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Trochanteric tip versus pyriformis entry for nails in femoral shaft fractures: Which is better?

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***Abstract*---Background:** Entry point, either piriformis fossa entry (PFE) or greater trochanter entry (GTE) are the two recognized for IMN, but still debatable, which is better. The aim of this study was to determine which of the two-entry points (PFE or GTE) is preferable to the other for IMN of femoral shaft fractures. **Method:** A retrospective comparative study of patients with closed femoral shaft fractures (AO type 32-A or B) fixed by antegrade IMN, either GTE or PFE was included. Collected data includes demographic characteristics of both groups, mechanism of injury, AO Classification, Winquist classification, time to surgery, and associated injuries. Operative details, complications and postoperative outcomes were recorded. Functional evaluation using Harris Hip Score (HHS) and RUST score was done at the final follow-up visits. **Results:** 56 patients were operated for femoral shaft fractures (26 GTE -IMN, and 30 PFE-IMN), with male predominance. The fractures were classified according to

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AO Classification by either type A (35 patients) or type B (21 patients). Patients were operated on after a meantime 2.76± 2.46 days. In the GTE-IMN group, there was a negative correlation between HHS and time from trauma to surgery, and there was a negative correlation between HHS and (age, duration of surgery). **Conclusion:** Nail introduction through the trochanteric tip was easier and safer to perform. Shorter operative time, better grip on the proximal femur were observed when the nails were introduced through the GT especially in elderly osteoporotic patients or when there is fracture comminution.

***Keywords*---**Femoral shaft, fractures, greater trochanter, piriformis, entry, intramedullary nailing.

Introduction

Management of femoral shaft fractures has changed dramatically since introducing intramedullary nailing (IMN) technique by Kuntscher in the 1940's (1). IMN with closed reduction and reaming is the standard of care for femoral shaft fractures and considered the preferable and widely acceptable treatment (2,3). improvement of the nailing technique and the nail design occurred over the past few decades. Entry point, either piriformis fossa entry (PFE) or greater trochanter entry (GTE) are the two recognized for IMN, but still debatable, which is the best (3,4). Factors affecting choice include nail design, location of the fracture, fracture comminution and patient factors (e.g., poly traumatized, pregnant, and obese patients)(3).

PFE-IMN affects the hip abductors and external rotators with possible injury of the medial circumflex femoral artery and superior gluteal nerve during dissection compared to GTE-IMN, which may impair the functional outcome with residual hip or thigh pain and sometimes limbing due to muscle affection (5,6). Too anterior or medial piriformis entry point may increase the risk of an iatrogenic femoral neck fracture, while too posterior but a high risk of avascular necrosis, especially in adolescents (3,7). Specially designed nails with proximal lateral bend (4 TO 6 degrees) for GTE-IMN have gained popularity and can avoid PFE-IMN complications, with remaining iatrogenic femoral fractures(1,8,9) . The two entries showed comparable overall union rate and complications (9).

Which is the optimal entry still controversial, superiority of one entry to the other difficult to be confirmed (1,10) . The aim of this study was to determine which of the two-entry points (PFE or GTE) is preferable than the other for IMN of femoral shaft fractures.

Methods

The study was a retrospective comparative study conducted from April 2021 to October 2023 at Menoufia university, Orthopedic department with minimum 1 year follow up. Patients with closed femoral shaft fractures (AO type 32-A or B) fixed by antegrade IMN either GTE or PFE operated within 3 weeks of injury were

included. The study was approved by our university institutional review board all patients had informed consent to be included in the study.

Patient with open fracture, pathological fracture, bilateral fracture, associated ipsilateral femoral neck, and lower third fractures received retrograde nail were excluded. Routine radiological evaluation including both hip joint and proximal femur (AP view), and affected femur showing knee and hip (AP and lateral view)
Data that was collected includes demographic characteristics of both groups (age, gender, side of the fracture, associated comorbidities), mechanism of injury, AO Classification, Winquist classification, Time from trauma to surgery, associated injuries.

Operative details about both groups was collected including mode of anesthesia, patient position during nail insertion, need for open reduction, nail design , use of traction table, nail length, nail diameter, need for cerclage after closed reduction ,pattern of proximal and distal locking screws, free hand technique for distal locking blots or use of target device for insertion of distal locking screws, duration of surgery (minute) starting from insertion of guide wire or skin incision for entry to closure of wound, intraoperative complications(including iatrogenic fracture).

Post operative complications and postoperative outcome were recorded including length of hospital stay (days), start of partial weight bearing (weeks), time of full weight bearing (weeks), time of union (month), and need for reoperation including dynamization. Functional evaluation using Harris Hip Score (HHS) and RUST (Radiographic Union Score for Tibial fracture) score was done at the final follow up visits.

Statistical analysis

Data was collected, tabulated, and statistically analyzed using an IBM compatible personal computer with SPSS version 26. qualitative data were expressed as Number (N), percentage (%), while quantitative data were expressed as mean ($\bar{x}$), standard deviation (SD). Student's t-test (t) used for comparison of quantitative variables between two groups of normally distributed data, while Mann-Whitney's test (U) was used for comparison of quantitative variables between two groups of not normally distributed data. Chi-square test (x2) was used to study association between qualitative variables. was used. Fisher's exact test for 2 x 2 tables when an expected cell counts of more than 25% of cases was less than 5. Pearson correlation coefficient test (r-test) was a test of significance used to study the correlation between two quantitative variables. Comparing two correlation coefficients by Fisher´s r to z transformation method. Significant difference if $P < 0.05$.

Results

56 patients were operated for femoral shaft fractures with IMN (26 patients received GTE -IMN, and 30 patients received PFE-IMN), with male predominance (46 patients). the mean age was 37.3±18.12 years ranging from 18 to83 years, the

GTE-IMN group was older than the PFE-IMN group but not reaching significance 0.591. (Table 1) (Fig 1-4)

Most of the injuries were high energy after road traffic injury (43 patients, 76.8%) or falling down (13 patients, 23.2%).29 fractures were right, and 27 patients were left. The fractures were classified according to AO Classification either type A (35 patients) or type B (21 patients), and was classified according to Winquist Classification into type 0 (28 patients,50%), type 1 (11 patients,19.6%), type 2 (7 patient,12.5%), and type3 (10 patients, 17.9%). patients was operated after a meantime 2.76± 2.46 days (ranging from 1 to 14 days). (Table 2)

22 patients had associated injuries including distal radius fracture, fracture humerus, contralateral patella fracture, fracture ribs, contralateral bone leg fracture, both bone forearm fracture, fracture elbow, contralateral hip dislocation, and contralateral isolated fracture tibia Patient was operated either in supine (30 patients) or lateral (26 patients) position. The lateral position was preferred in obese patients, fragile osteoporotic patients, unavailability of traction table and presence of ipsilateral fracture hindering the use of traction table. Traction using traction table was DONE IN 25 patients,44.6% (most of them were in the GTE-IMN group) this because the easier access of GTE-IMN allowed the use of traction table, while lateral decubitus without traction table was most commonly used in the PFE-IMN. (Fig 2) (Table 3)

Most of the patients were operated on using spinal± epidural anathesia,9 patients (16.1%) had open reduction before nail insertion, 5 patients needed addition of cerclage wiring to maintain the reduction of the fractures, while the remaining was successful through closed methods. (Table 3)
Nail length range from 34 to 40 cm, with nail diameter range from 10 to 12 cm. Two distal locking screws were successful in all patients with target device insertion in 44 patients, 78.6% and free hand insertion in 12 patients, 21.4%. (Table 3)

The PFE- IMN was straight nails with two proximal and two distal locking screw (Fig 4), while different nail designs was used in GTE-IMN according to the manufacturer, the most commonly used construct was nails allow two oblique screws to the neck, one oblique from the greater trochanter to the lesser, and one or two transverse at the level or just below the lesser trochanter; Greater to lesser trochanter screw was cannulated or non-cannulated. The second design was two screws only towards the neck (reconstruction nails). a third design allows one oblique screw from the greater trochanter and another transverse screw. All the GTE-IMN had lateral bend proximally (4 to 6) and two distal locking screws. (Fig 3)

Pattern of proximal locking screws for GTE-IMN was One transverse and one from GT to LT (20/26 patients,76.9%), One lag screw to the neck and antirational screw (2 patient), two lag screws to neck (2 patient), one screw from greater to the lesser trochanter screw (1 patient), and two lag screws to the neck and one transverse cortical (1 patient). All patients with PFEIMN had two distal transverse screws. (Fig 1,2,3)

Operative time calculated from the incision for nail entry, to closure of wounds, the mean operative time was 78.51±17.39 (range from 52 to 125 minutes), GTEIMN had lower operative time (72.35±13.66 minutes) compared to PFEIMN (83.87±18.51minitues) with significant difference p value = 0.012. (Table 4)
No major intraoperative complication encountered, but two cases have extension of the fracture in the proximal segment during nail insertion, one with small butterfly, the other on fracture line was extended to just below the lesser trochanter which was enforced with 3 locking screws to the proximal segment (one transverse and 2 to the neck)

The mean length of hospital stay was 4.04±1.46 days ranging from 2 to 7 days. Partial weight bearing was started as early as possible with a mean time 3.9±1.43 weeks and full bearing without aids was reached at a mean time 8.51±1.39 weeks. (Table 4)

All included cases achieved union with a men time to union5.83±1.31 months ranging from 4 to 9 months. 8 patients, 4 in each group encountered post operative complications, 2 have delayed union, 4 have superficial wound infection, and 2 have leg length discrepancy with less than 2 cm shortening. 3 patients needed nail dynamization (2 patients from GTE-IMN and 1 patient from PFE-IMN).

The mean Harris hip score was 93.48±9.12(ranging from69 to 100points) with a better functional outcome of GTEIMN group compared to PFEIMN group but not reaching significance p value = 0.117. the mean RUST score was 10.52±1.33 (ranging from 7 to 12) with no statistical difference between both groups p value = 0.761. (Table 4)

No statistical difference between both groups regards need for dynamization, length of hospital stays, time of union, start of partial weight bearing, time of full weight bearing, HHS, and RUST score.
In GTE-IMN group, there was negative correlation between HHS and time from trauma to surgery (P value <0.05) and no correlation between HHS and (age, duration of surgery, length of hospital and time of union). (Table 5)
In PFE-IMN group, there was negative correlation between HHS and (age, duration of surgery) (P value <0.05) and no correlation between HHS and (time from trauma to surgery, length of hospital stays and time of union). (Table 5)

Discussion

Femoral shaft fracture is one of the most common fractures encountered in orthopedics. Most occur in young adults due to high energy injury. It can be life threating due to open wounds, fat embolism, ARDS, or multiple organ failure(11).
Intramedullary nails are the treatment of choice for shaft femur fractures in adults. Lower rates of infection, reproducible rates of union , mechanical stability controlling rotation and length ,shorter hospital stay, early mobilization , improved function and rehabilitation periods are advantages of IMN (3).GTE-IMN are superior to the PFE-IMN, with shorter duration of surgery requiring lesser radiation exposure, lesser damage to musculature and better functional outcomes, avoidance of iatrogenic fracture of the femoral neck , avoidance of

intracapsular infection, and easier insertion especially in obese patients. Varus collapse and issues with union are not significantly different between the two groups (1,11–13) .
Alignment of piriformis fossa with anatomical axis of the femur allows straight antegrade IMN insertion (14). While nails with lateral bends were fashioned for a simpler insertion through the greater trochanter tip as its lateral to the anatomical axis (15).
It was observed that GTEIMN required a small incision, minimum dissection, technically simpler entry, shorter operative time, and rapid recovery and rehabilitation compared to PFEIMN.
In a meta-analysis (5 studies) reported average duration of surgery in the GTE group was 67.7 min, while in PFE group it was 85.9 min, the duration of surgeries in the PFE group was significantly higher; p = 0.0001 (1) In another study The mean operative time for the GTE group was 90.7 min vs. 112.7 min for the piriformis entry(16)
No major varus malalignment, Trendelenburg gait was observed in both groups. A meta-analysis confirmed higher rates of abductor issues in PE group(1) . Varus mal alignment associated with GTEIMN didn't lead to problems with union in femoral shaft fractures, when compared to PFEIMN (1,11)

The trochanteric nail designs with proximal lateral bends minimize the chances of eccentric reaming and subsequent malalignment(4,17) .while PFE-IMN may require abductor fiber division which may result in abnormal function of abductors (weakness, lurch, Trendelenburg gait) (17,18).
2 cases had iatrogenic fracture during nail insertion in the GTEIMN group. Greater trochanteric nails with an entry point lateral and anterior to the trochanter have been found to be associated with increased risk of iatrogenic fracture than a more medial entry in intertrochanteric fractures(3).
Nail entry in both groups has no effect on union with comparable outcome from this point it would be better to shift to GTEIMN for femoral shaft fractures as it is easier with shorter operative time.

Regarding HHS, GTEIMN provide better outcomes than PFEIMN. This also was comparable to Kumar et al with average HHS in the PE group was 80.02, while in the GT group it was 84.65 (1)
It is better to shift to GTE nails for femoral shaft fractures as it avoids the complications associated with PFE nails with better functional outcomes, recently different designs of GTE nails are available this guarantees easier shift. GTE-IMN allowed a more stable construct especially in elderly population and osteoporotic patient with additional protection of the neck using the neck directed screws, also in case of iatrogenic fracture during nail insertion still there is a solution to add the neck screws to have a more stable construct. The easier insertion in obese patents and patients on traction table compared to PFE-IMN favors the use of the GTE-IMN. This was also supported in literature (19,20).
There are some limitations of this study, being retrospective with low sample size, and use of different designs and manufacturers for both nails groups. Conclusions from the study should be interpreted carefully and future randomized prospective studies are required.

Conclusion

Nail introduction through the trochanteric tip was easier and safer to perform. Shorter operative time, better grip on the proximal femur were observed when the nails were introduced through the GT especially in elderly osteoporotic patients or when there is fracture comminution.

Declarations:

Ethics approval and consent to participate
The study was conducted after the approval of the institutional review board of Menoufia university-faculty of medicine-EGYPT and written informed consent from patients
Consent for publication
NOT APPLICABLE
Availability of data and materials
Available on request, the corresponding author is the responsible for data availability (I B)

Competing interests

No competing interests

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Authors' contributions

All authors have read and approved the manuscript
Ayman Ebied: Conceptualization, Methodology, Investigation,
Writing - original draft, Writing - review & editing, Visualization.
Adel Ibrahim El-Seedy: Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Visualization.
Mohammed Shahin: Methodology, Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Visualization.
Ismail Badr: Methodology, Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Visualization.

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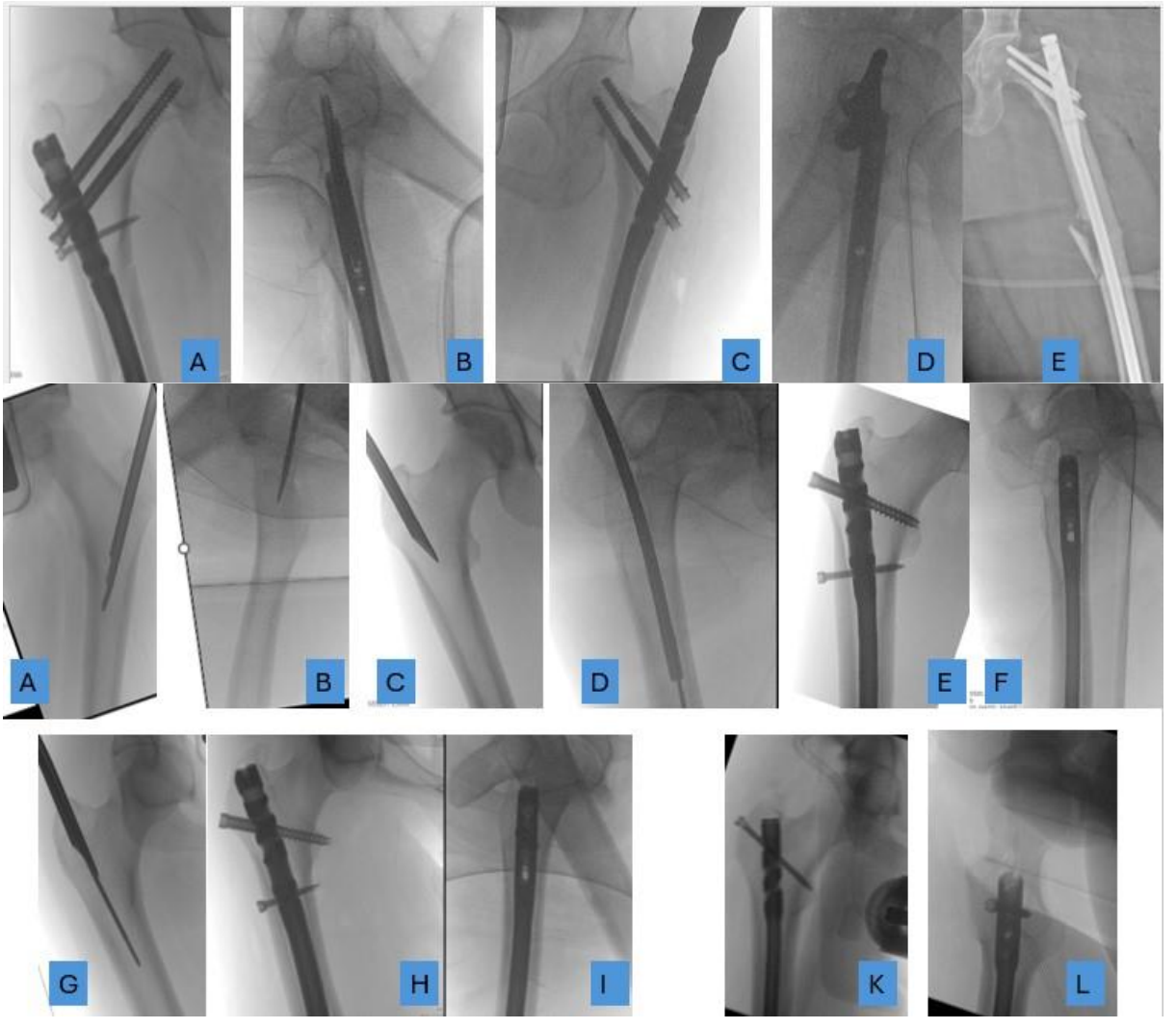
Figure legends:

Figure 1: Different GTE-IMN design with different choices of proximal locking screws: nail design allow to neck screws .one oblique from greater trochanter to the lesser and one(A.B) or two(C,D,E) transverse(greater to lesser trochanter and one transverse was chosen),(A, B) Greater to lesser trochanter screw was not canulated, while in (C,D,E) it was canulated.

Figure 2: GTE-IMN entry:(A,B)image intensifier images in the anteroposterior and lateral(cross table ,lateral decubitus, without traction table) views.(C,D,E,F):nail entry using awl in anteroposterior view, reduction tool and olive tip wire introduction in cross table lateral view, anteroposterior and lateral views after nail introduction.(G,H,I) nail entry using awl in anteroposterior view over a guide wire introduction, anteroposterior and lateral cross table views after nail introduction.(K.L) anteroposterior and lateral (traction table)views after nail introduction.

Figure 3: GTE-IMN design which allow different choices of proximal locking screws (two neck screws. one oblique from greater trochanter to the lesser and two transverse screws: A, B iatrogenic extension of the fracture to the posteromedial cortex with a more secure choice with two neck screws and one transverse.(C,D,E) iatrogenic butterfly fracture at the fracture site in old female 70 years old and the neck was protected with 2 neck screws.

Figure 4: PFE-IMN entry: (A-D) straight nails with 2 proximal locking screws.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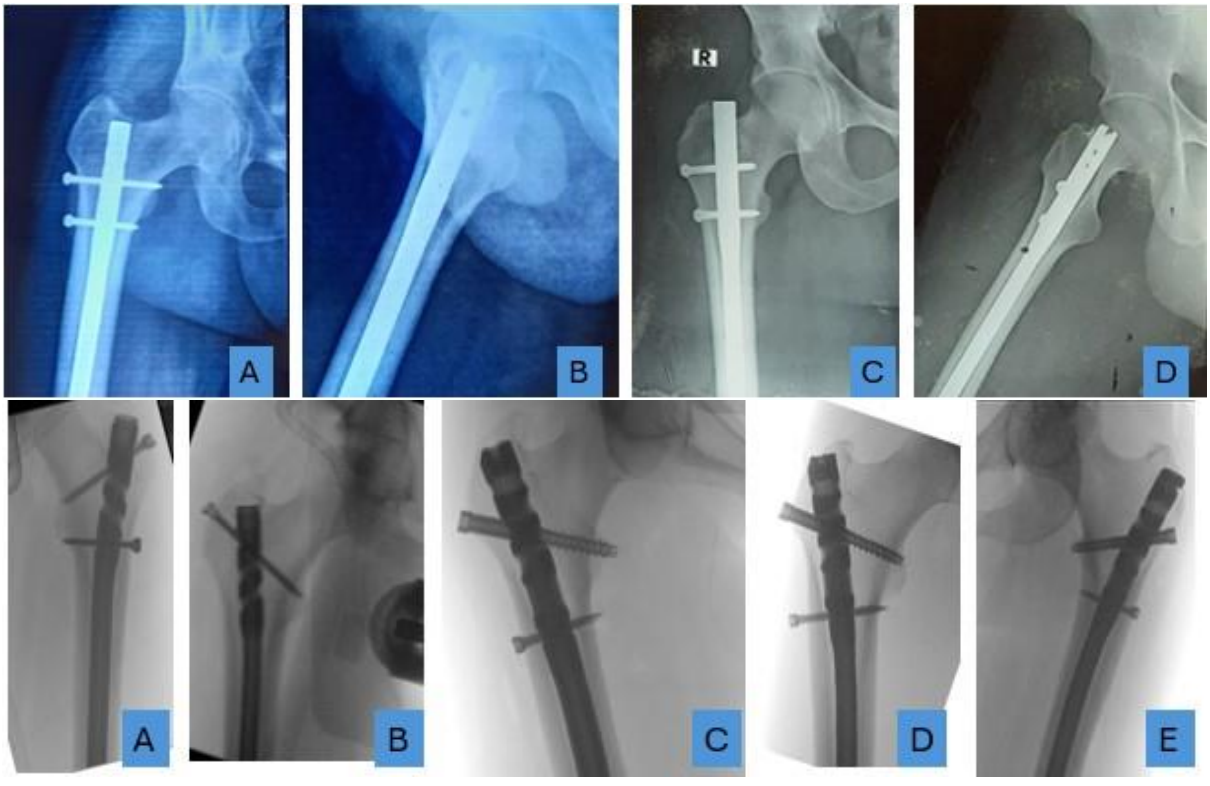
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Table (1): Socio-demographic characteristics of studied patients

Socio demographic characteristics		Total(n=56)		GTE-IMN (n=26)		PFE-IMN (n=30)		Test of significant	P value
		No.	%	No.	%	No.	%		
Age (years)**:**	Mean ± SD	37.3±18.12		38.81±19.23		36.17±17.35		U=0.540	0.591
	Range	18-83		18-83		18-66			
Gender	Male	46	82.1	22	84.6	24	80.0	FE =0.202	0.737
	Female	10	1.9	4	15.4	6	20.0		

PFE-IMN: Piriformis fossa intramedullary nail entry
GTE-IMN: Greater trochanter intramedullary nail entry
U= Mann-Whitney FE= Fisher's Exact Test

Table (2): Pre-operative characteristics of studied patients

Variable			Total (n=56)		GTE-IMN (n=26)		PFE-IMN (n=30)		Test of significant	P value
			No.	%	No.	%	No.	%		
Mechanism of injury	RTA		43	76.8	21	80.8	22	73.3	x2=0.432	0.511
	Falling down		13	23.2	5	19.2	8	26.7		
Side of femoral fracture	Right		29	51.8	13	50.0	16	53.3	x2=0.062	1
	Left		27	48.2	13	50.0	14	46.7		
AO Classification	A=35	32A1	9	16.1	6	23.1	3	10.0	x2=9.541	0.089
		32A2	8	14.3	6	23.1	2	6.7		
		32A3	18	32.1	7	26.9	11	36.7		
	B=21	32B1	9	16.1	1	3.8	8	26.7		
		32B2	9	16.1	5	19.2	4	13.3		
		32B3	3	5.4	1	3.8	2	6.7		
Winquist classification	Type 0		28	50.0	16	61.5	12	40.0	x2=2.861	0.413
	Type 1		11	19.6	4	15.4	7	23.3		
	Type 2		7	12.5	3	11.5	4	13.3		
	Type 3		10	17.9	3	11.5	7	23.3		
Time from trauma to surgery	Mean ± SD		2.76± 2.46		3.07±2.89		2.48±2.34		U=0.589	0.556
	Range		1-14		1-14		1-10			

U= Mann-Whitney x2= Chi-Squared test

Table (3): Intra-operative characteristics of studied patients

Variable		Total(n=56)		GT-IMN (n=26)		PF-IMN (n=30)		Test of significant	P value
		No.	%	No.	%	No.	%		
Patient position	Lateral	26	46.4	2	7.7	24	80.0	**x2**=29.279	<0.001**
	Supine	30	53.6	24	92.3	6	20.0		
Mode of anesthesia	Spinal	52	92.9	23	88.5	29	96.7	FE=1.414	0.234
	General	4	6.7	3	11.5	1	3.3		
Need for open reduction	Yes	9	16.1	6	23.1	3	10.0	FE=1.766	0.277
	No	47	83.9	20	76.9	27	90.0		
Implant	IMN femur with proximal lateral angle 4 degrees	22	39.3	22	84.6	0	0.0	**x2**=56	<0.001**
	Reconstruction Nail	4	7.1	4	15.4	0	0.0		
	Straight antegrade IMN femur	30	53.6	0	0.0	30	100.0		
Traction table	Yes	25	44.6	20	76.9	5	16.7	**x2**=20.464	<0.001**
	No	31	55.4	6	23.1	25	83.3		
Nail length	Mean ± SD	37.67±1.7		38.23±1.82		37.2±1.45		t=2.361	0.022*
	Range	34-40		34 - 40		34- 40			
Nail diameter	Mean ± SD	11.57±0.66		11.81±0.40		11.37±0.67		t=2.639	0.011*
	Range	10-12		11-12		10-12			
Need for cerclage	Yes	5	8.9	2	7.7	3	10.0	FE=0.091	1
	No	51	91.1	24	92.3	27	90.0		
Free hand or using target device	Using target device	44	78.6	14	53.8	30	100.0	**x2**=17.622	<0.001**
	Free hand	12	21.4	12	46.2	0	0.0		
Duration of surgery (minute)	Mean ± SD	78.51±17.39		72.35±13.66		83.87±18.51		t=2.598	0.012*
	Range	52-125		52-100		55-125			

PFE-IMN: Piriformis fossa entry intramedullary nail
GTE-IMN: Greater trochanter entry intramedullary nail
t= student t test **x2**= Chi-Squared test
FE= Fisher's Exact Test
*= P value <0.05 significant **= P value <0.001 highly significant

Table (4): post-operative outcomes of studied patients

Variable		Total (n=56)		GT-IMN (n=26)		PF-IMN (n=30)		Test of significant	P value
		No.	%	No.	%	No.	%		
Need for dynamization	Yes	3	5.4	2	7.7	1	3.3	FE=0.522	0.592
	No	53	94.6	24	92.3	29	96.7		
Length of hospital stay (days)	Mean ± SD	4.04±1.46		4±1.1		4.07±1.7		U=0.322	0.747
	Range	2-7		3-6		2-7			
Time of union (month)	Mean ± SD	5.83±1.31		5.96±1.18		5.71±1.4		t=0.693	0.491
	Range	4-9		4-9		4-9			
Start of partial weight bearing (weeks)	Mean ± SD	3.9±1.43		3.9±1.41		4±1.46		U=0.218	0.828
	Range	2-7		2-7		2-7			
Time of full weight bearing (weeks)	Mean ± SD	8.51±1.39		8.4±1.33		8.6±1.45		t=0.472	0.639
	Range	5-12		7-12		5-12			
Harris Hip Score	Mean ± SD	93.48±9.12		95.54±6.4		91.7±10.73		t=1.592	0.117
	Range	69-100		77-100		69 - 100			
RUST score	Mean ± SD	10.52±1.33		10.57±1.13		10.47±1.5		t=0.306	0.761
	Range	7-12		8-12		7-12			

PF-IMN: Piriformis fossa intramedullary nail entry
GT-IMN: Greater trochanter intramedullary nail entry
t= student t test **x2**= Chi-Squared test
FE= Fisher's Exact Test

Table (5): Correlation between Harris Hip Score and different risk factors in two surgical techniques

Variable	GT-IMN (n=26)		PF-IMN (n=30)		P value of z test
	r	P value	r	P value	
Age	-0.344	0.08	-0.424	0.02*	0.741
Time from trauma to surgery	-0.435	0.027*	0.122	0.521	0.038*
Duration of surgery (minute)	-0.239	0.239	-0.441	0.015*	0.555
Length of hospital stay (days)	0.154	0.454	-0.012	0.952	0.277
Time of union (minute)	-0.271	0.180	-0.358	0.052	0.733

r= correlation coefficient

*= P value <0.05 significant **= P value <0.001 highly significant