acceptable and 10 cases had been poor. It is found that the failure rate markedly increased with worsening of reduction. Abram *et al.* reported a significant link between the quality of reduction and failure rate [18]. In our study there was a significant correlation between TAD and final results *P* less than 0.001. Also, Abram *et al.* had recorded the same results [18]. Also, there is a significant correlation between lag position and failure rate which increases with the superior position of the lag screw leading to screw cut-out or hardware failure. other authors e.g Abram *et al.*, and Mavrogenis *et al.*, reported that a central or inferior lag position is better than the superior lag screw [18,21]. No obvious correlation between lateral wall thickness and the final results of our study. Deng *et al.* reported that in patients with intertrochanteric fractures getting PFNA, lateral wall thickness did not affect the effectiveness of reduction or the result [22]. This study revealed a significant correlation between NSA and failure rate, failure rate markedly increased with varus malunion (NSA<120) and decreased with neutral NSA (120–135). Zhang *et al.* reported in their study that failure is more likely with a more varus neck-shaft angle [23]. Apart from bad technique, lag screw cut-out increases in cases with severe fracture comminution or very bad bone quality due to osteoporosis. In the late 1980s, the Gamma nail was first developed. It provides the biomechanical benefits of intramedullary nailing. Although the initial reports on the use of the Gamma nail were positive, several authors, including Gaebler *et al.* in 1992 and Zafiropoulos *et al.* in 1995, emphasized the relatively high complication rate associated with its use [24]. Gamma nail implants result in three-point loading in the femoral trochanter and diaphyseal cortices, which exposes the femur to a high frequency of intraoperative and postoperative refractures. The trochanter to diaphysis angle in a typical patient is not the same as the mediolateral curve of the original gamma nail. This mismatch between the nail shape and the femoral anatomy can cause iatrogenic shaft fractures [25]. The gamma 3 nail decreases the load of the femur in three locations, which is known to increase the risk of refracture because it has a mediolateral curve of 4º as opposed to 10º in earlier versions of the gamma nail. So, more importantly, gamma 3 nails offered much-decreased rates of implant failure and delayed healing in this frail elderly group, reducing the need for revision surgery [26]. From our study, we concluded several items which are very important during the fixation of intertrochanteric fractures with gamma nails to reduce the risk of implant failure. Perform a perfect fracture reduction in both anterior-posterior and lat views before the beginning of fixation. The entry point should go through the medial side of the greater trochanter not through the piriformis fossa to avoid fracture angulation or through the lateral side of the greater trochanter to avoid trochanter avulsion or fracture. Use recent-generation nails like gamma 3 nails which have a radius of curvature that fits the anatomical shape of the femur better to avoid iatrogenic femoral fractures or fractures under the distal tip of the nail. Use a nail diameter of 2 mm less than the reamed diameter to avoid the complications that may occur due to the difference between the mediolateral curvature of the hip of the patients and that of the nail. Short gamma nails are easier to use for fixation than long ones. The TAD must not exceed 25 mm. Be sure that the NSA is neutral not n varus or valgus as the center of rotation of the femoral head must be in line with the tip of the greater trochanter. The lag screw should be central in the neck in lateral view and better to be inferior to central in the neck in anterior-posterior view, especially in patients with short necks. In this study, we had some limitations. It is a nonrandomized retrospective study, small sample size in comparison with other studies, poor recording and keeping of the personal and operative data of the patients, and, bad compliance of patients who suffered from postoperative complications.

Conclusion

It is concluded that this study supported the previous series in the literature, which proved that intramedullary gamma nails give good results when used to fix unstable intertrochanteric fractures. They have a lower complication rate when compared with other types of implants. Ideal fracture reduction, ideal implant choice, and application can lessen the rate of complications.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Parker MJ, Handoll HH. Intramedullary nails for extracapsular hip fractures in adults. Cochrane Database Syst Rev 2009; 3:CD004961.

2 Kaplan K, Miyamoto R, Levine BR, Egol KA, Zuckerman JD. Surgical management of hip fractures: an evidence-based review of the literature. II. Intertrochanteric fractures. J Am Acad Orthop Surg 2008; 16:665–73.

3 Dequeker J, Gautama K, Roh YS. Femoral trabecular patterns in asymptomatic spinal osteoporosis and femoral neck fracture. Clin Radiol 1974; 25:243–6.

4 Zain BS, Olerud S, Karlstrom G. Archives of Orthopaedic and Traumatic Surgery The Influence of Age on the Morphology of Trochanteric Fracture. Arch Orthop Trauma Surg 1984; 103:156–161.

5 Rapp K, Büchele G, Dreinhöfer K, Bücking B, Becker C, Benzinger P. Epidemiology of hip fractures Systematic literature review of German data and an overview of the international literature Electronic supplementary material. Z Gerontol Geriat 2019; 52:10–6.

6 Zhang WQ, Sun J, Liu CY, Zhao HY, Sun YF. Comparing the Intramedullary Nail and Extramedullary Fixation in Treatment of Unstable Intertrochanteric Fractures. Sci Rep 2018; 8:1–8.

7 Okcu G, Ozkayin N, Okta C, Topcu I, Aktuglu K. Which implant is better for treating reverse obliquity fractures of the proximal femur: A standard or long nail? Clin Orthop Relat Res 2013; 471:2768–75.

8 GJ H, TA I, DJ B. Reverse obliquity fractures of the intertrochanteric region of the femur. J Bone Joint Surg Am 2001; 83:5.

9 Leung KS, Chen CM, Sato K, Lai CH, Mahaisavariya B, Suntharalingam S. Multicenter trial of modified gamma nail in east Asia. Clin Orthop 1996; 323:146–54.

10 Leung KS, Procter P, Robioneck B, Behrens K. Geometric mismatch of the gamma nail to the Chinese femur. Clin Orthop 1996; 323:42–8.

11 Haynes RC, Poll RG, Miles AW, Weston RB. Failure of femoral head fixation: a cadaveric analysis of lag screw cut-out with the gamma locking nail and AO dynamic hip screw. Injury 1997; 28:337–41.

12 Evans EM. The treatment of trochanteric fractures of the femur. J bone joint surg Br 1949; 31B:190–203.

13 Duymus TM, Aydogmus S, Ulusoy İ, Kececi T, Adiyeke L, Dernek B, Mutlu S. Comparison of Intra- and Extramedullary Implants in Treatment of Unstable Intertrochanteric Fractures. J Clin Orthop Trauma 2019; 10:290–5.

14 Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Jt Surg Am 1969; 51:737–55.

15 Mohamed A, Hammouda A, Akl Y. Comparison between Gamma Nail and Proximal Femoral Nail in Management of Unstable Intertrochanteric Fractures. Al-Azhar Int Med J 2021; 1:1–5.

16 LC F, CA B, N M, A M, D O-D, G T. The Failure Incidence of Trochanteric Fracture Fixation Using Gamma Nail or PFNA. Gerontol Geriatr Res 2021; 7:4.

17 Horner NS, Samuelsson K, Solyom J, Bjørgul K, Ayeni OR, Östman B. Implant-Related Complications and Mortality After Use of Short or Long Gamma Nail for Intertrochanteric and Subtrochanteric Fractures A Prospective Study with Minimum 13-Year Follow-up. JBJS Open Access 2017; 2:E0026.

18 Abram SGF, Pollard TCB, Andrade AJMD. Inadequate 'three-point' proximal fixation predicts failure of the Gamma nail. Bone Jt J 2013; 95 B: 825–30.

19 Parker M, Handoll H. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures. Cochrane Database Syst Rev 2008:CD000093.

20 Baumgaertner MR, Curtin SL, Lindskog DM. Intramedullary versus extramedullary fixation for the treatment of intertrochanteric hip fractures. Clin Orthop Related Res 1998; 348:87–94.

21 Mavrogenis AF, Panagopoulos GN, Megaloikonomos PD, Igoumenou VG, Galanopoulos I, Vottis CT, *et al*. Complications after hip nailing for fractures. Orthopedics 2016; 39:e108–16.

22 Deng HL, Cong YX, Huang H, Zhang BF, Fu YH, Lei JL, *et al*. The Effect of Integrity of Lateral Wall on the Quality of Reduction and Outcomes in Elderly Patients with Intertrochanteric Fracture: A Controlled Study. Biomed Res Int 2021; 2021:6563077.

23 Zhang W, Antony Xavier RP, Decruz J, Chen YD, Park DH. Risk factors for mechanical failure of intertrochanteric fractures after fixation with proximal femoral nail antirotation (PFNA II): a study in a Southeast Asian population. Arch Orthop Trauma Surg 2021; 141:569–75.

24 Gaebler C, Stanzl-Tschegg S, Tschegg EK, Kukla C, Menth-Chiari WA, Wozasek GE, *et al*. Implant failure of the gamma nail. Injury 1999; 30:91–9.

25 Luque Pérez R, Checa Betegón P, Galán-Olleros M, Arvinius C, Valle-Cruz J, Marco F. Nailing unstable pertrochanteric fractures: does size matters? Arch Orthop Trauma Surg 2022; 142:145–55.

26 Cheng YX, Sheng X. Optimal surgical methods to treat intertrochanteric fracture: A Bayesian network meta-analysis based on 36 randomized controlled trials. J Orthop Surg Res 2020; 15:402.